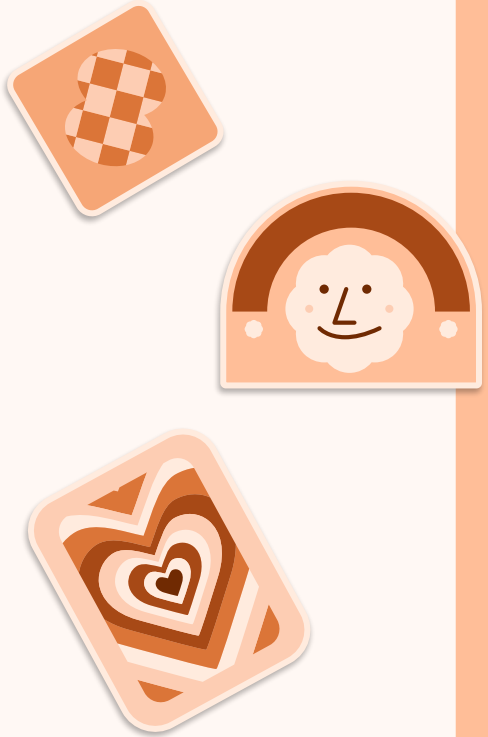
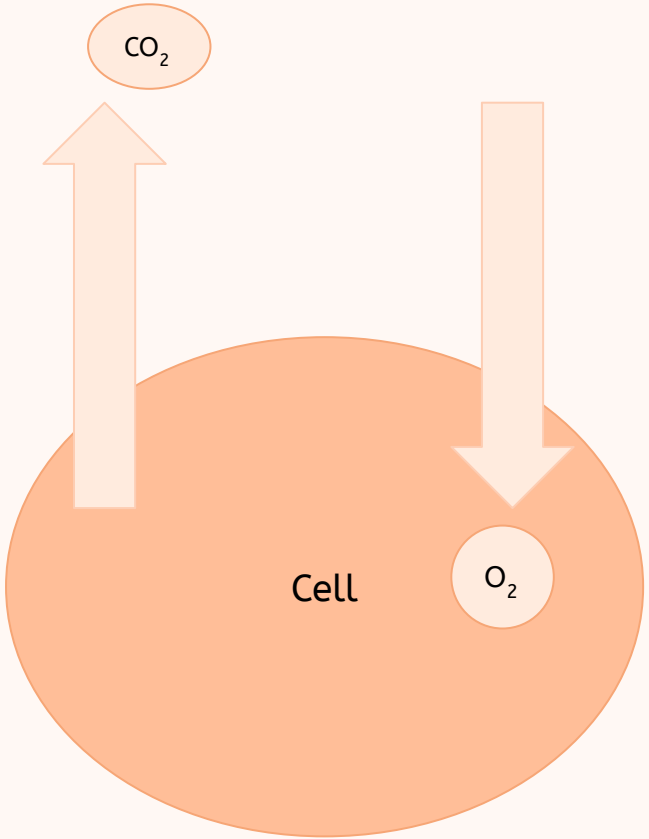
Gas Exchange

Presentation by Laurie, Slides by Slidesgo



Gas Exchange



Respiratory Media

Air > H_2O

- Easier moving (through small passages)
  - Less dense
  - Less viscous
- Less need for efficiency – Only 25% of O_2 in inhaled air used
- Higher concentration of O_2 in air

