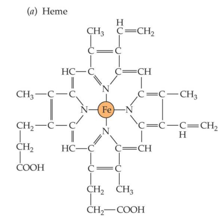
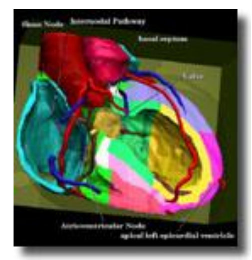
Circulation

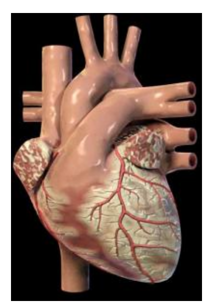
Transport of oxygen and carbon dioxide in body fluids

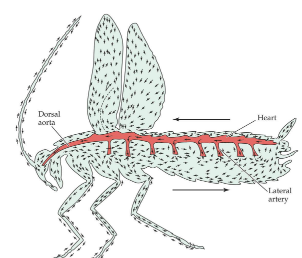


Circulation and Hearts



Circulation in vertebrates and invertebrates





Respiratory pigments Increase the amount of oxygen carried by blood

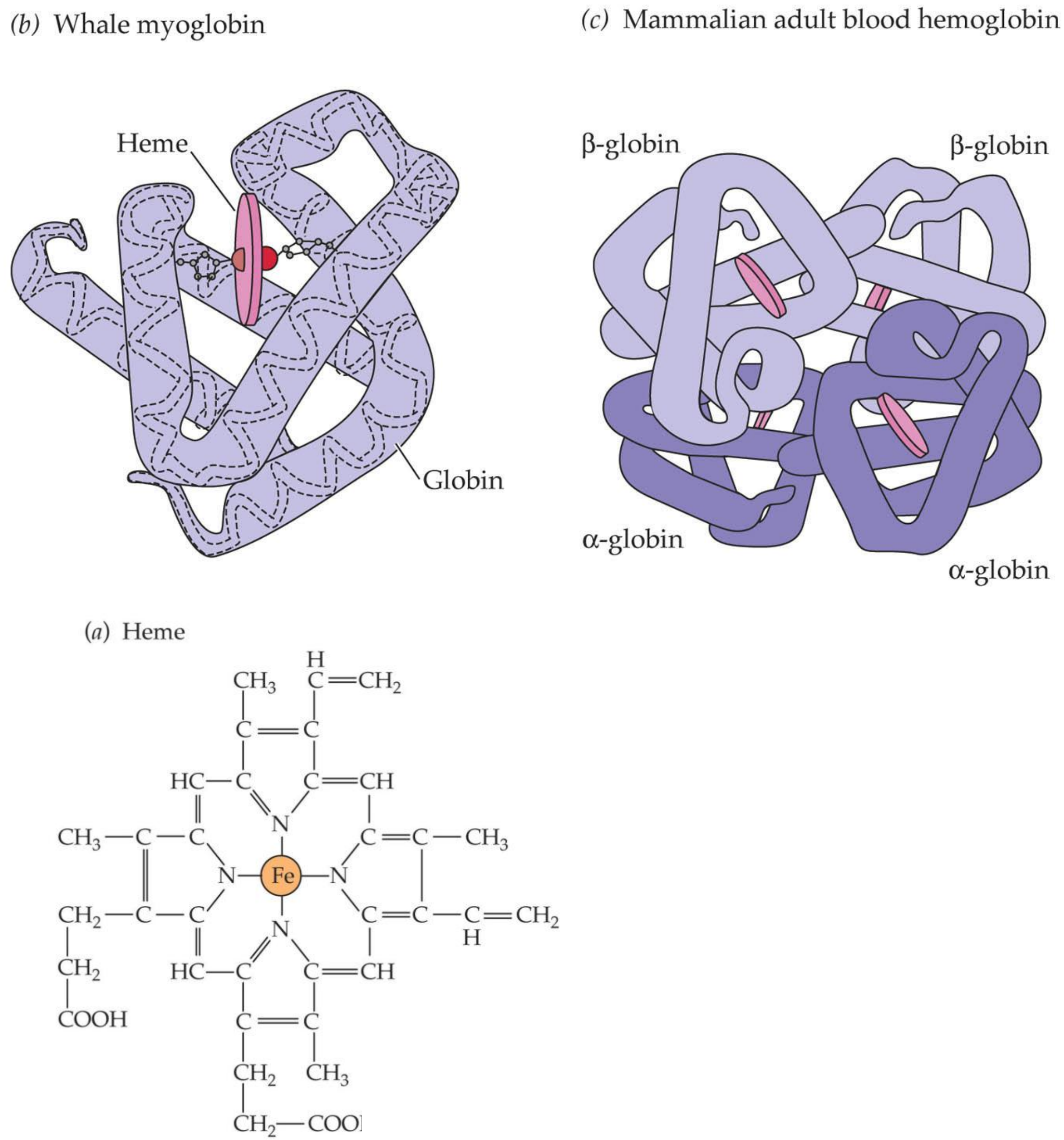
Respiratory pigments undergo reversible combination with O2

