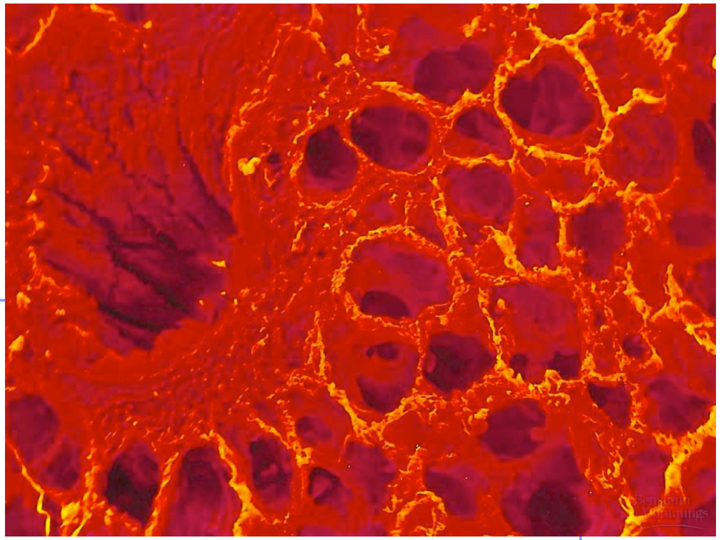
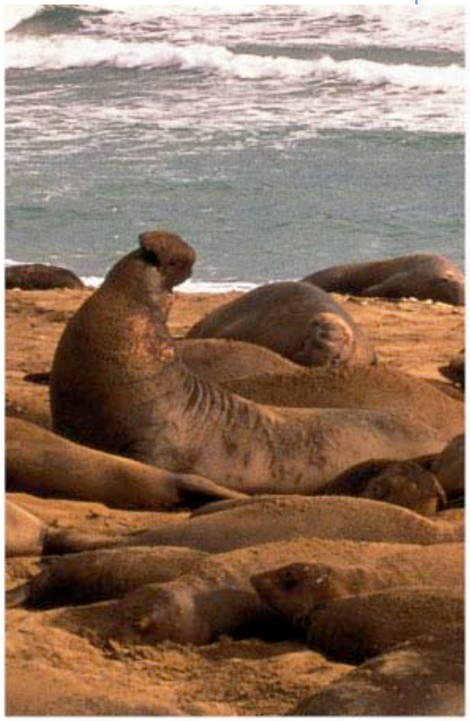
alveoli



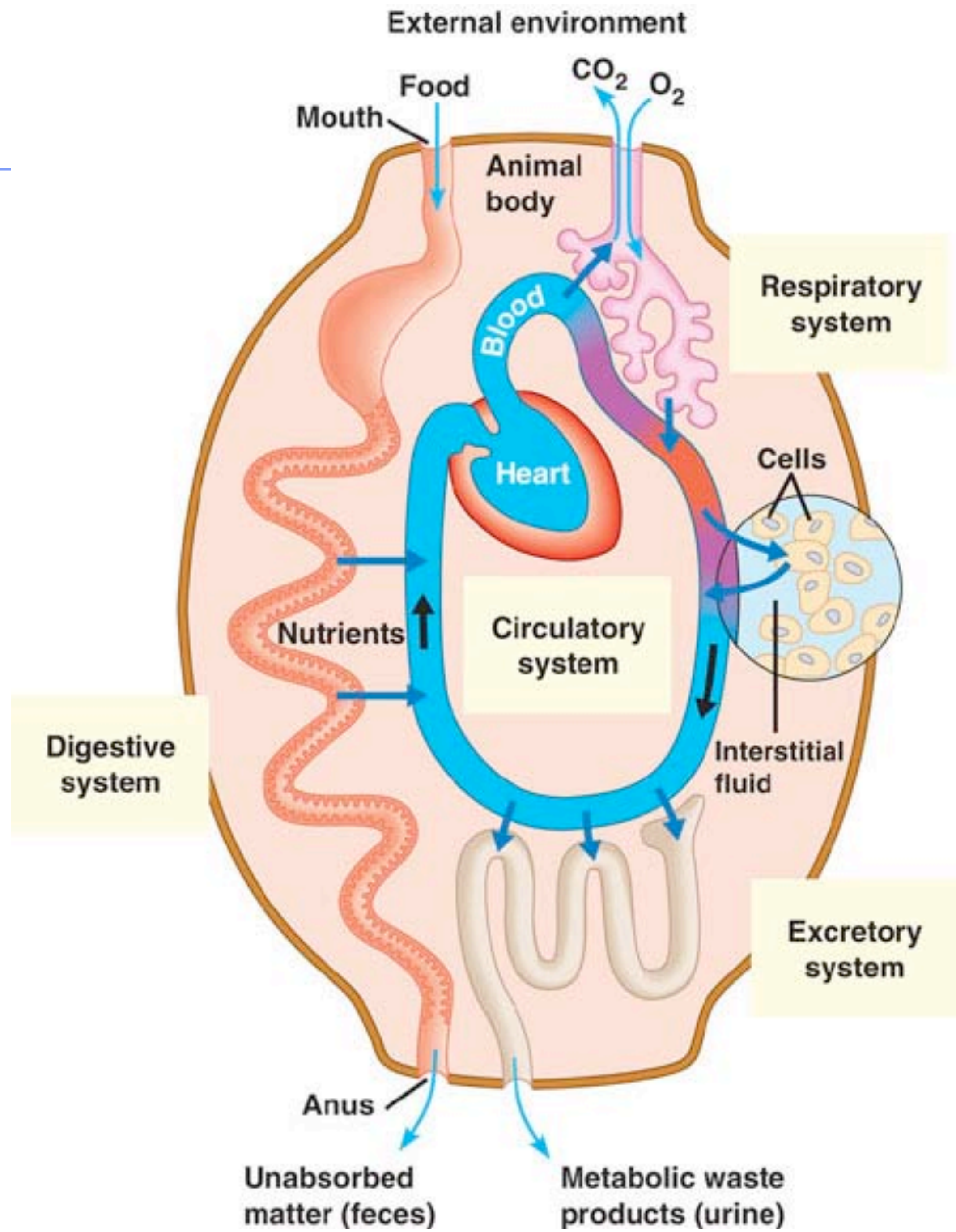
Chapter 42.

Gas Exchange

gills

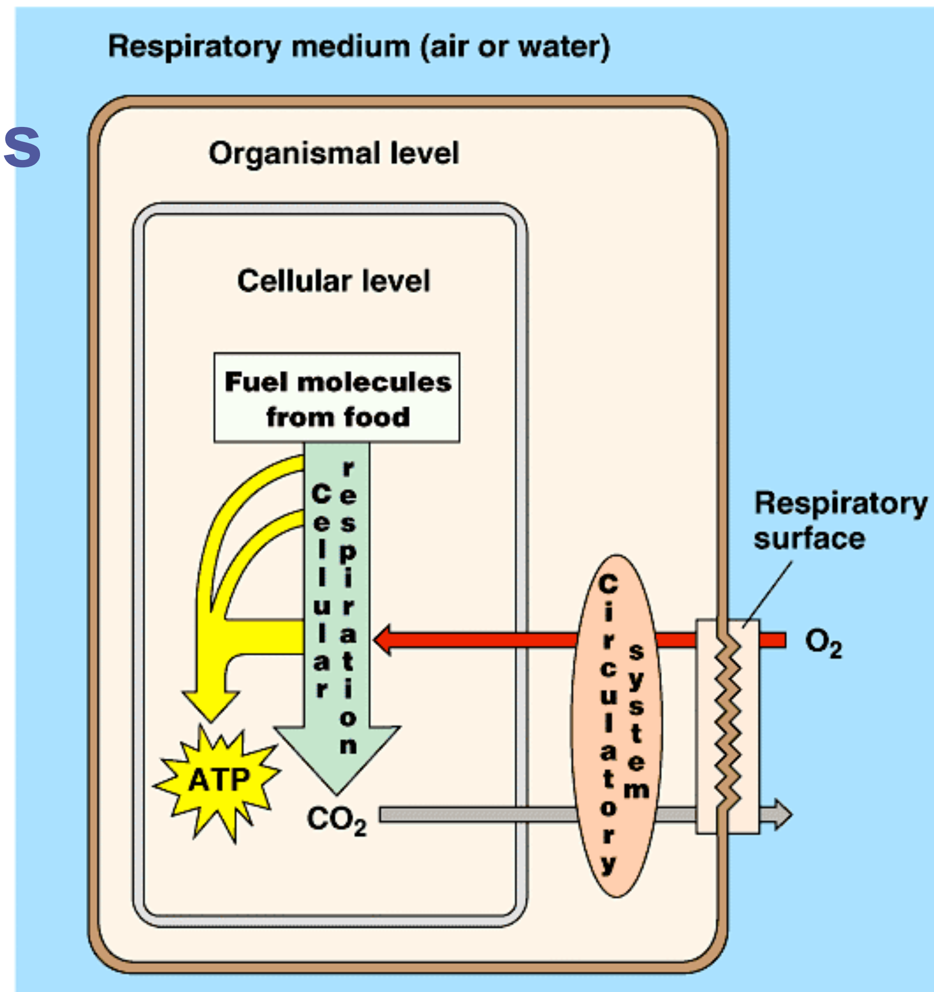


elephant seals


External environment
Food
Mouth
CO_2
O_2
Animal body
Blood
Respiratory system
Heart
Cells
Nutrients
Circulatory system
Interstitial fluid
Digestive system
Excretory system
Anus
Unabsorbed matter (feces)
Metabolic waste products (urine)