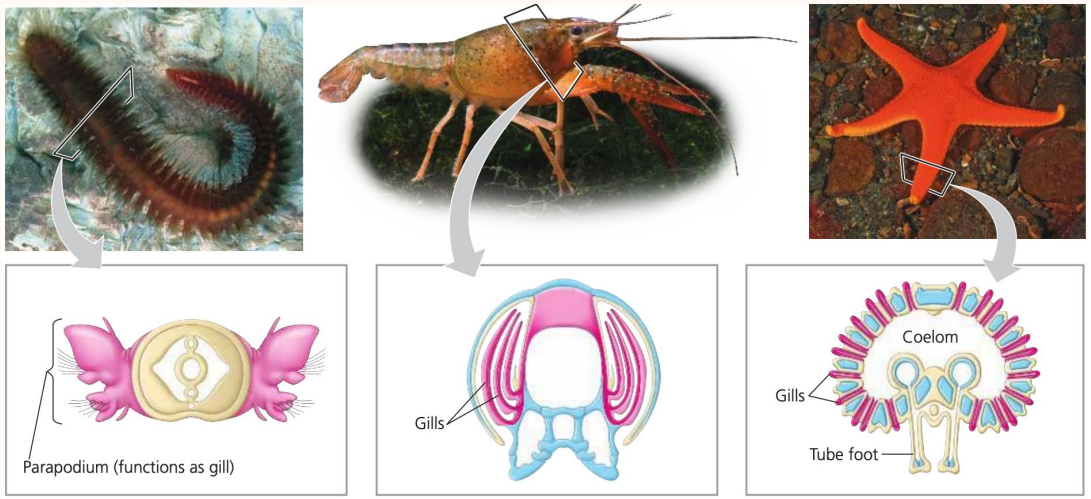
Respiratory Surfaces

- Plasma membranes must always touch aqueous solution
  - Respiratory surfaces always moist
- Usually large and thin
  - O_2 and CO_2 move by diffusion
    - Rate $\propto$ SA, $\sim\propto$ path for diffusion
- Types
  - Simple
    - Every cell close to external environment
    - Fast diffusion
    - Sponges, cnidarians, flatworms
  - Skin
    - Network of capillaries below skin
    - Earthworms, amphibians
  - Gills, tracheae, lungs

Gills

- Large surface area
- Ventilation (respiratory medium moves over respiratory surface) maintains gradients of CO_2 and O_2 for gas exchange
  - Move gills or move water over gills
  - Crayfish and lobsters – paddles to drive water over gills
  - Mussels and clams – move water with cilia
  - Octopuses and squids – take in and eject water
  - Fishes – swimming and mouth movements

Gills

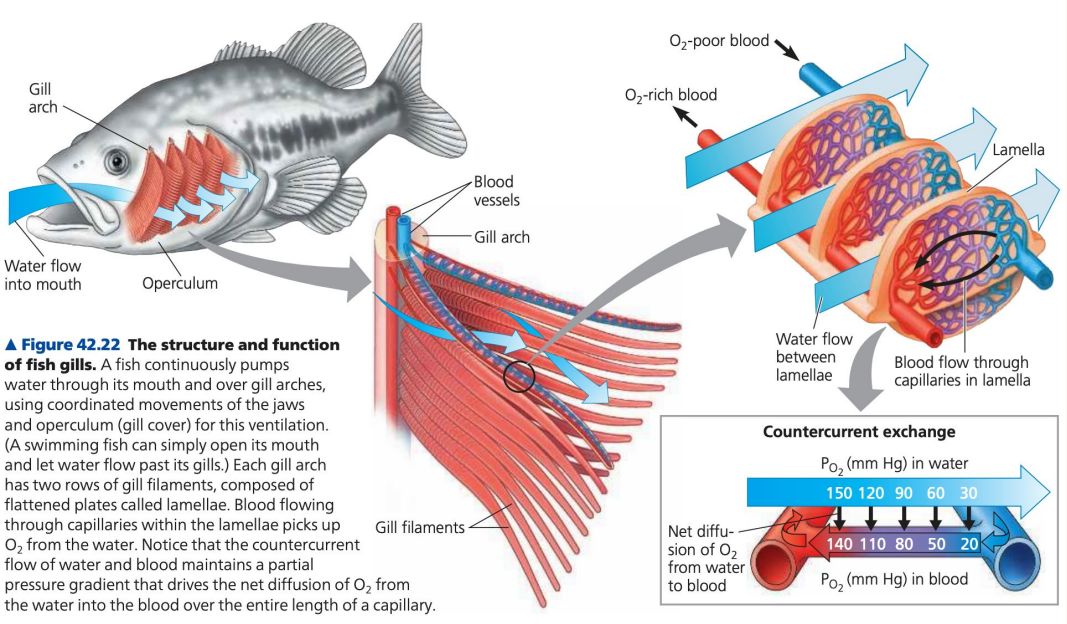


(a) Marine worm. Many polychaetes (marine worms of the phylum Annelida) have a pair of flattened appendages called parapodia (singular, *parapodium*) on each body segment. The parapodia serve as gills and also function in crawling and swimming.