Oxygen is chemically combined with the pigment

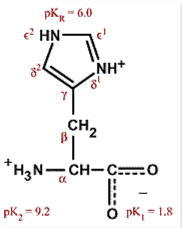
All respiratory pigments are metalloproteins

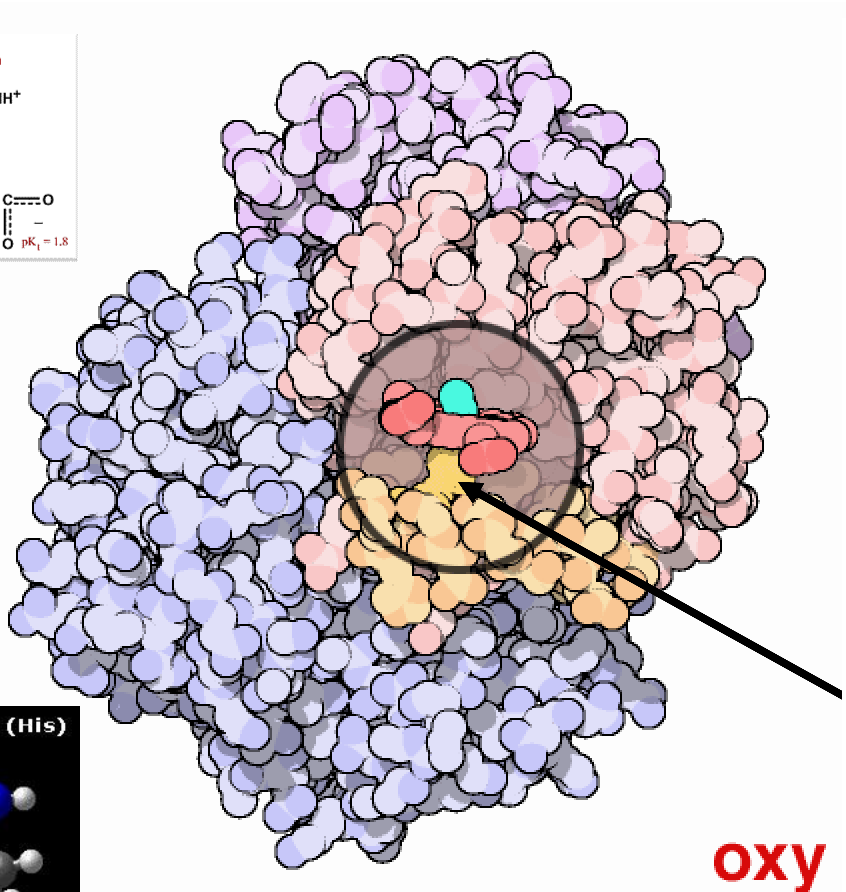
Hemoglobin is a metalloprotein, the heme group binds O_2