Gas exchange

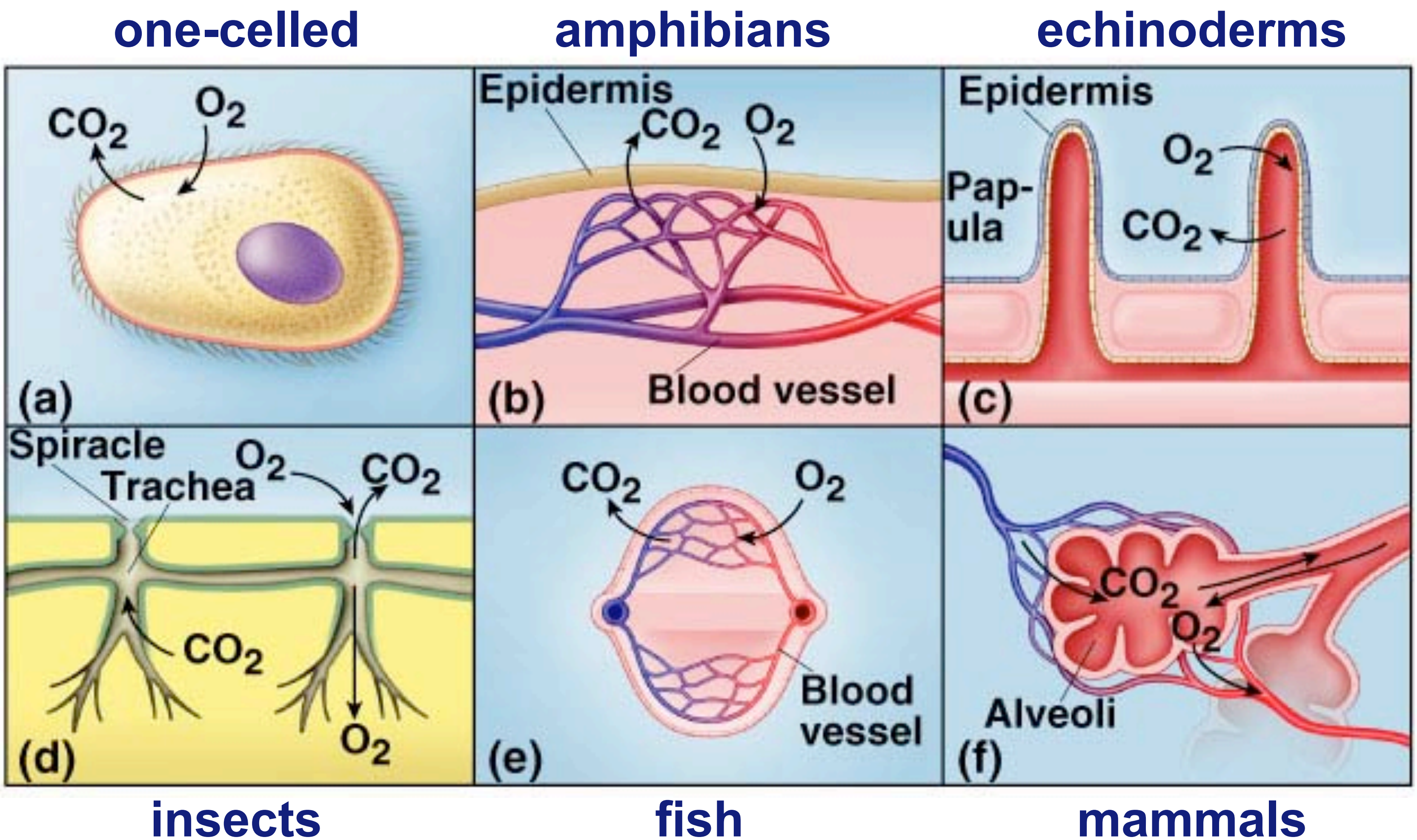
- O_2 & CO_2 exchange
  - exchange between environment & cells
  - provides O_2 for aerobic cellular respiration
    - need <u>moist</u> membrane
    - need high surface area



Optimizing gas exchange

- **Why high surface area?**
  - maximizing rate of gas exchange
  - CO_2 & O_2 move across cell membrane by diffusion
    - rate of diffusion proportional to surface area
- **Why moist membranes?**
  - moisture maintains cell membrane structure
  - gases diffuse only dissolved in water

Gas exchange in many forms…



water vs. land

endotherm vs. ectotherm

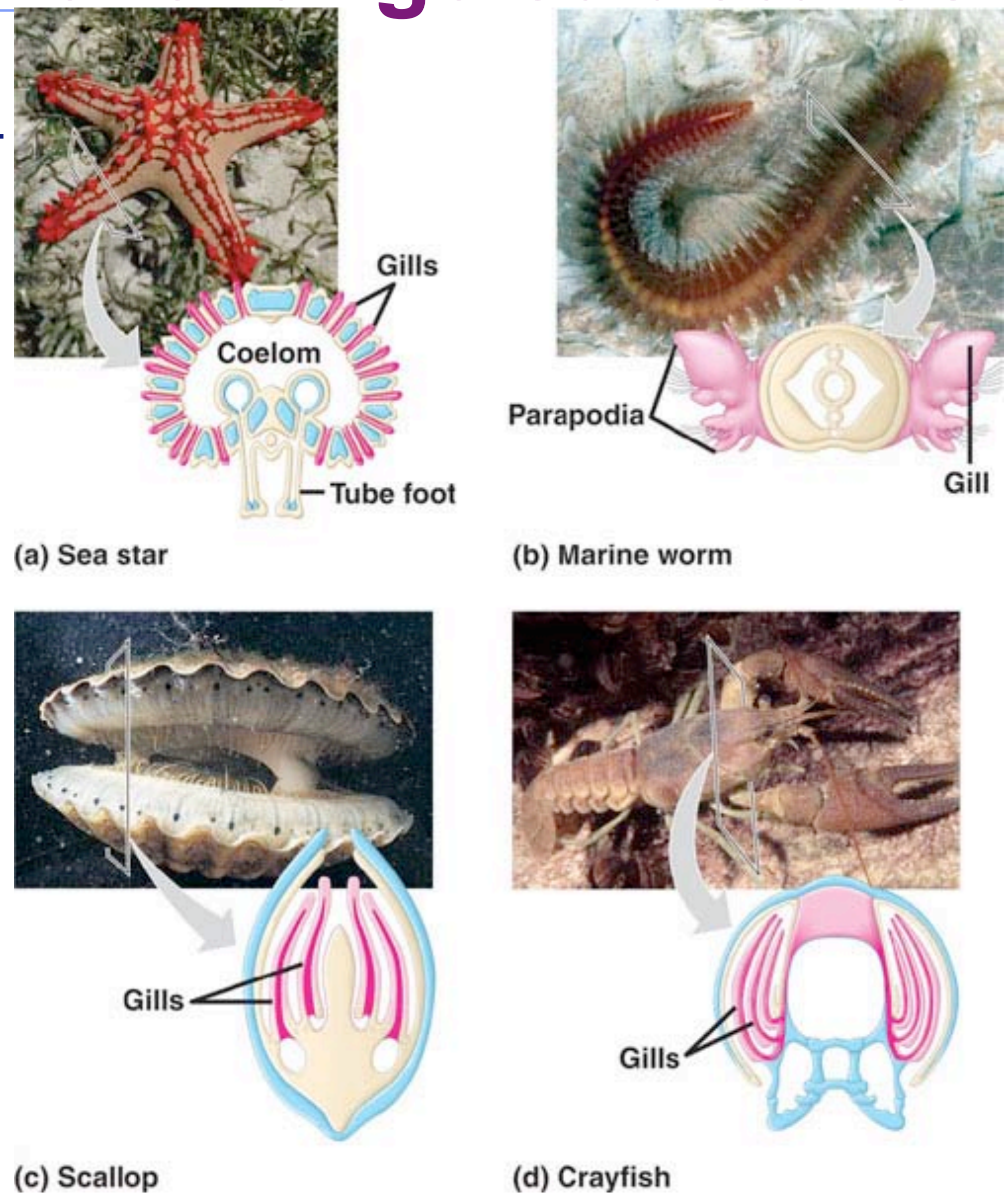
Evolution of gas exchange structures

Aquatic organisms

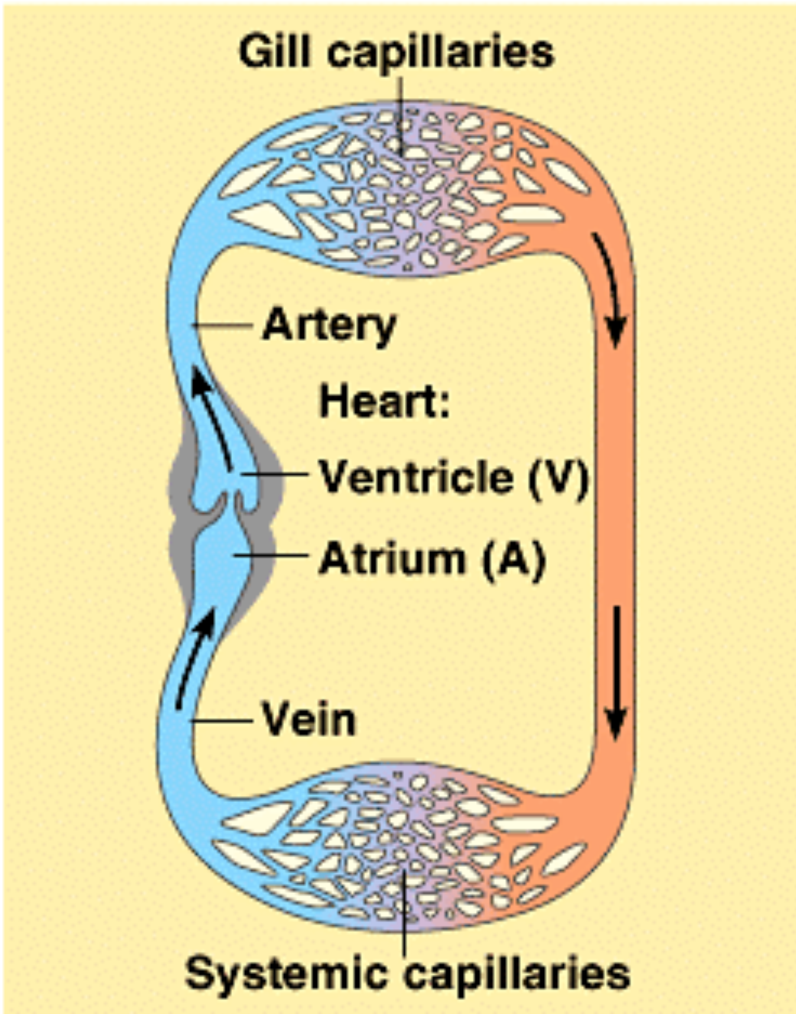
external systems with lots of surface area exposed to aquatic environment