(b) Crayfish. Crayfish and other crustaceans have long, feathery gills covered by the exoskeleton. Specialized body appendages drive water over the gill surfaces.

(c) Sea star. The gills of a sea star are simple tubular projections of the skin. The hollow core of each gill is an extension of the coelom (body cavity). Gas exchange occurs by diffusion across the gill surfaces, and fluid in the coelom circulates in and out of the gills, aiding gas transport. The tube feet surfaces also function in gas exchange.

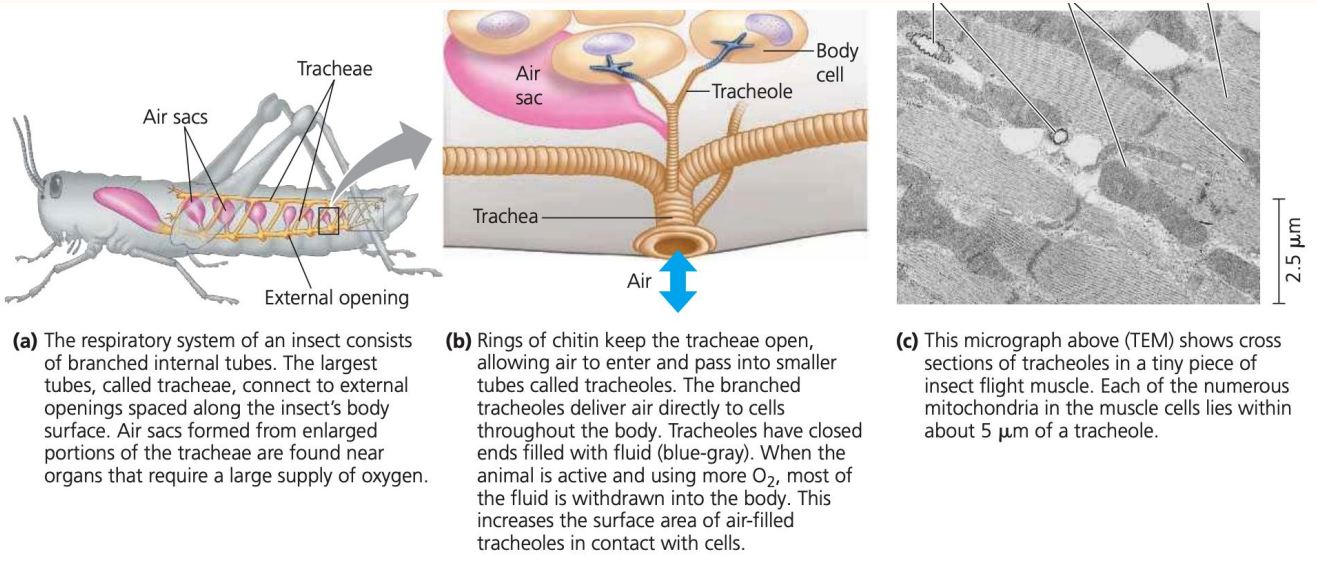
Gills in fish



▲ **Figure 42.22 The structure and function of fish gills.** A fish continuously pumps water through its mouth and over gill arches, using coordinated movements of the jaws and operculum (gill cover) for this ventilation. (A swimming fish can simply open its mouth and let water flow past its gills.) Each gill arch has two rows of gill filaments, composed of flattened plates called lamellae. Blood flowing through capillaries within the lamellae picks up O_2 from the water. Notice that the countercurrent flow of water and blood maintains a partial pressure gradient that drives the net diffusion of O_2 from the water into the blood over the entire length of a capillary.