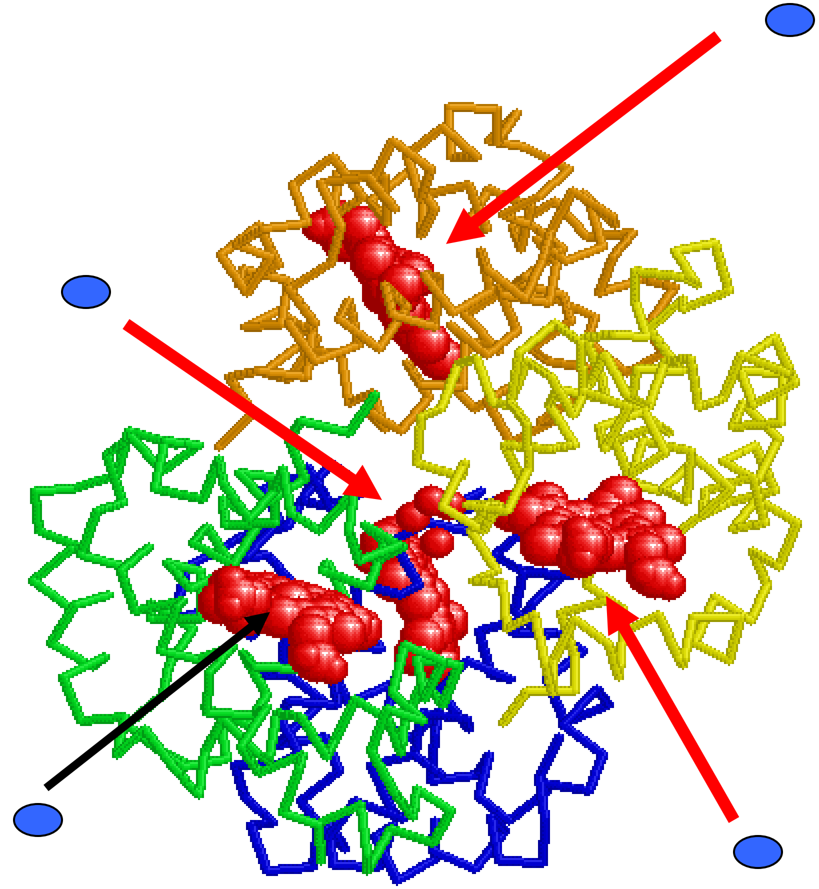
Heme is a metalloporphyrin

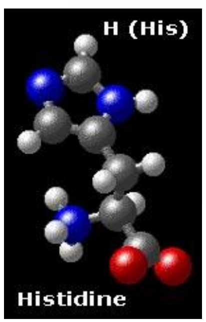


Respiratory pigments undergo reversible combination with O2





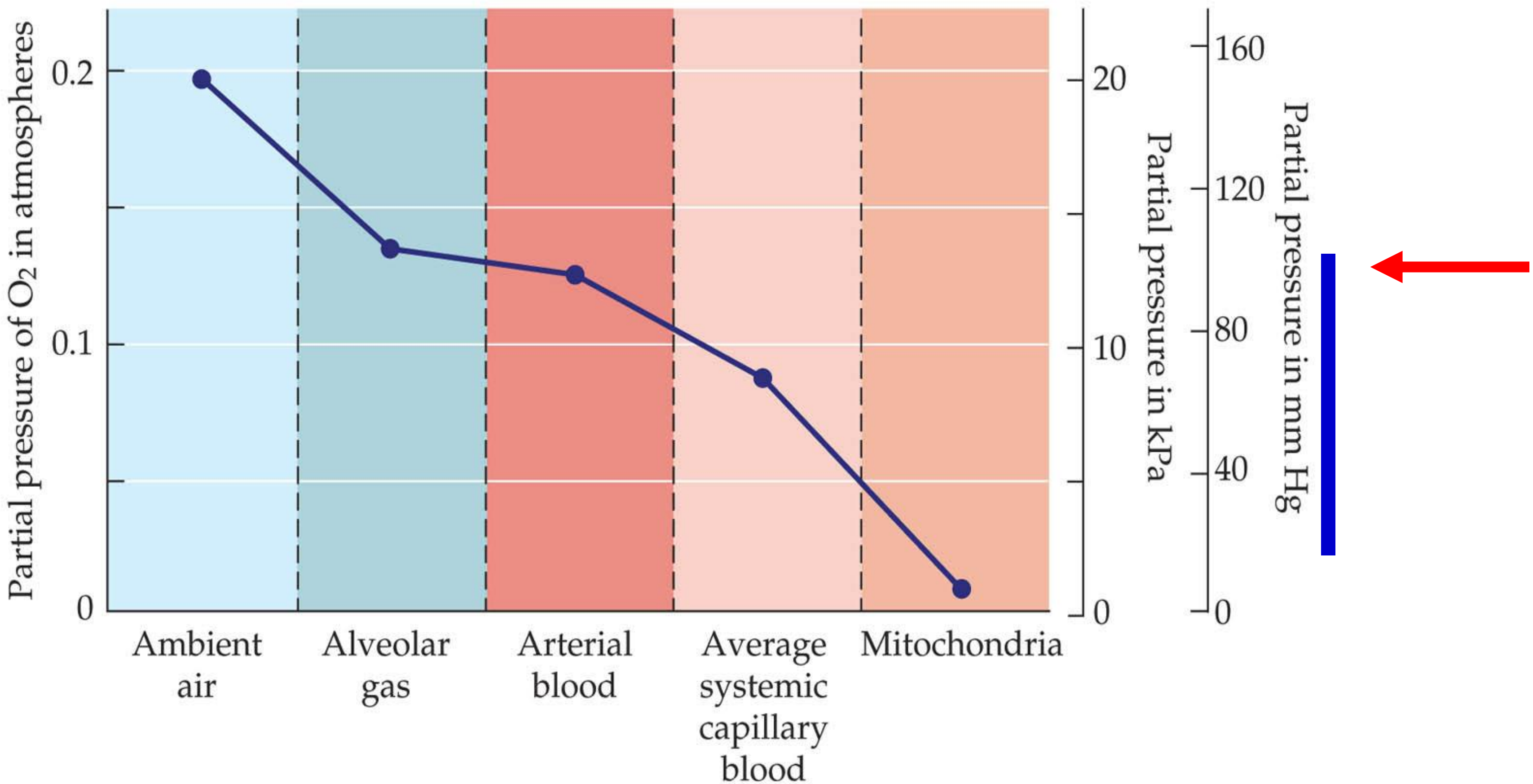




Cooperativity: binding of one oxygen increases affinity for others (total of 4)