Terrestrial

moist internal respiratory surfaces with lots of surface area



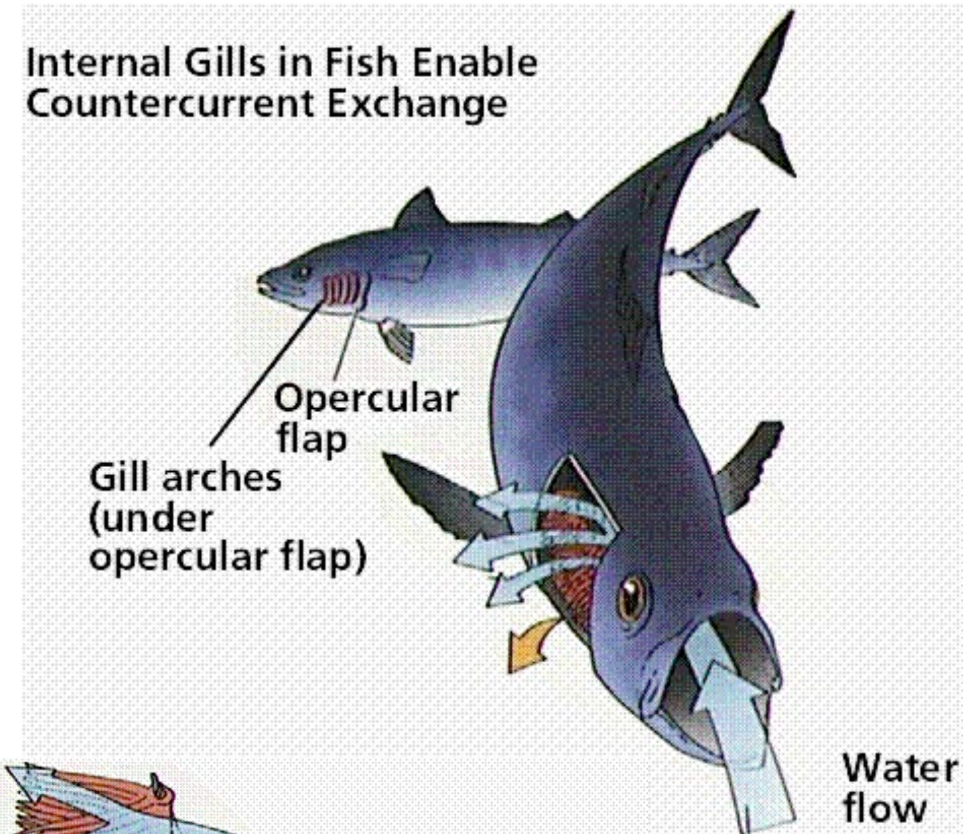
Gas Exchange in Water: Gills

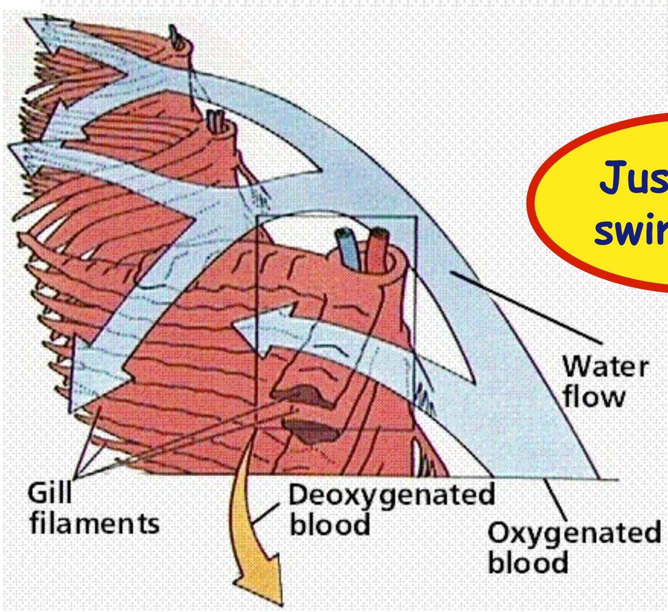


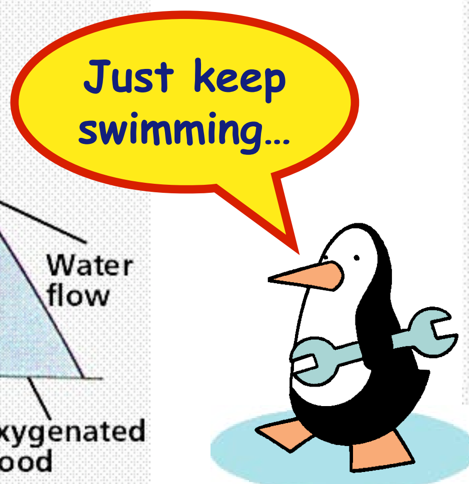
(a) Fish

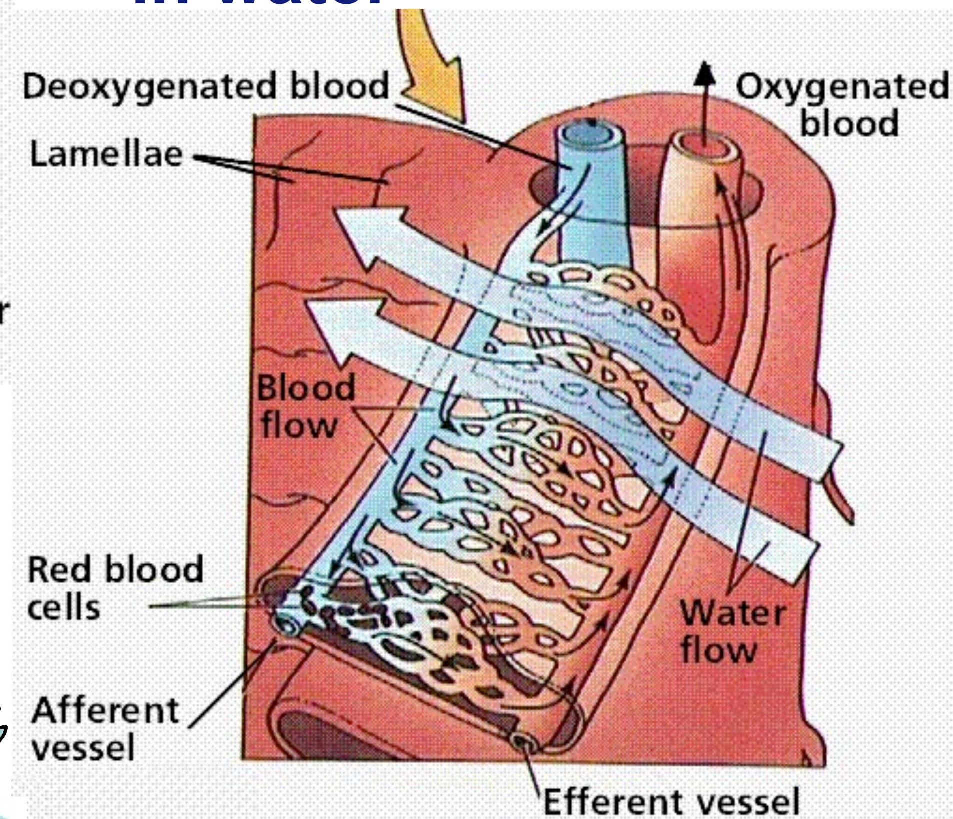
Function of gills

- out-foldings of body
- surface suspended in water



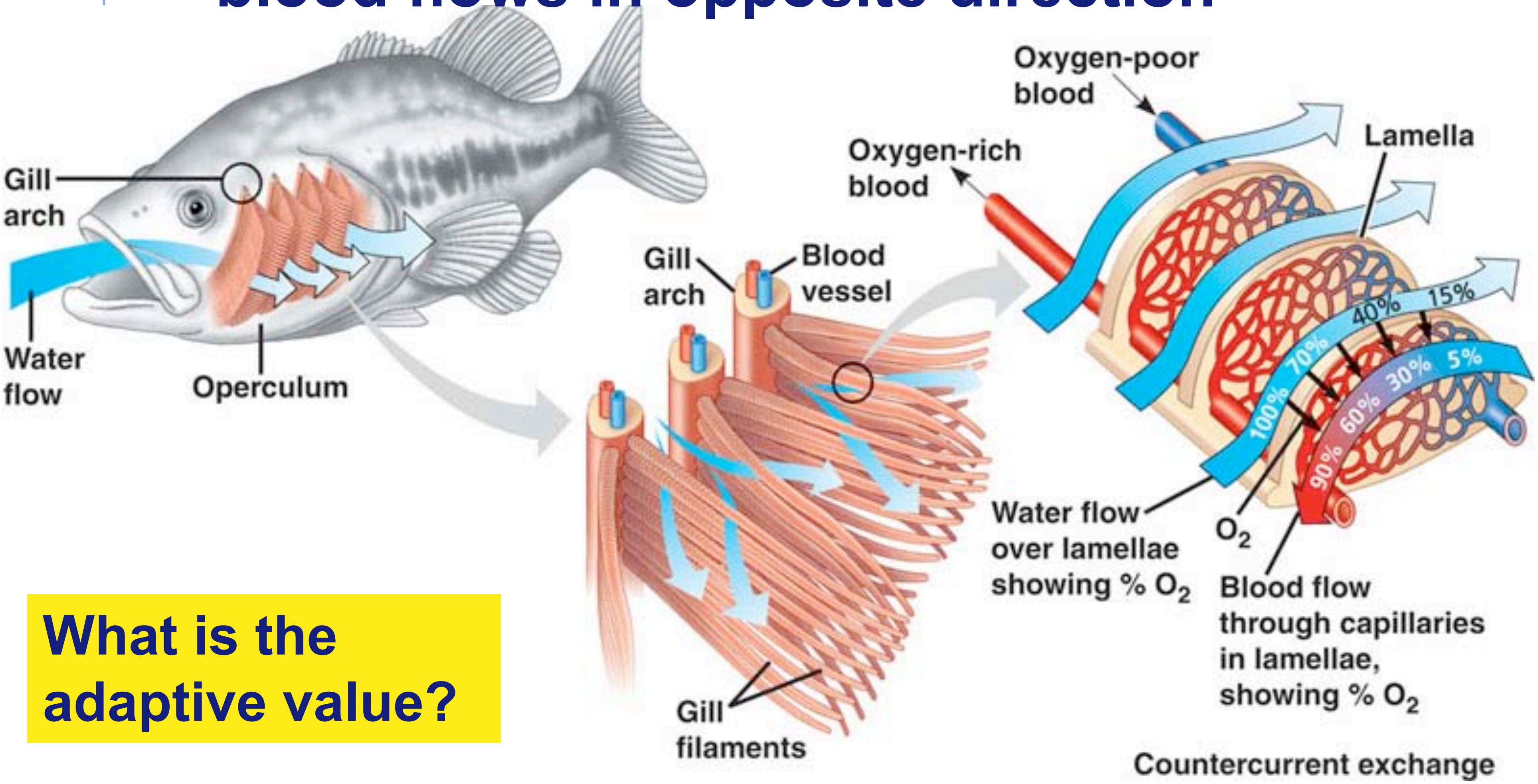






Counter current exchange system

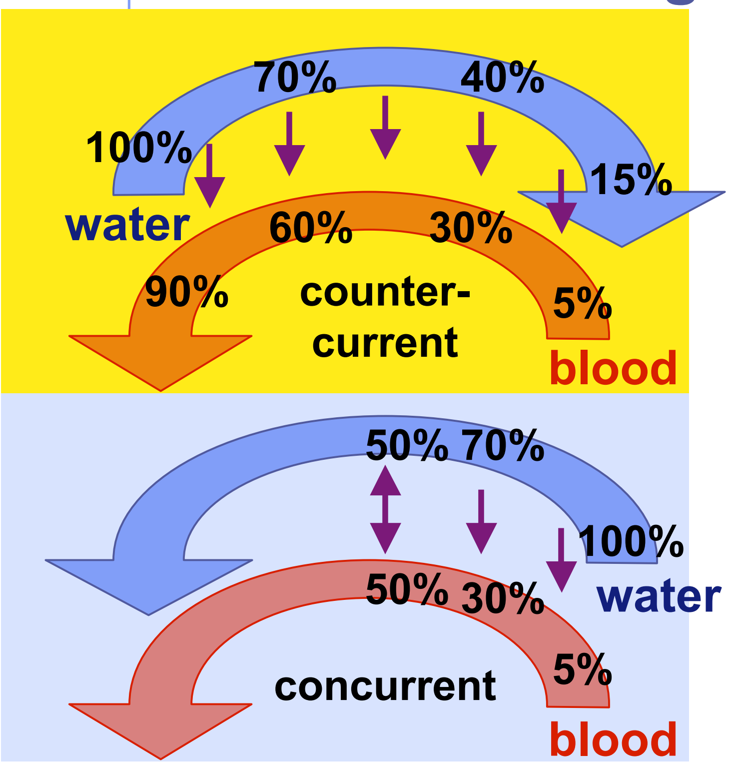
- Water carrying gas flows in one direction, blood flows in opposite direction