Tracheal System (Insects)

Spiracles → Trachea → Tracheoles → Moist, fluid-filled ends
More O_2 supplied by motion when flying



(a) The respiratory system of an insect consists of branched internal tubes. The largest tubes, called tracheae, connect to external openings spaced along the insect's body surface. Air sacs formed from enlarged portions of the tracheae are found near organs that require a large supply of oxygen.

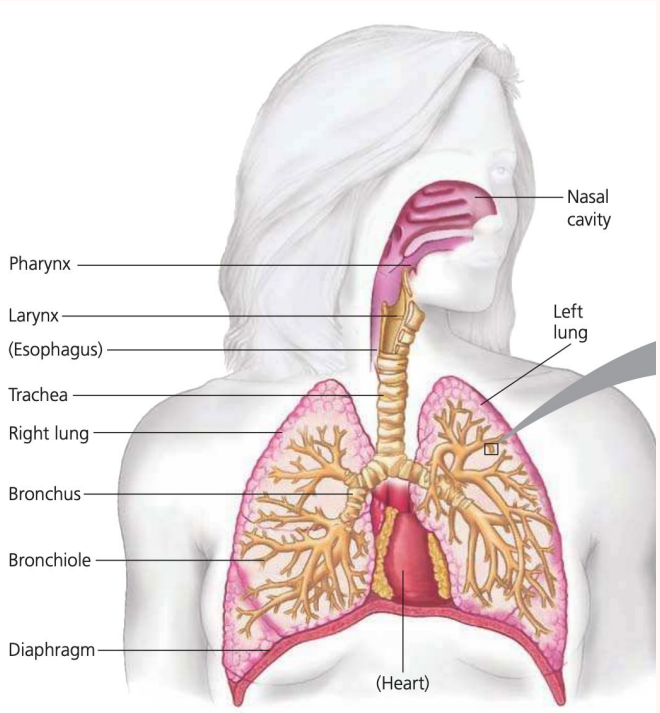
(b) Rings of chitin keep the tracheae open, allowing air to enter and pass into smaller tubes called tracheoles. The branched tracheoles deliver air directly to cells throughout the body. Tracheoles have closed ends filled with fluid (blue-gray). When the animal is active and using more O_2, most of the fluid is withdrawn into the body. This increases the surface area of air-filled tracheoles in contact with cells.

(c) This micrograph above (TEM) shows cross sections of tracheoles in a tiny piece of insect flight muscle. Each of the numerous mitochondria in the muscle cells lies within about 5 µm of a tracheole.

Lungs

- Acts with circulatory system
- Degree of use varies among vertebrates without gills
  - Amphibians use skin and have small or nonexistent lungs
  - Reptiles and mammals depend entirely on lungs
    - Turtles supplement breathing with other gas exchange methods
  - May be present in some aquatic vertebrates in oxygen-poor water or receding water