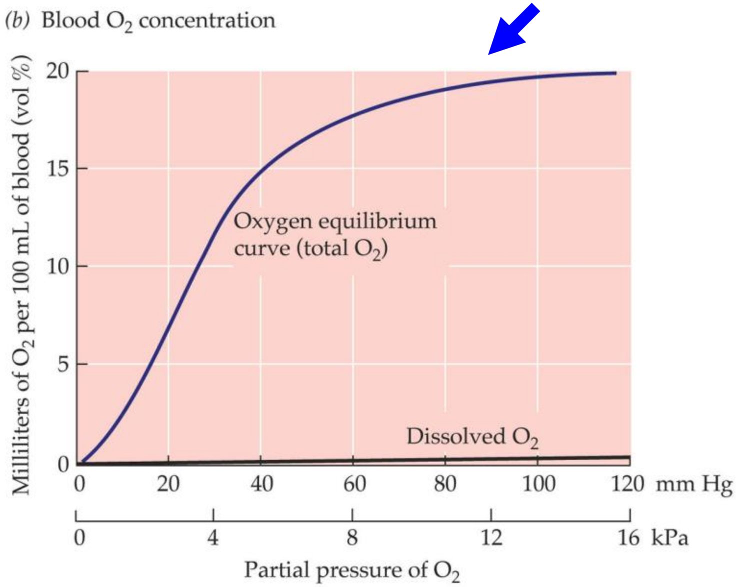
As **oxygen** binds to the iron atom in the center of the **heme**, it pulls a **histidine** amino acid upwards on the bottom side of the heme. This shifts the position of an entire alpha helix, shown here in **orange** below the heme.

This motion is propagated throughout the protein chain and on to the other chains, ultimately causing the large rocking motion of the other subunits (*b*) The oxygen cascade in people

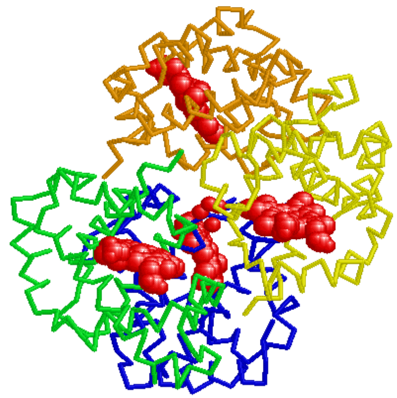


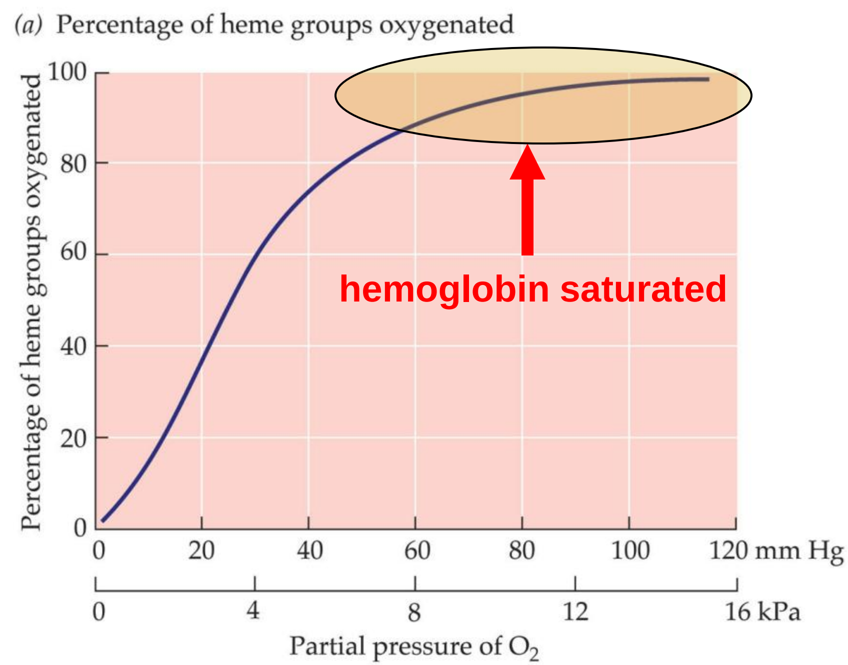
Typical <u>oxygen equilibrium curves</u> for human arterial blood

Most O_2 is transported combined with hemoglobin



- **Affinity for a ligand**
- **Binding sites**
- **Highly specific**
- **Conformational changes**
- **Saturated**
- **Allosteric sites (regulate)**

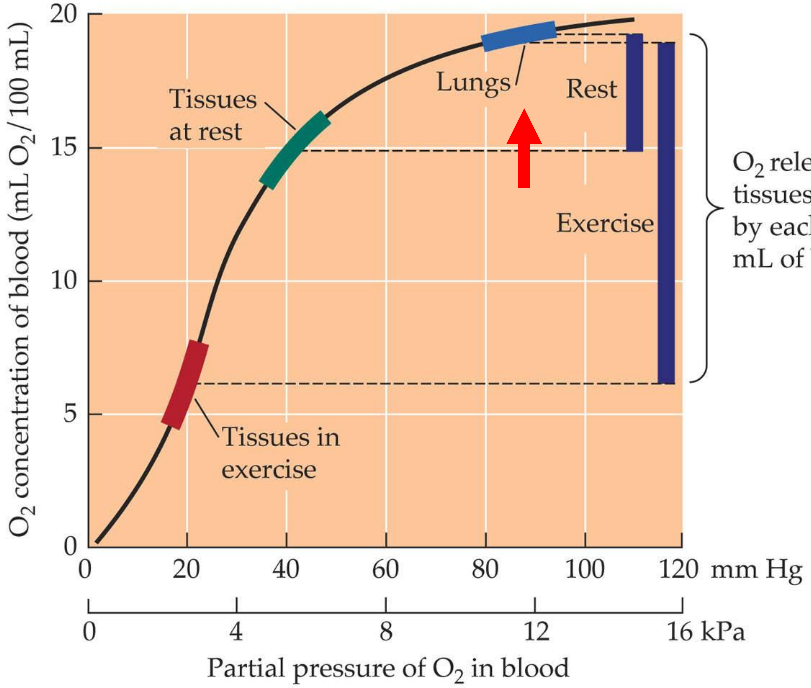




There is a relation between the amount of O_2 bound To hemoglobin and the O_2 partial pressure.