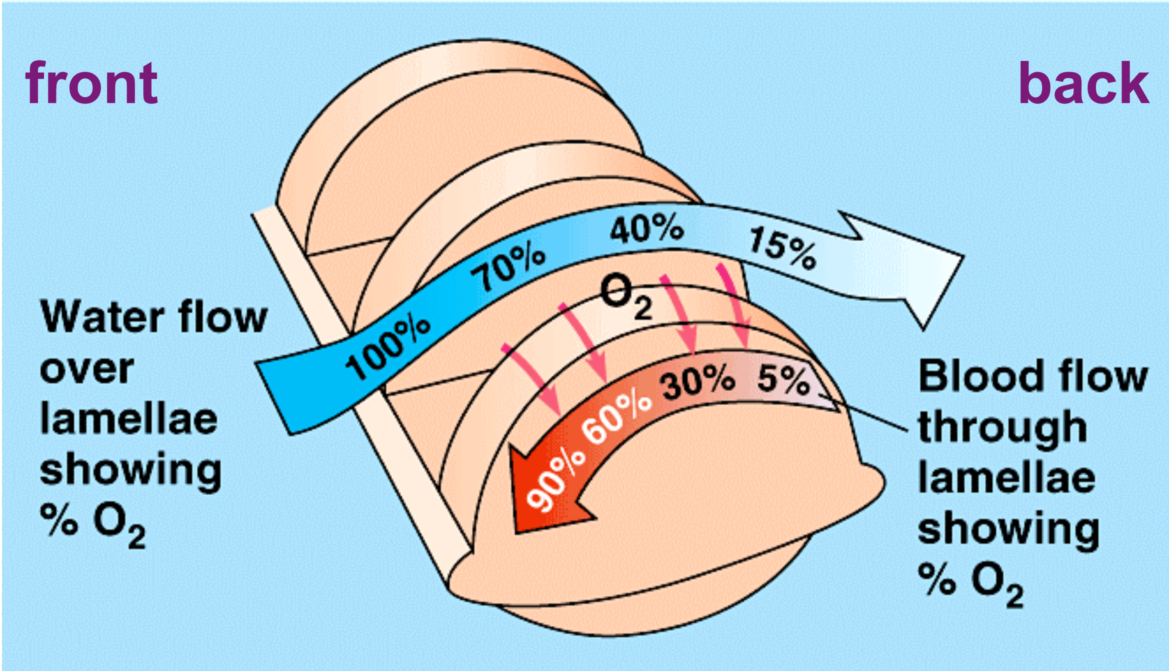


What is the adaptive value?

How counter current exchange works

- Blood & water flow in opposite directions
- Maintains <u>diffusion gradient</u> over whole length of gill capillary
  - maximizing O_2 transfer from water to blood



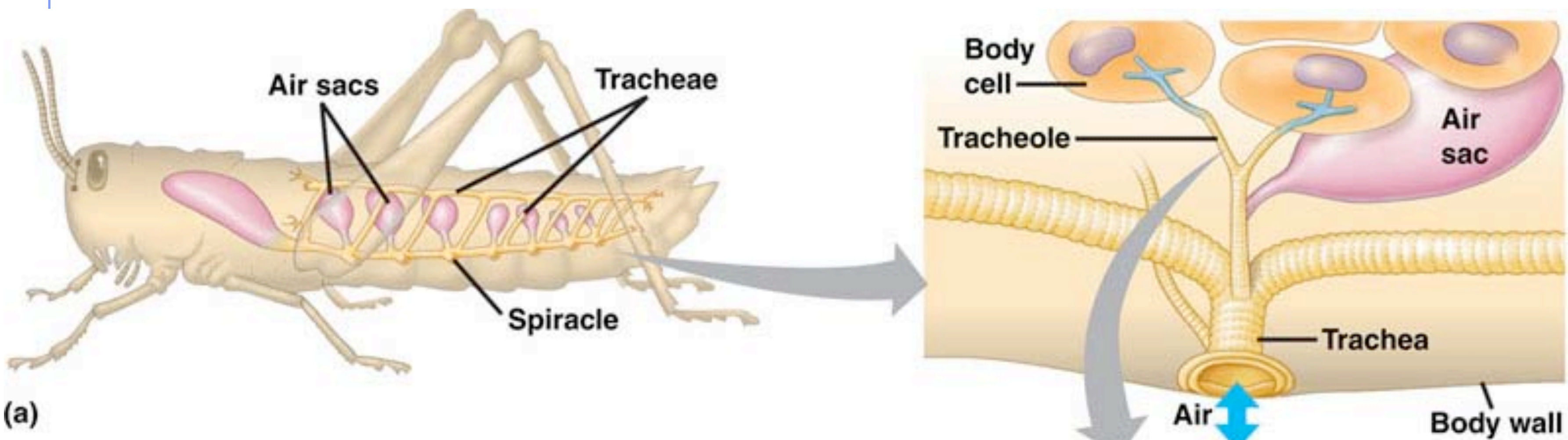


Gas Exchange on Land

- Advantages of terrestrial life
  - air has many advantages over water
    - higher concentration of O_2
    - O_2 & CO_2 diffuse much faster through air
      - respiratory surfaces exposed to air do not have to be ventilated as thoroughly as gills
    - air is much lighter than water & therefore much easier to pump
      - expend less energy moving air in & out

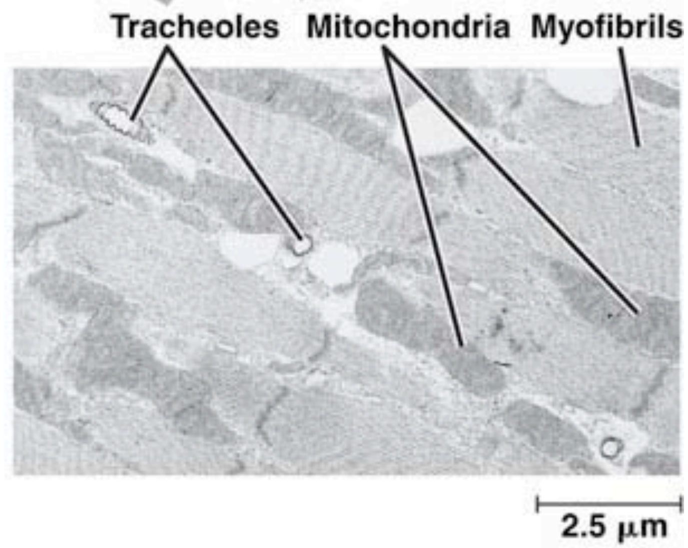
- Disadvantages
  - keeping large respiratory surface moist causes high water loss

Terrestrial adaptations



Tracheae

- air tubes branching throughout body
- gas exchanged by diffusion across moist cells lining terminal ends, not through open circulatory system

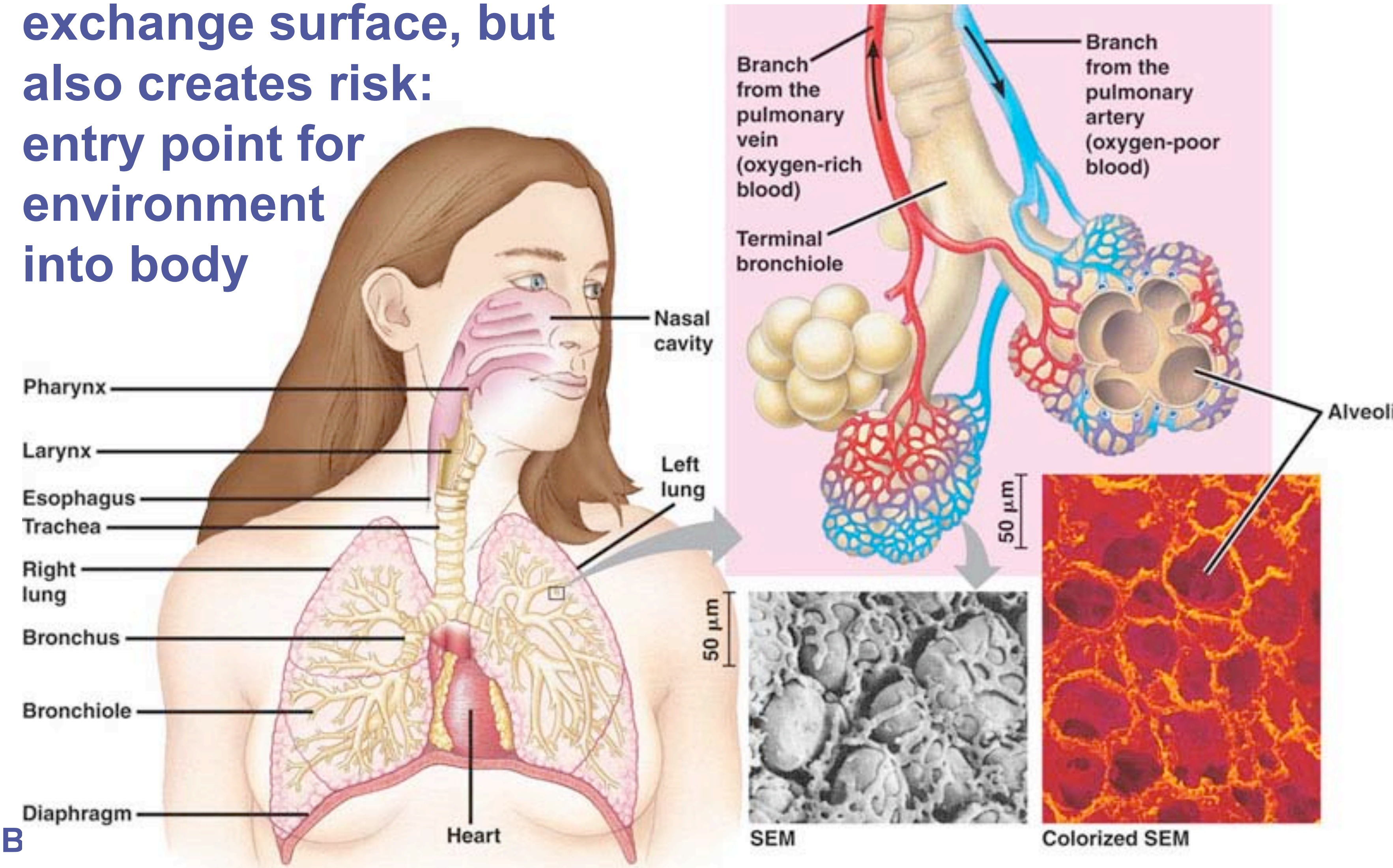


How is this adaptive?