Mammalian Lungs

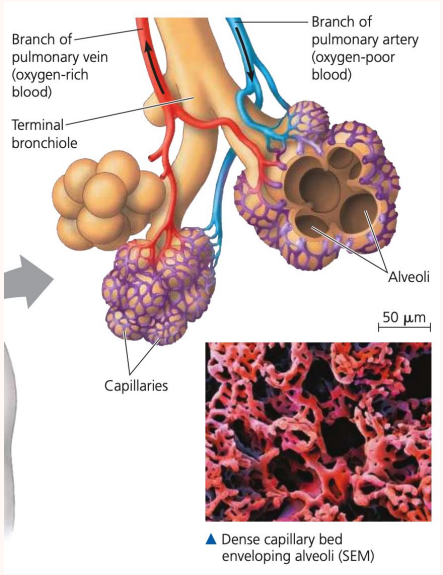


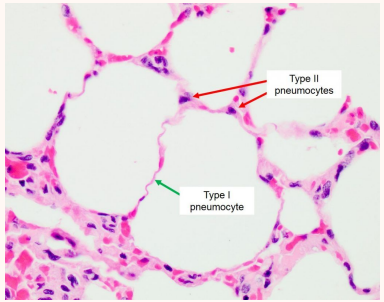
- Lungs are in thoracic cavity, enclosed by ribs and diaphragm
- Nostrils
  - Filter, warm, humidify, and sample air
- Pharynx + Larynx (cartilage)
  - Moves up to tip epiglottis over glottis if swallowing
  - Cystic fibrosis (CFTR channels)
- Trachea (cartilage)
  - Vocal folds/cords
- Left/right bronchi
- Bronchioles
- Terminal bronchioles
- Respiratory bronchioles + Alveoli

Conducting zone

Respiratory zone

Alveoli





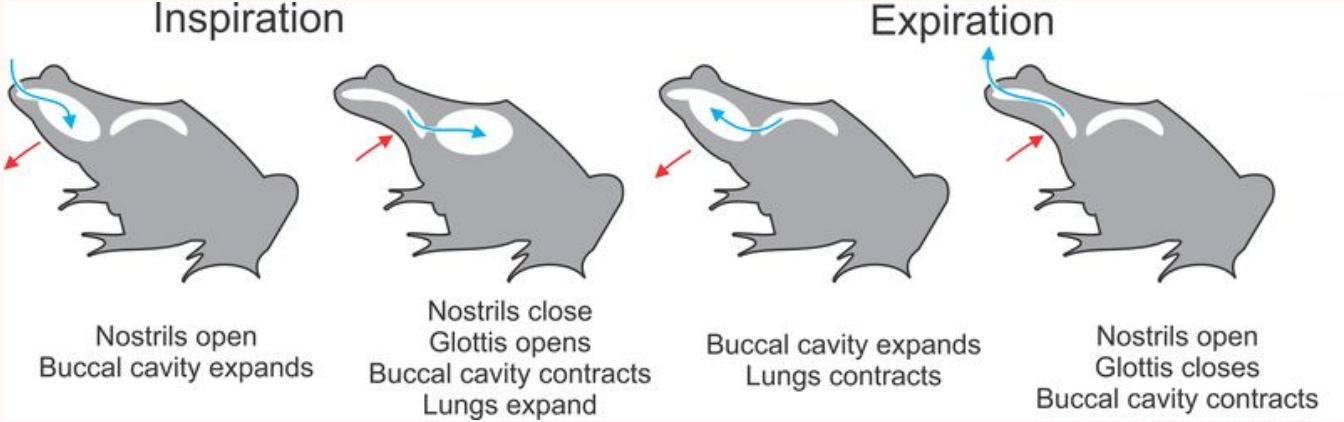
- 100 m^2 of surface area (50x that of skin)
- Easily to contaminate
  - White blood cells patrol
  - Silicosis from coal dust
- Type I alveolar cells
  - Flat, epithelial
  - Line air-facing surfaces
- Type II alveolar cells
  - Make surfactant
    - Respiratory distress syndrome (Mary Ellen Avery)
- Pores permit flow between some alveoli

https://ohiostate.pressbooks.pub/app/uploads/sites/36/2017/05/Alveoli-with-labels-1024x811.jpg

Amphibian Breathing

- Positive-pressure

1. Muscles lower oral cavity floor and air is drawn in through nostrils
2. Nostrils and mouth close and oral cavity floor rises, forcing air down trachea
3. Exhalation – air expelled by elastic recoil and compression of muscular body wall