The amount of O_2 **<u>bound</u>** or **<u>released</u>** by hemoglobin depends on the partial pressure.

Oxygen delivery by human blood at rest and during vigorous exercise

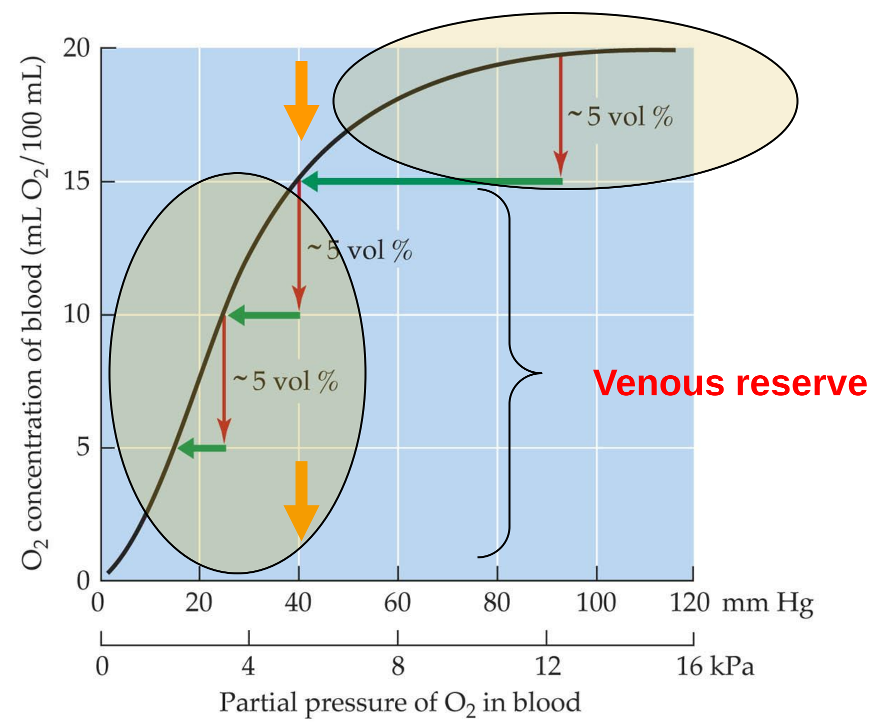


ANIMAL PHYSIOLOGY, Figure 22.5 © 2004 S

HB is well oxygenated in the breathing tissues

AT REST Only a modest fraction of oxygen is released in the tissues **(25%)**

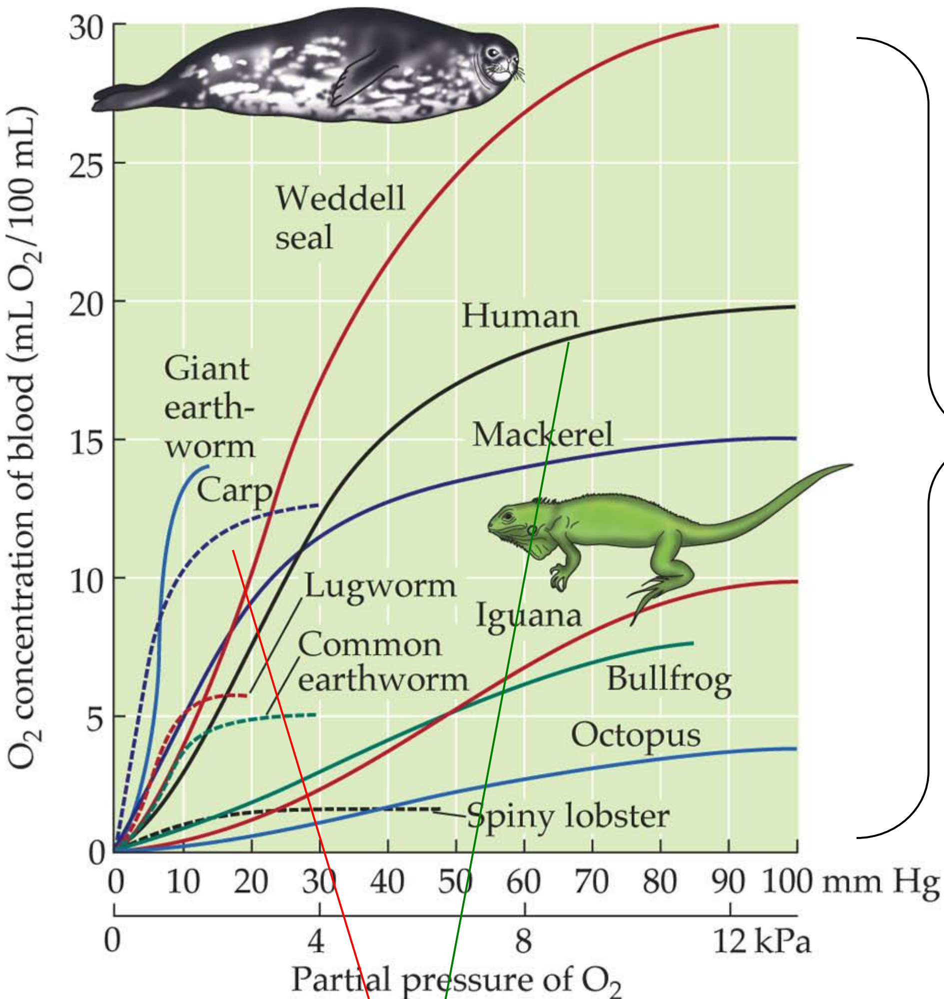
Easy de-oxygenation **Easy oxygenation**