Lungs

spongy texture, honeycombed with moist epithelium

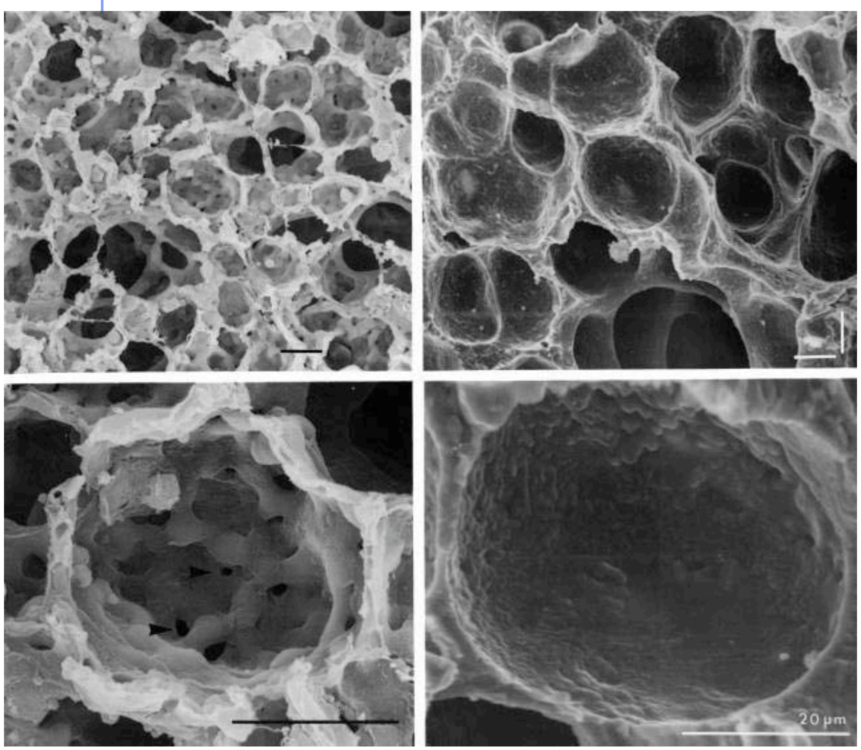
exchange surface, but also creates risk: entry point for environment into body

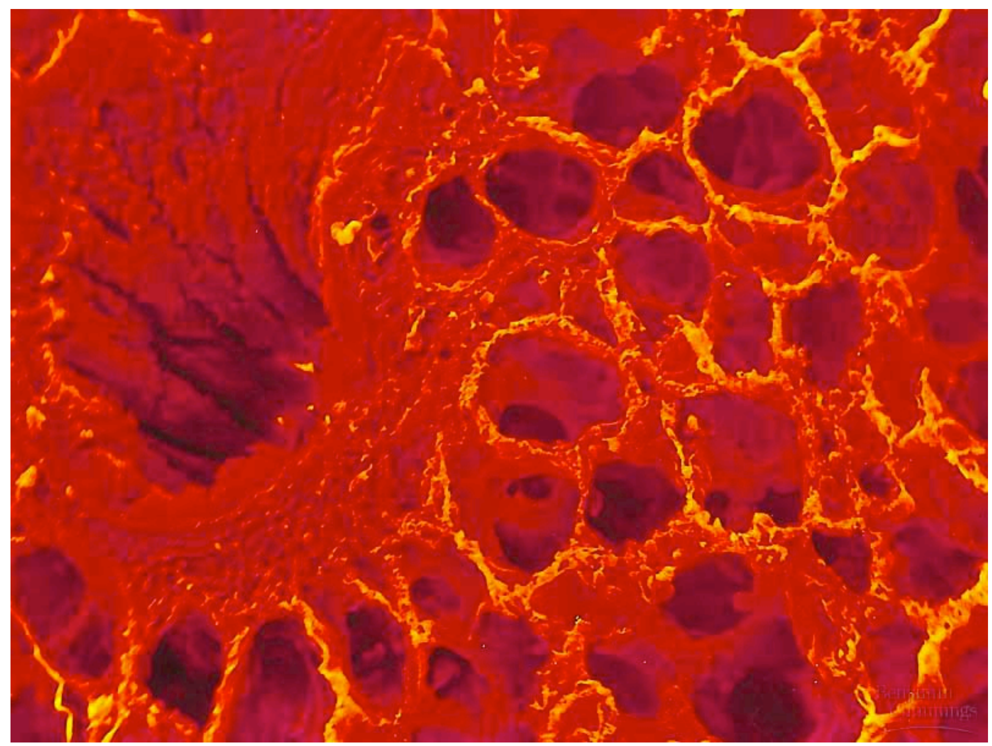


AP B

Alveoli

- **Gas exchange across thin epithelium of millions of alveoli**
  - total surface area in humans ~100 m^2



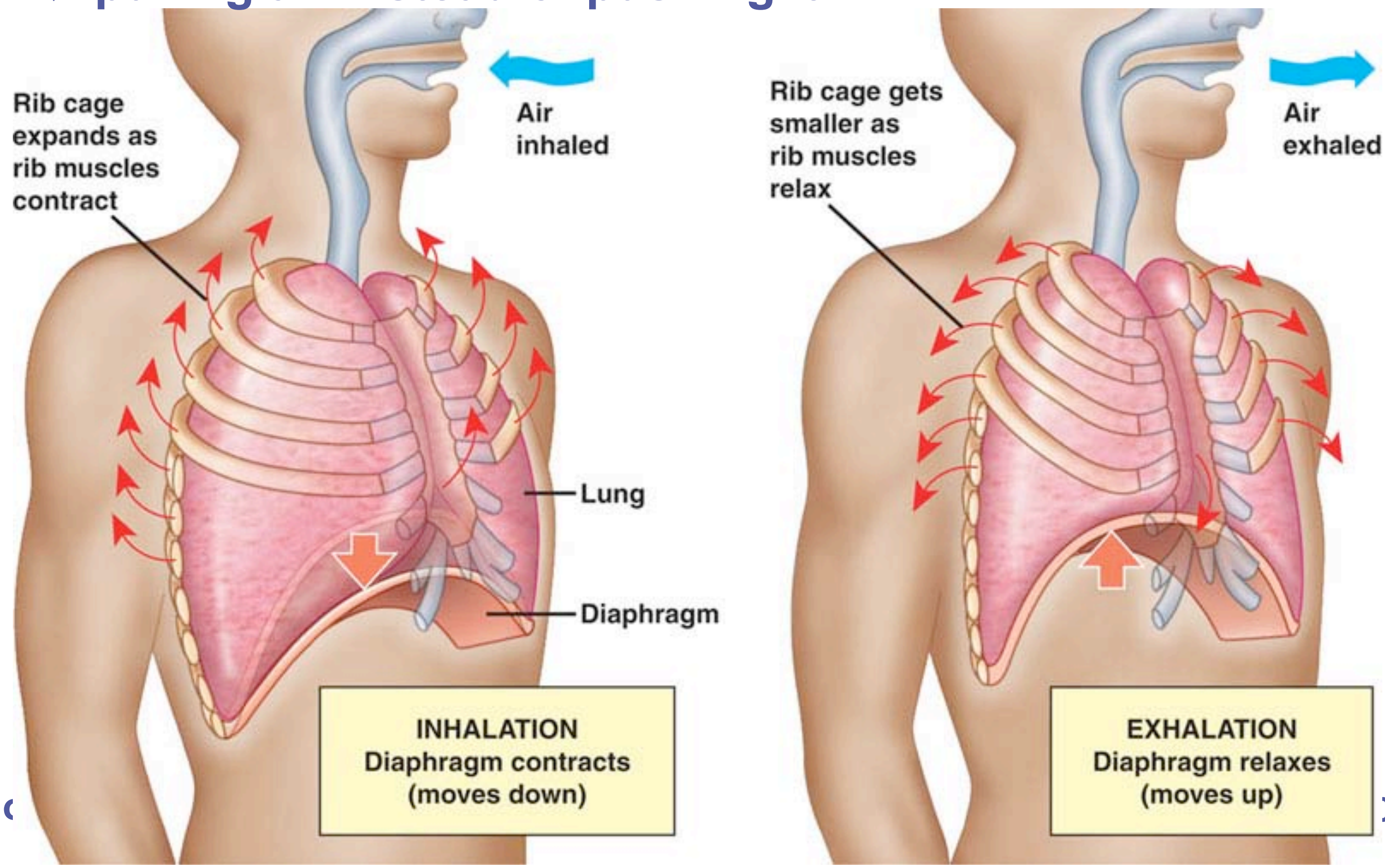


Mechanics of breathing

- Air enters nostrils
  - filtered by hairs, warmed & humidified
  - sampled for odors
- Pharynx → glottis → larynx (vocal cords) → trachea (windpipe) → bronchi → bronchioles → air sacs (alveoli)
- Epithelial lining covered by cilia & thin film of mucus
  - mucus traps dust, pollen, particulates
  - beating cilia move mucus upward to pharynx, where it is swallowed

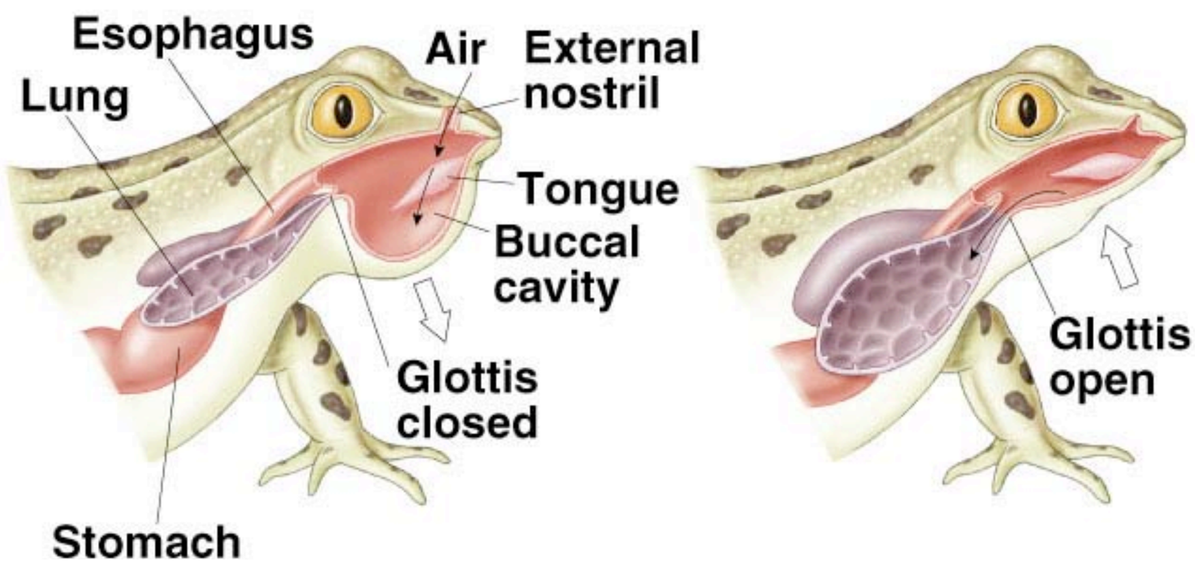
Negative pressure breathing

- **Breathing due to changing pressures in lungs**
  - air flows from higher pressure to lower pressure
  - pulling air instead of pushing it