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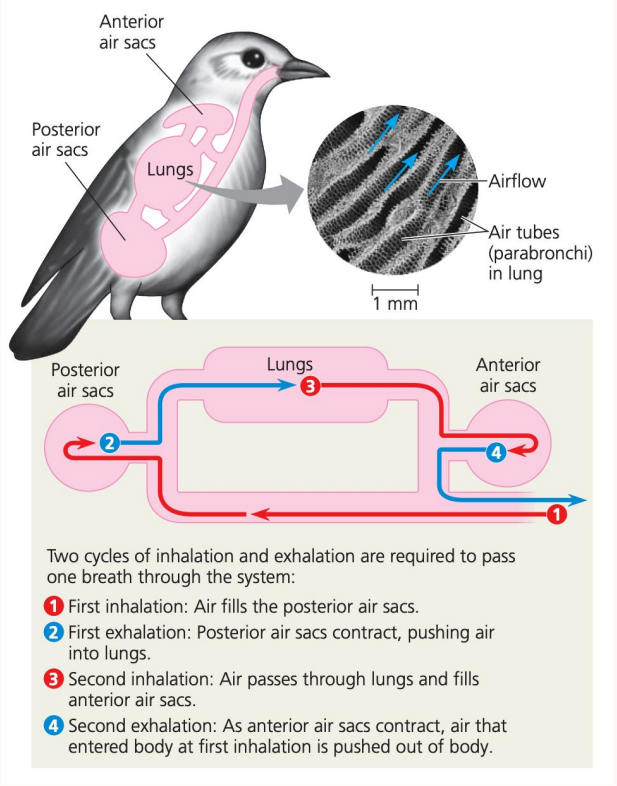
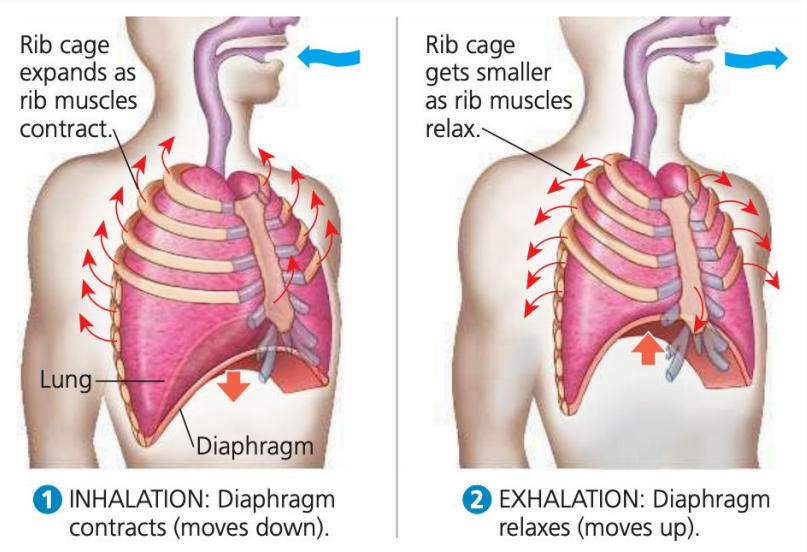
Bird Breathing

- Passing air requires 2 cycles of inhalation and exhalation
- Very efficient
  - Air only passes over gas exchange surface in one direction
  - Fresh air doesn't mix with air that has already conducted gas exchange