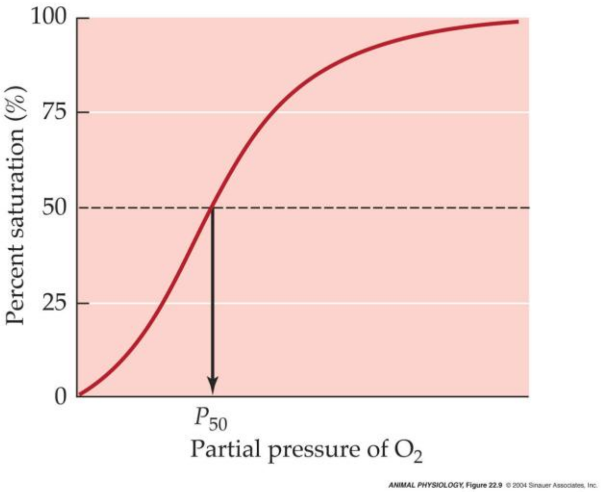
As O_2 partial pressure of blood falls, less of a drop is required to cause unloading of a large vol of O_2

- **3 times more O_2 is extracted from blood at exercise.**
- **4 times more circulation**
- **4x3 = <u>12 times more O_2 to tissues</u>**

A diversity of blood oxygen equilibrium curves

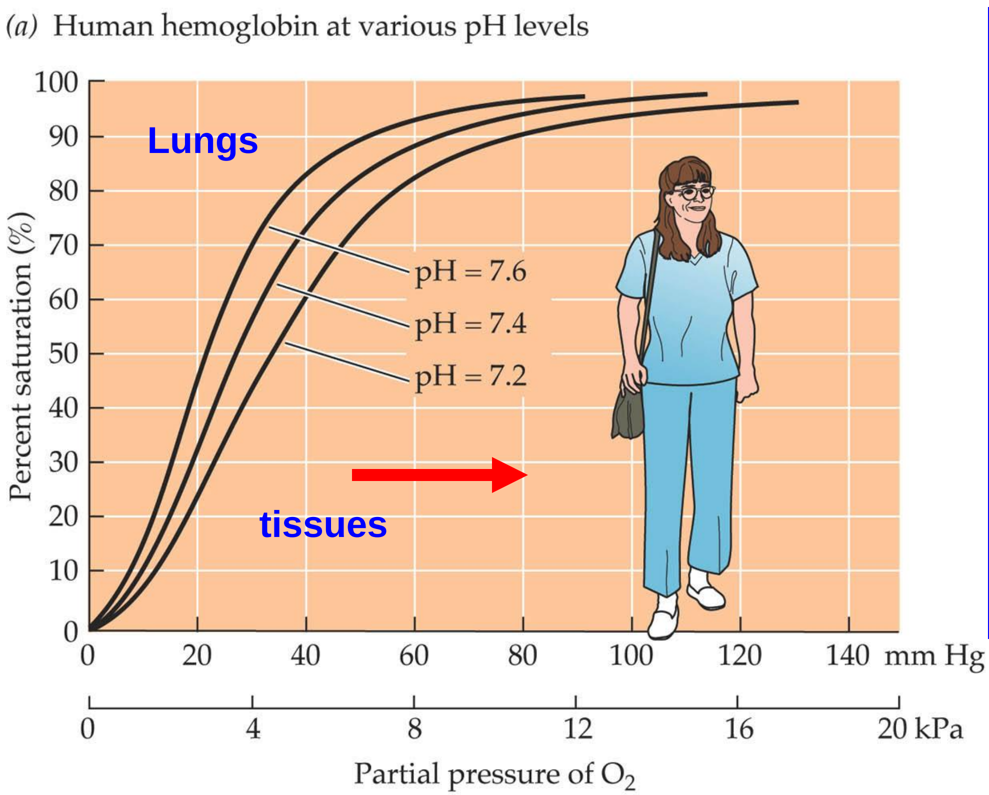