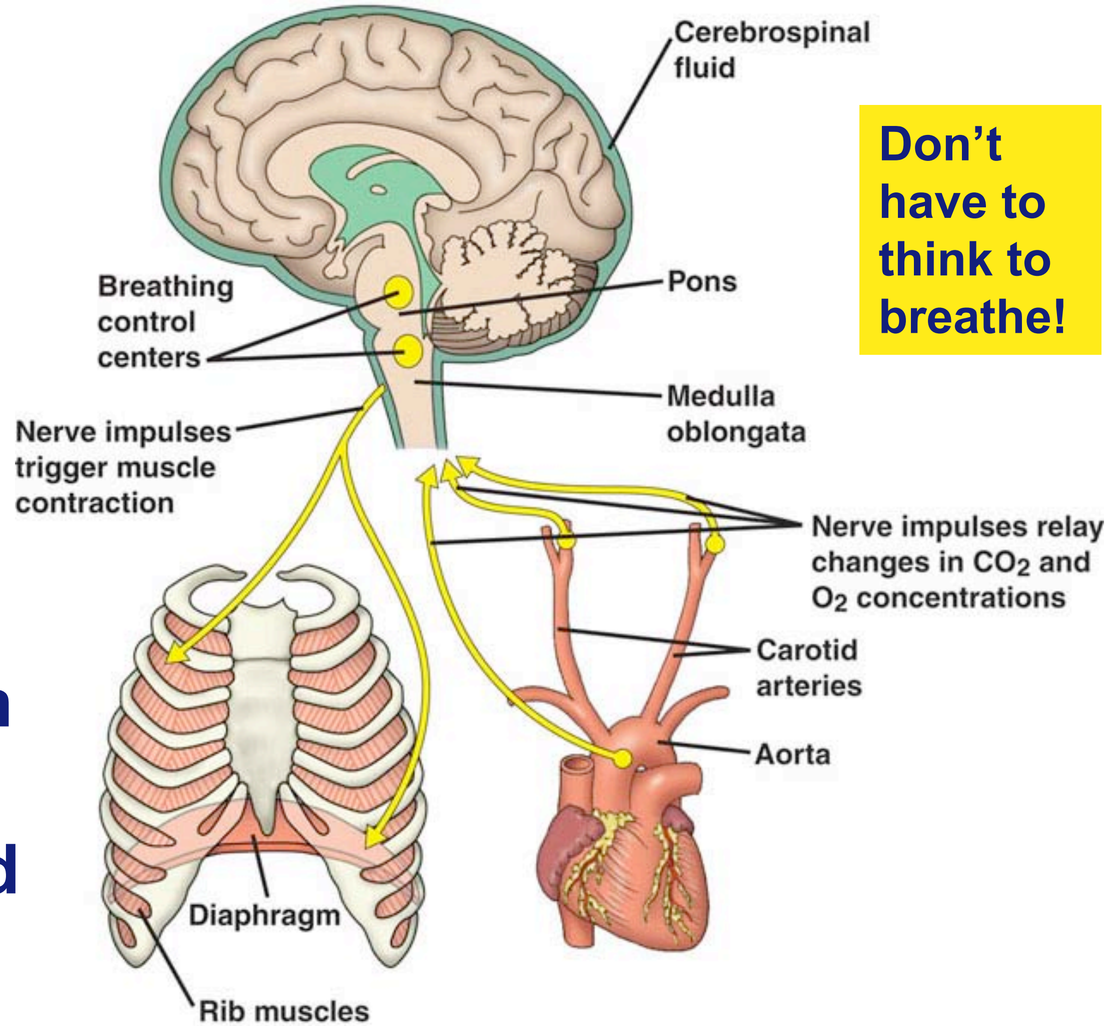
Positive pressure breathing

- Frogs
  - draw in air through nostrils, fill mouth, with mouth & nose closed, air is forced down the trachea



Autonomic breathing control

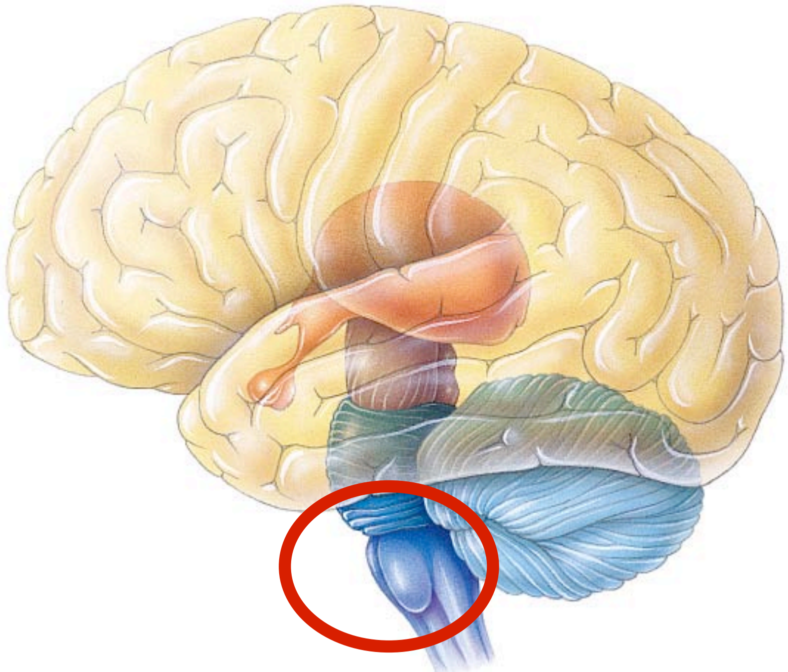
- Medulla sets rhythm & pons moderates it
  - coordinate respiratory, cardiovascular systems & metabolic demands
- Nerve sensors in walls of aorta & carotid arteries in neck detect O_2 & CO_2 in blood



Don't have to think to breathe!

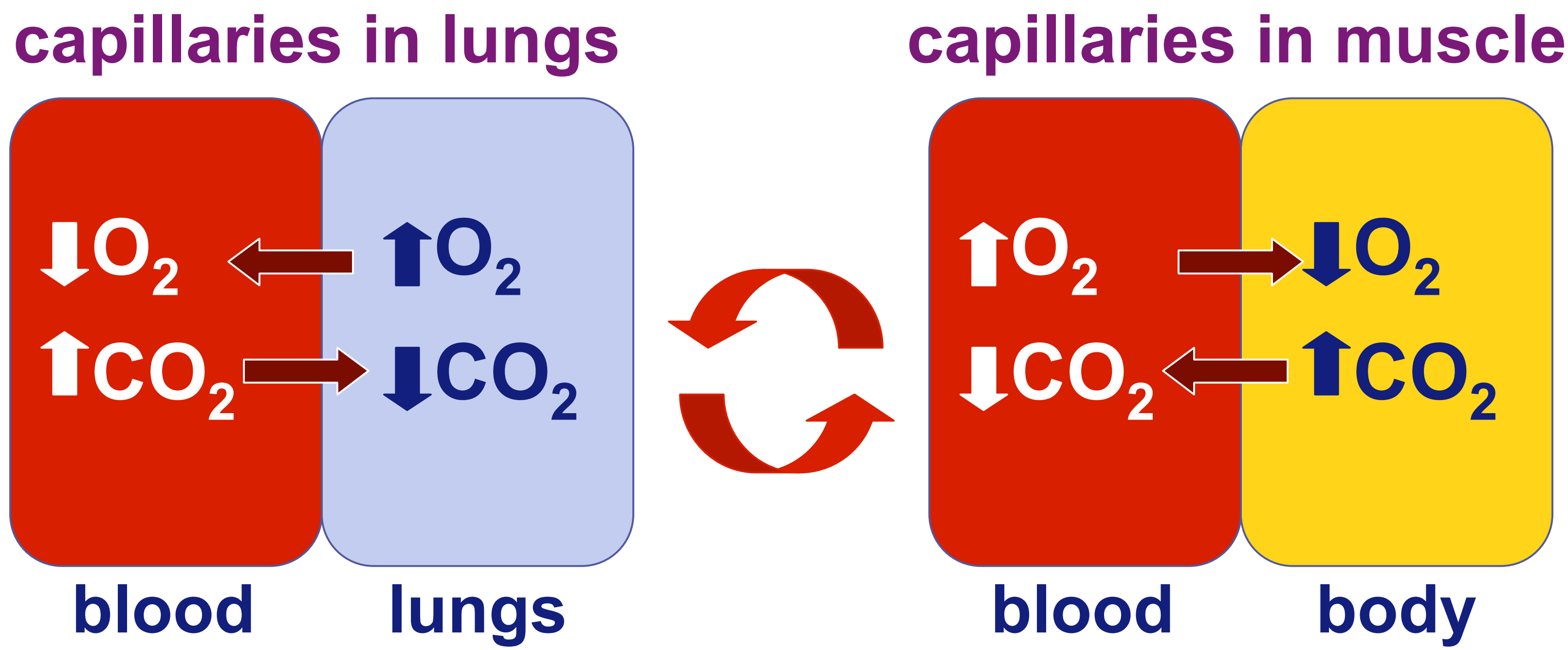
Medulla monitors blood

- Monitors CO_2 level of blood
  - measures pH of blood & cerebrospinal fluid bathing brain
    - $CO_2 + H_2O \rightarrow H_2CO_3$ (carbonic acid)
    - if pH decreases then increase depth & rate of breathing & excess CO_2 is eliminated in exhaled air

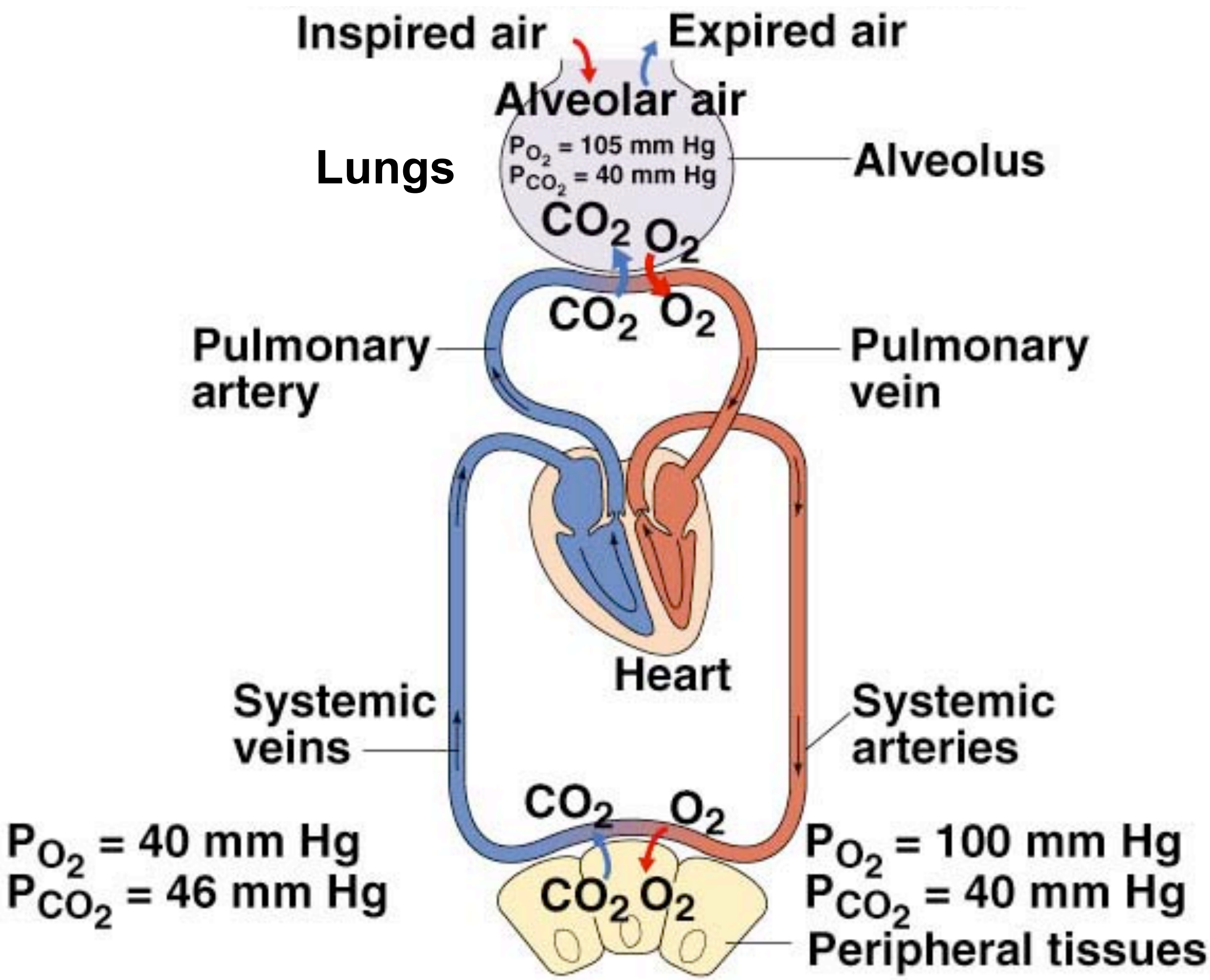


Diffusion of gases

- **Concentration & pressure drives movement of gases into & out of blood at both lungs & body tissue**