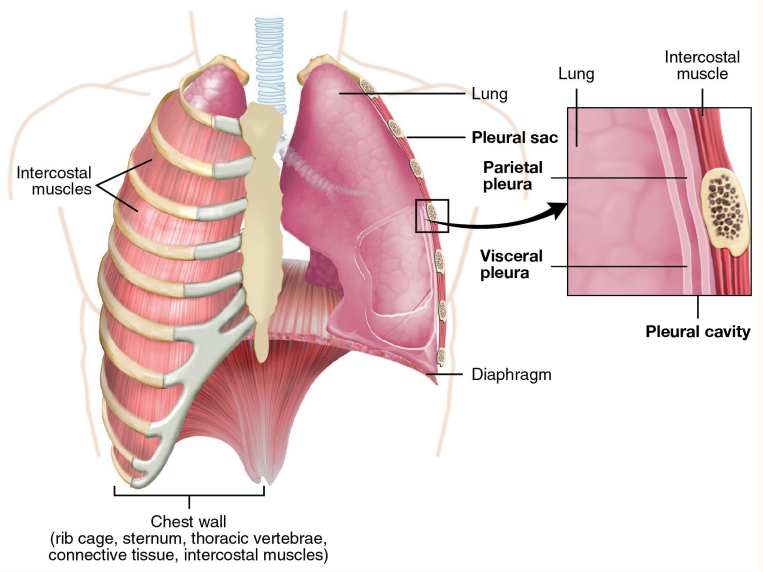
Mammalian Breathing

- Negative-pressure breathing
- Muscles expand thoracic cavity → lower pressure inside body → air drawn in
  - Diaphragm contracts, which expands cavity downward
  - Rib muscles pull ribs upward and sternum outward
- Active inhalation, passive exhalation



Thoracic Cavity

- Muscles and connective tissue at neck at the top
- Diaphragm at the bottom
- Spinal column, ribs, sternum, and intercostal muscles make walls
- Pleural sac forms double membrane around lungs
  - Hand in balloon
  - Visceral pleura coats lung and is attached with connective tissue
  - Parietal pleura is attached to thoracic wall and diaphragm
  - Intrapleural fluid lubricates pleural surfaces so they slide while breathing
    - Surface tension keeps layers together like water between glass



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Additional Info

- Other muscles help expand thoracic cavity during exercise
  - Kangaroos' organs in their abdomens move like a piston
- Tidal volume – volume inhaled/exhaled with each breath
- Vital capacity – volume at max inhalation/exhalation
- Residual volume – air remaining after forced exhalation
  - Increases with age
- Air in alveoli has less O_2 than atmosphere because atmospheric air mixes with residual air
  - Why birds do well at high altitudes

Control of Breathing in Humans

- Medulla oblongata in the brain (and pons)
  - Uses pH of cerebrospinal fluid to measure CO_2 concentration
  - O_2 levels usually not used

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

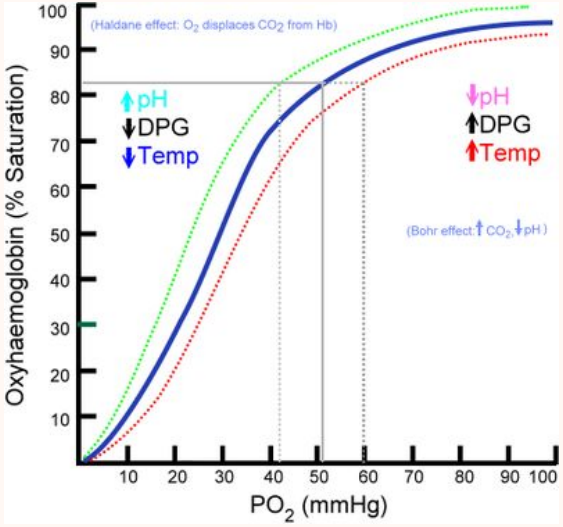
Respiratory Pigments

O_2 has low solubility in water

- Hemocyanin
  - Copper makes it blue
  - Arthropods and molluscs, spiders
  - Blue when oxygenated, colorless when not
- Hemoglobin
  - 4 subunits
  - Polypeptide + heme group (with iron)
- Chlorocruorin
  - Iron
  - Earthworms, leeches, marine worms, some lizards
  - Green when oxygenated, light green when not
  - Biliverdin
- Hemoerythrin
  - Iron
  - Marine worms + brachiopods
  - Purple when oxygenated, colorless when not

Dissociation Curves

- Hemoglobin exhibits cooperativity
  - Steep slope = small change in oxygen content leads to massive loading/unloading of oxygen
- Bohr shift (low pH decreases affinity for oxygen)