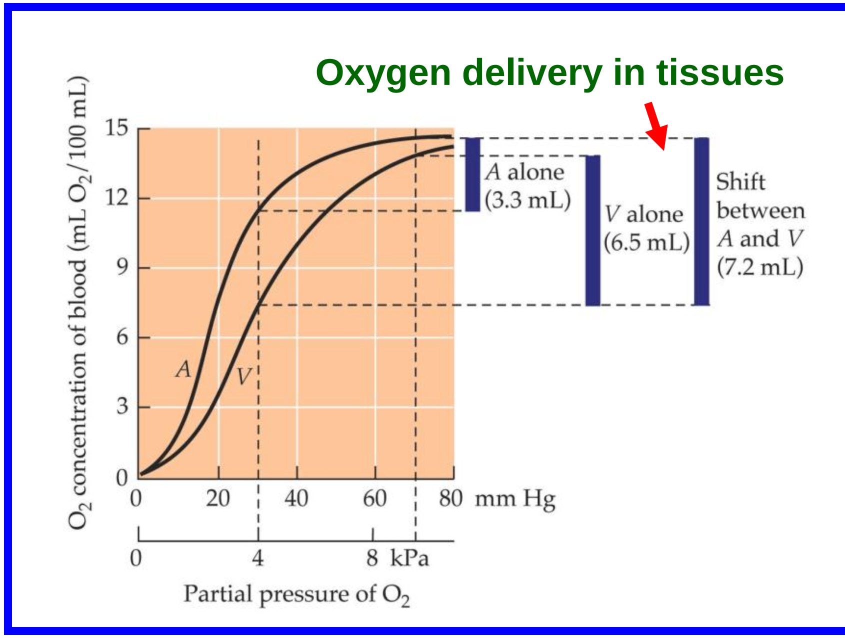
Height **(more pigment)**



Shape : **Affinity**

The **Bohr effect**: decrease in pH or increase on CO_2 decrease affinity for O_2





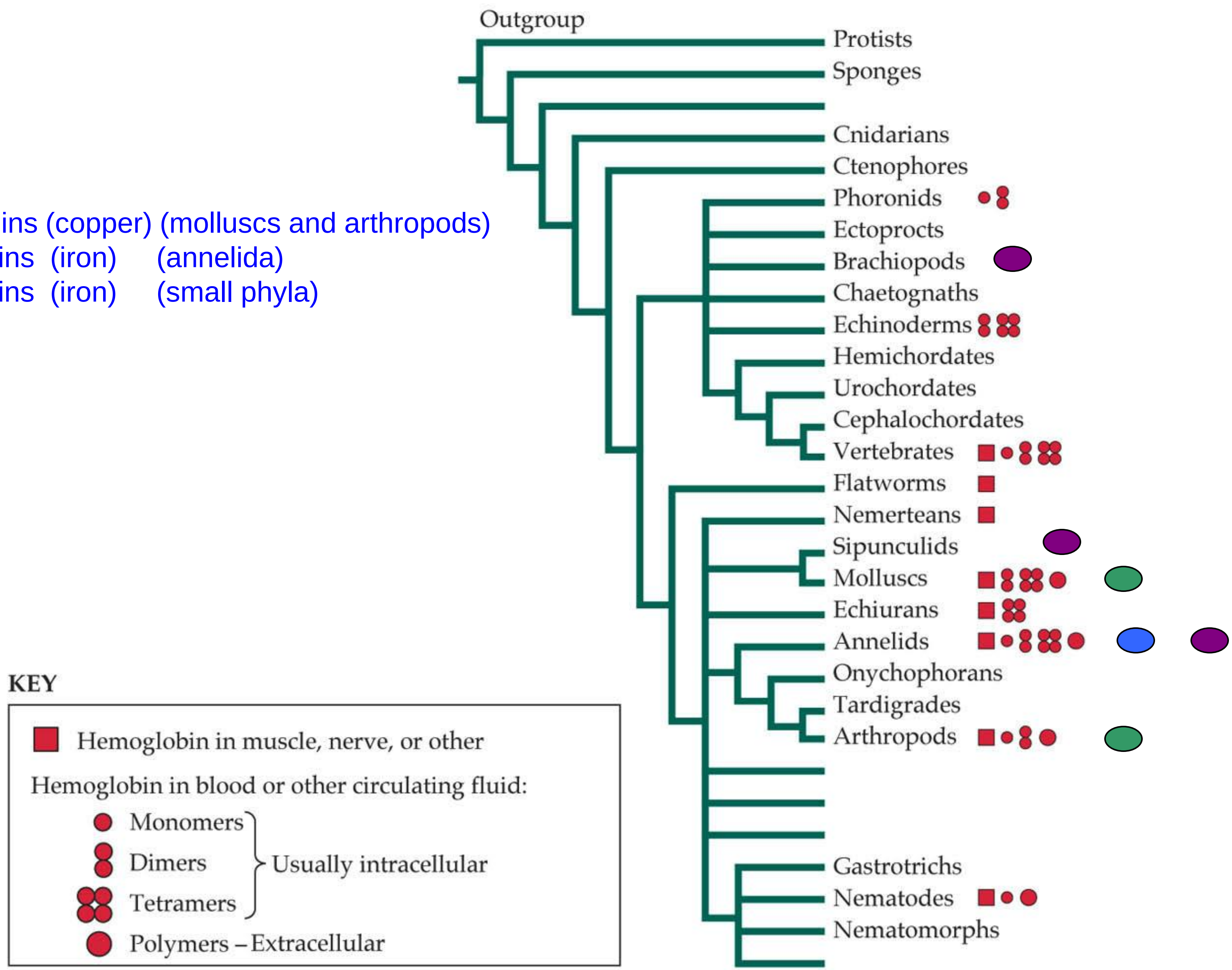
The **Bohr effect** enhances O_2 delivery because it promotes unloading in systemic tissues and loading on breathing organs