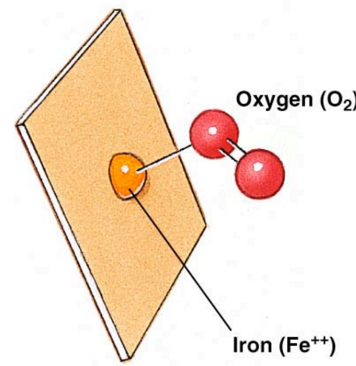


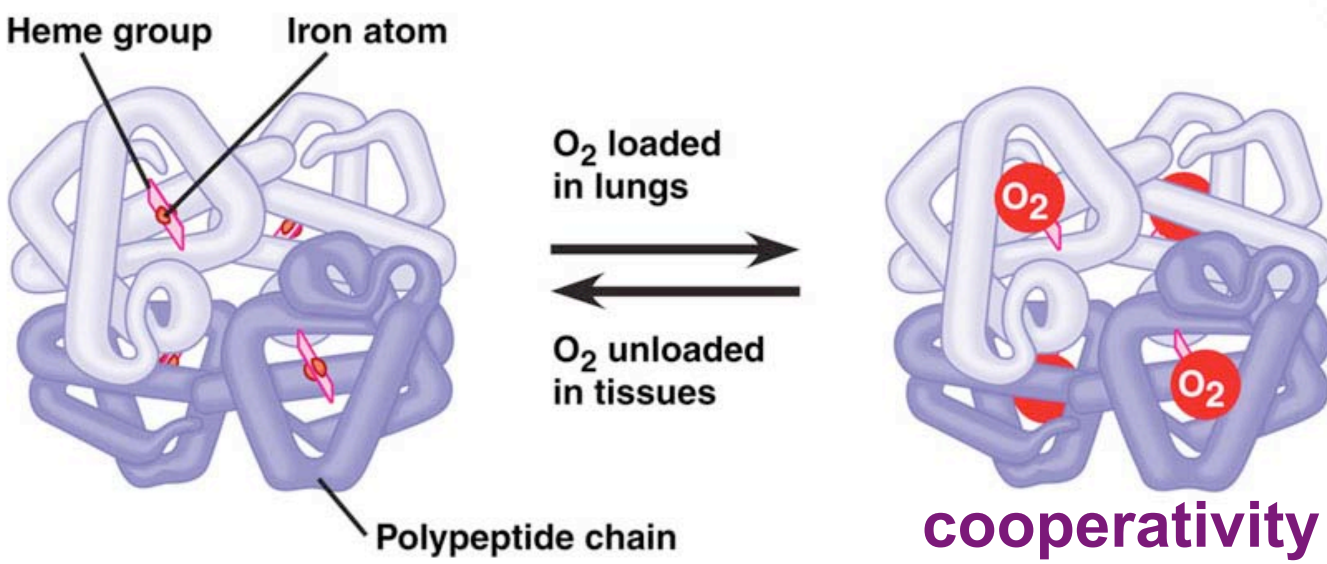
Pressure gradients



Hemoglobin

- **Why use a carrier molecule?**
  - O_2 not soluble enough in H_2O for animal needs
    - hemocyanin in insects = copper (bluish)
    - hemoglobin in vertebrates = iron (reddish)
- **Reversibly binds O_2**
  - loading O_2 at lungs or gills & unloading in other parts of body

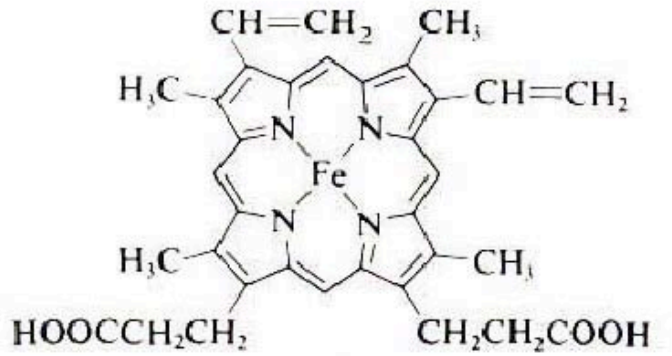




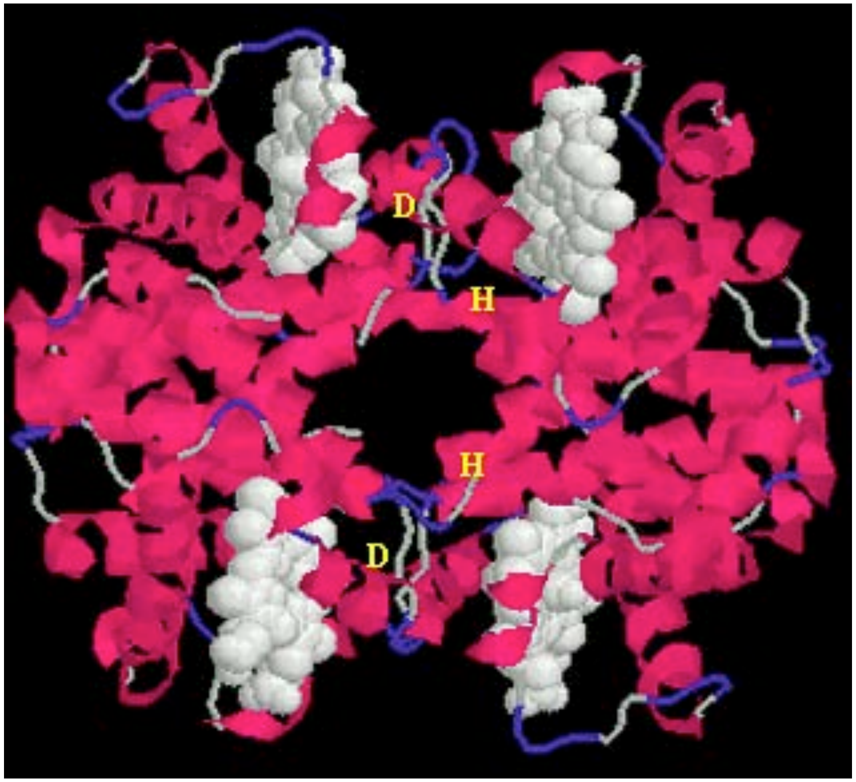
cooperativity

Hemoglobin

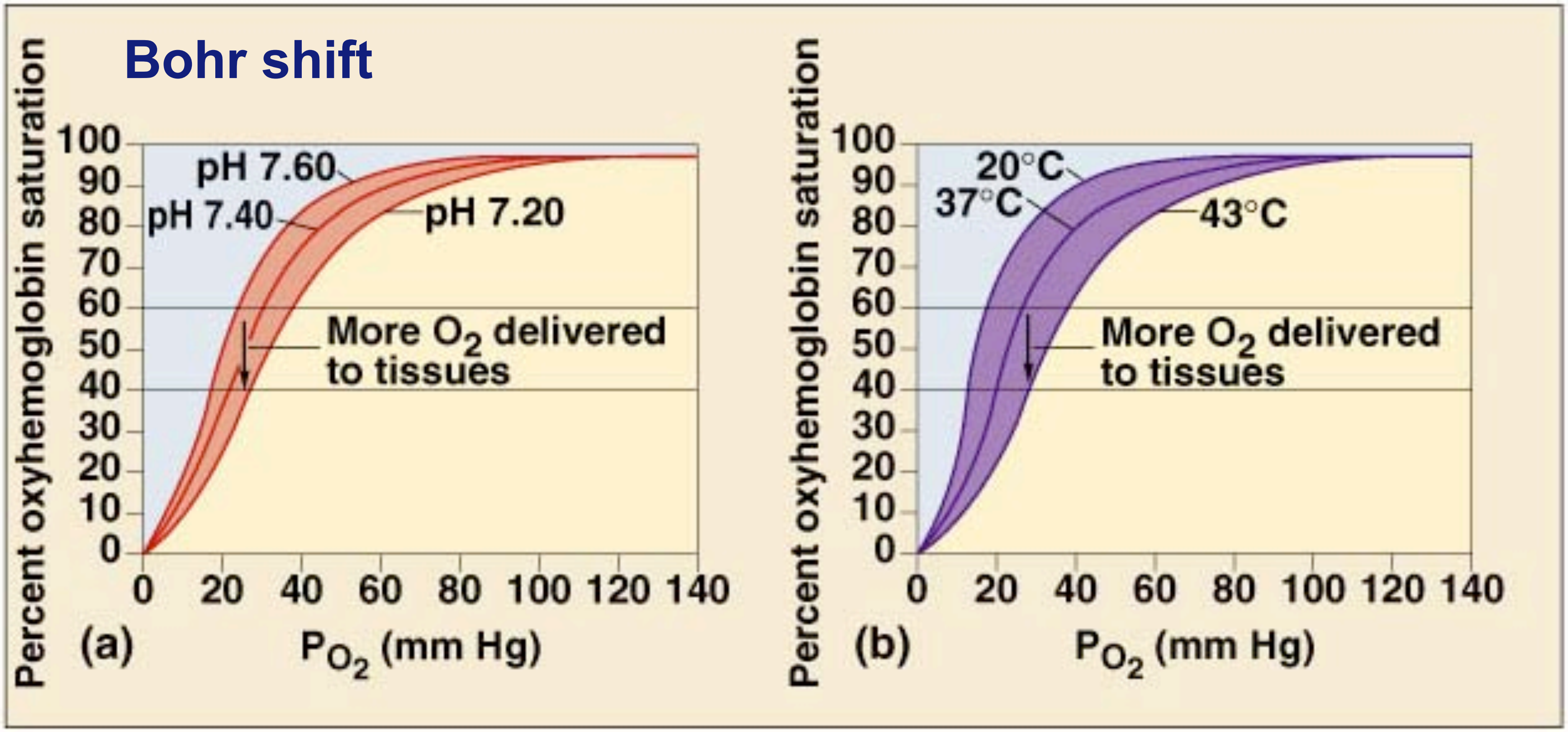
- **Binding O_2**
  - loading & unloading from Hb protein depends on cooperation among protein's subunits
  - binding of O_2 to 1 subunit induces remaining subunits to change shape slightly increasing affinity for O_2
- **Releasing O_2**
  - when 1 subunit releases O_2, other 3 quickly follow as shape change lowers affinity for O_2