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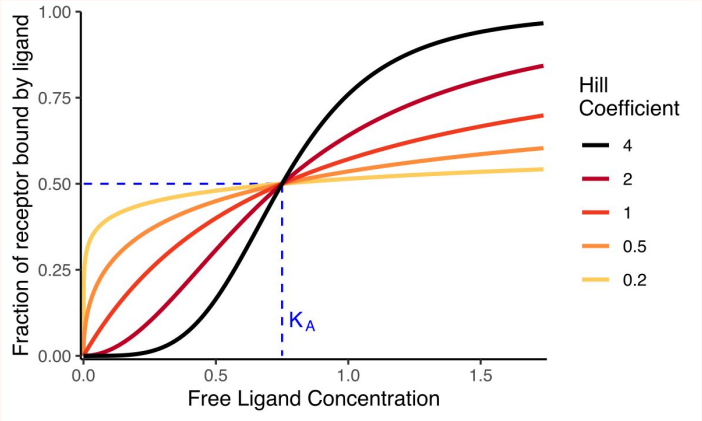
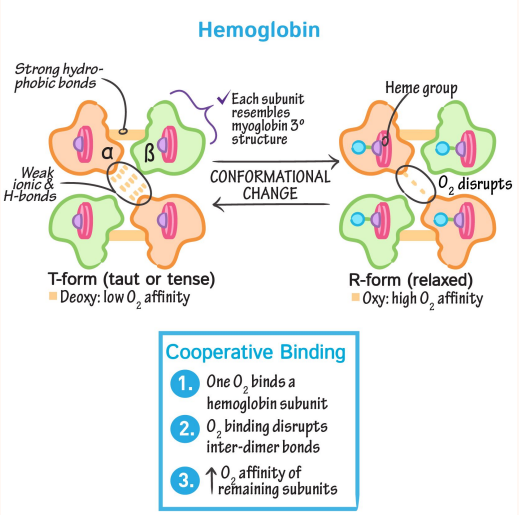
Hemoglobin Cooperativity

Myoglobin vs. Hemoglobin cooperativity





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Respiratory Adaptations for Divers

- Weddell seal can dive for more than an hour
  - Twice the volume of blood per body mass
  - Lots of myoglobin
- Cuvier’s beaked whale can dive for more than 2 hours
- Conserve oxygen
  - Glide for most of the time
  - Blood routed to most important tissues

Practice!

All of the following factors increase the release of oxygen from hemoglobin in systemic capillaries, EXCEPT:
W) High temperature
X) Low temperature
Y) Acidic pH levels
Z) Low partial pressure of oxygen

Which of the following is NOT true regarding human hemoglobin?
W) It is a tetramer
X) It exhibits binding cooperativity
Y) It exhibits a sigmoidal saturation curve
Z) It exhibits higher affinity for oxygen than myoglobin

2016 Opens

Questions 21 & 22. SELECT ALL THAT APPLY.

A.

B.

C.

D.

21. Which organisms in the figures above utilize holoblastic cleavage?

22. Which of the organism above in the figure above utilizes positive pressure breathing?

2016 Opens

27. Manuel has just finished an intense 10-kilometer running race. His body has

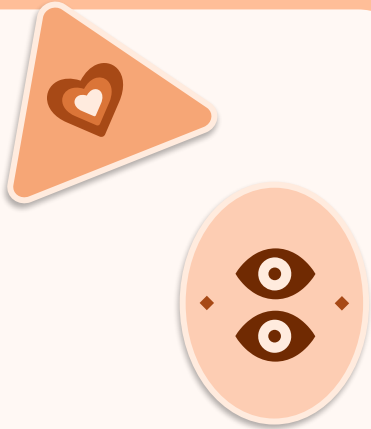
A. An increased level of carbonic acid and increased pH of body fluids.
B. An increased level of carbonic acid and decreased pH of body fluids.
C. A decreased level of carbonic acid, and increased pH of body fluids.
D. A decreased level of carbonic acid and decreased pH of body fluids.
E. No change in level of carbonic acid or pH.

2013 Opens

24. The binding affinity of hemoglobin to O_2 in the bloodstream is greatest at relatively

A. High pH and high CO_2 concentration.
B. High pH and low CO_2 concentration.
C. Low pH and high CO_2 concentration.
D. Low pH and low CO_2 concentration.
E. Low pH, and does not depend on CO_2 concentration.

THANKS!



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