Heme group

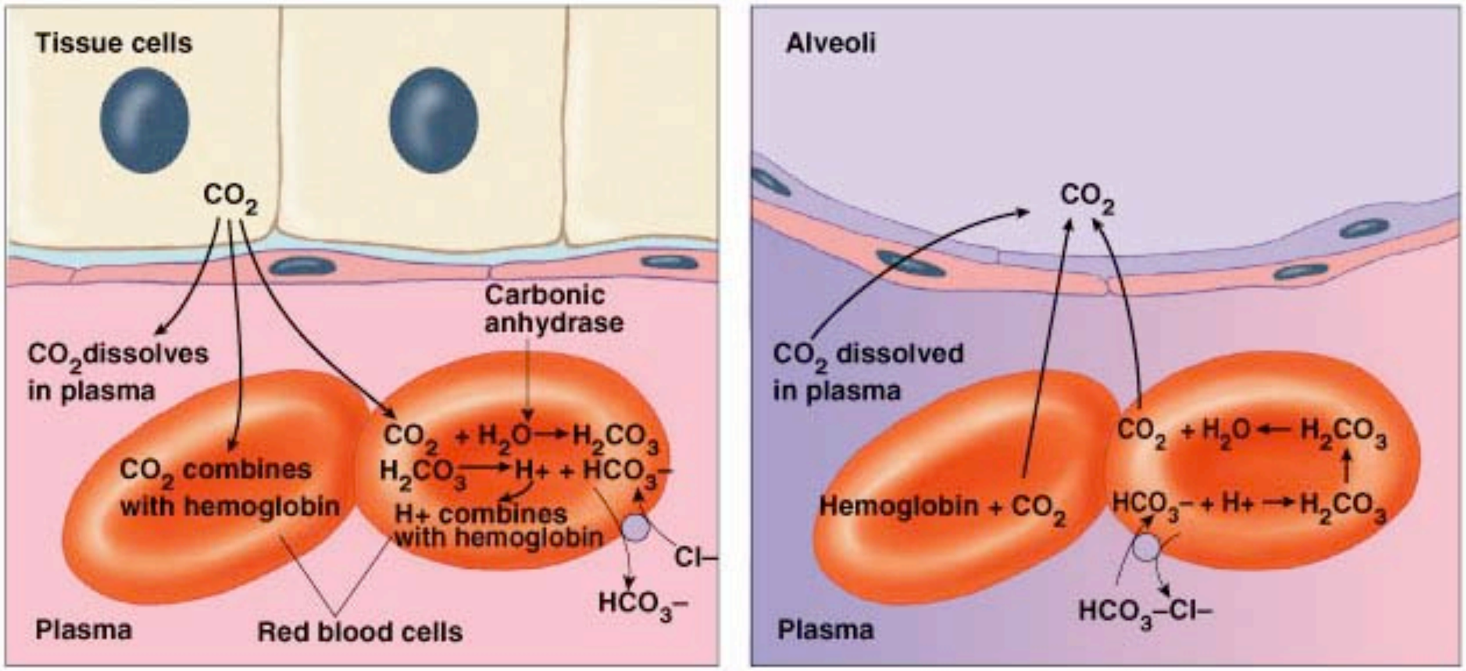


O_2 dissociation curves for hemoglobin



- drop in pH lowers affinity of Hb for O_2
- active tissue (producing CO_2) lowers blood pH & induces Hb to release more O_2

Transporting CO_2 in blood

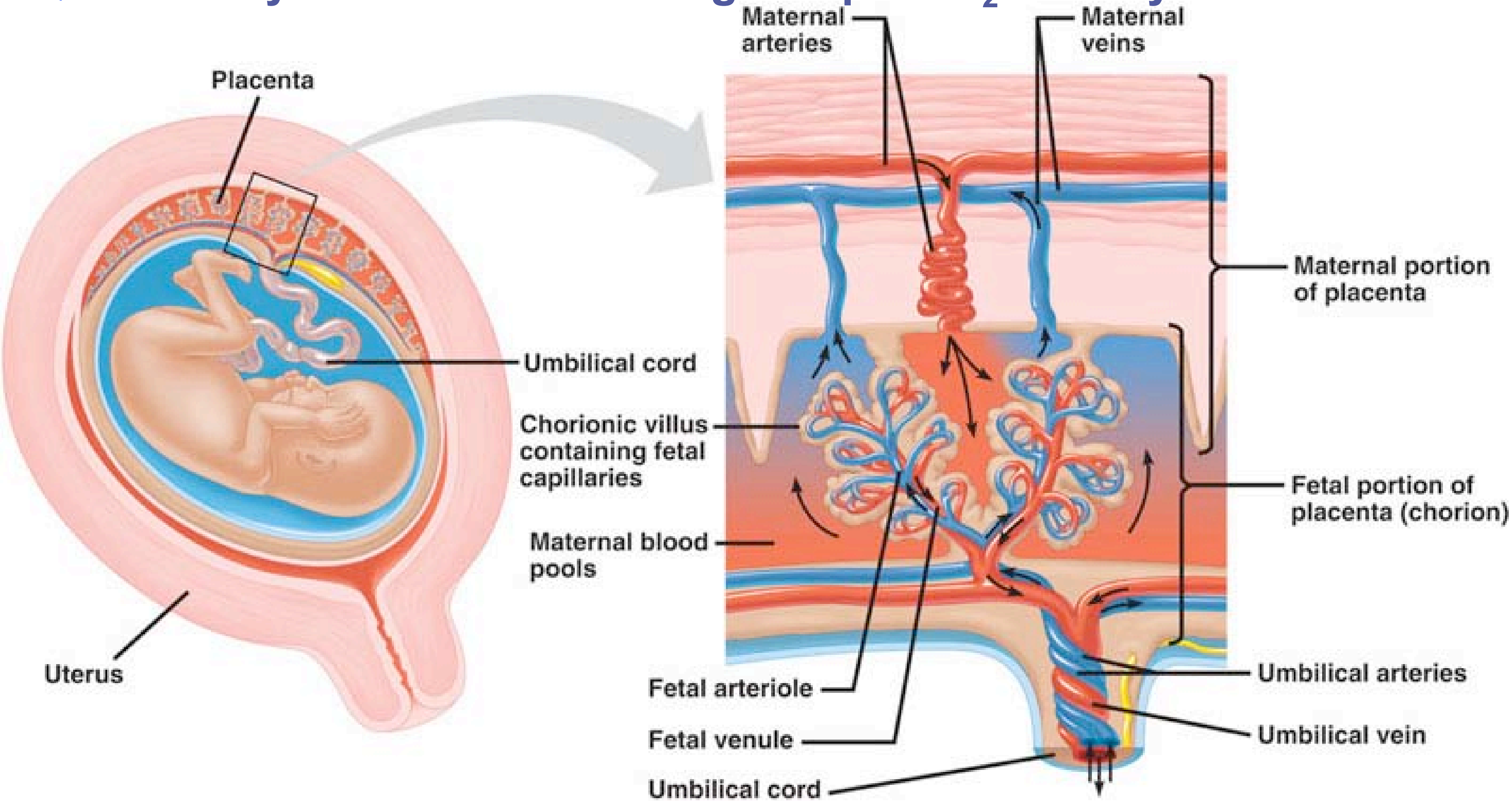


- Dissolved in blood plasma
- Bound to Hb protein
- Bicarbonate ion (HCO_3^-) & carbonic acid (H_2CO_3) in RBC
  - enzyme: carbonic anhydrase reduces CO_2

AP

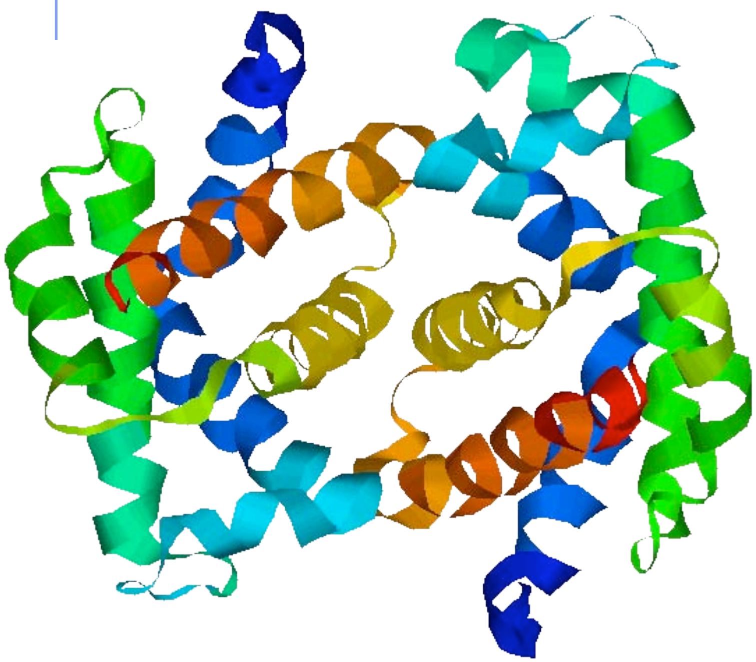
Adaptations for pregnancy

- **Mother & fetus exchange O_2 across placental tissue**
  - why would mothers Hb give up its O_2 to baby's Hb?

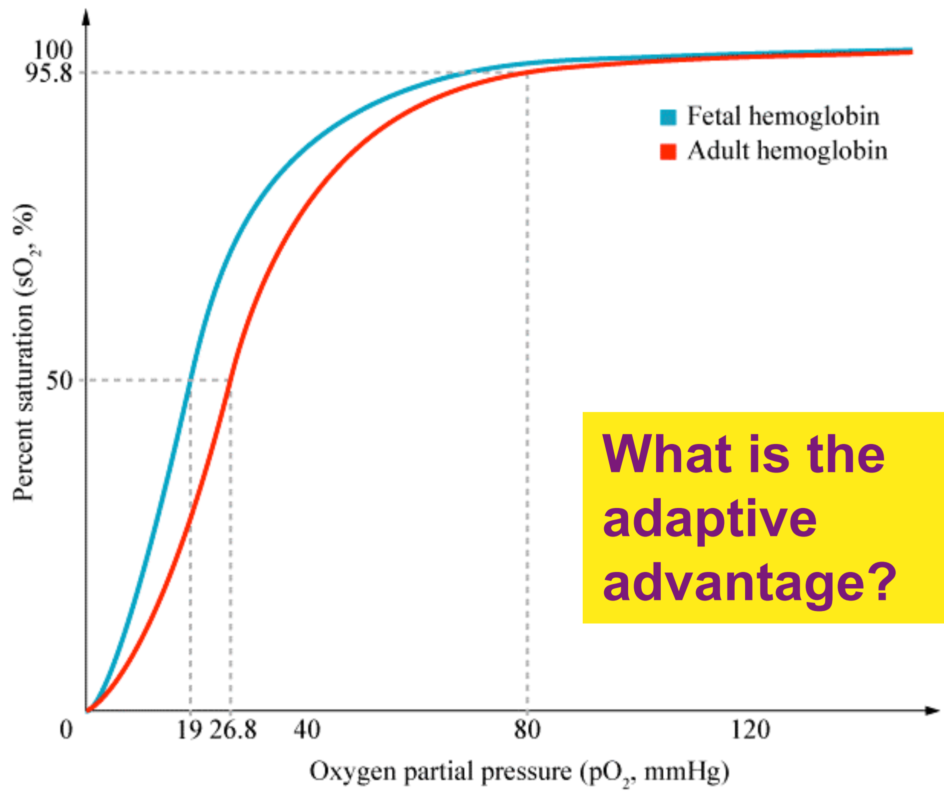


Fetal hemoglobin

- **HbF has greater affinity to O_2 than Hb**
  - low O_2% by time blood reaches placenta
  - fetal Hb must be able to bind O_2 with greater attraction than maternal Hb



2 alpha & 2 gamma units



What is the adaptive advantage?

Any Questions??