CO_2 increase results in H^+ increase, that combine with Hb and allosterically favor O_2 dissociation

HCO_3^- **formation: $CO_2 + H_2O \leftrightarrows HCO_3^- + H^+$** → **$HbO_2 + H^+ \leftrightarrows HbH^+ + O_2$**

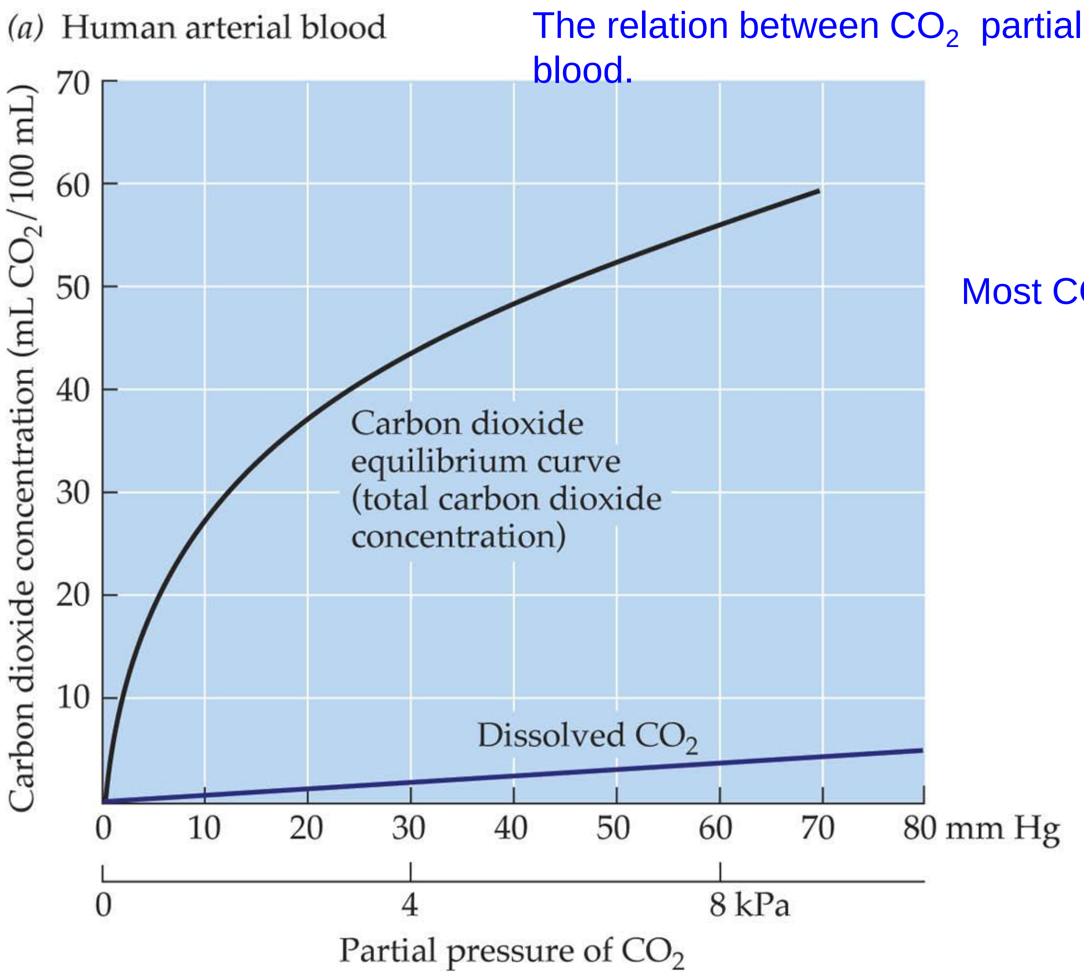
The distribution of hemoglobins in animals

Hemocyanins (copper) (molluscs and arthropods)
Clorocruorins (iron) (annelida)
Hemerythrins (iron) (small phyla)



ANIMAL PHYSIOLOGY, Figure 22.3

Carbon dioxide equilibrium curves

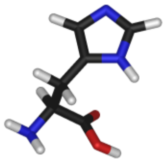


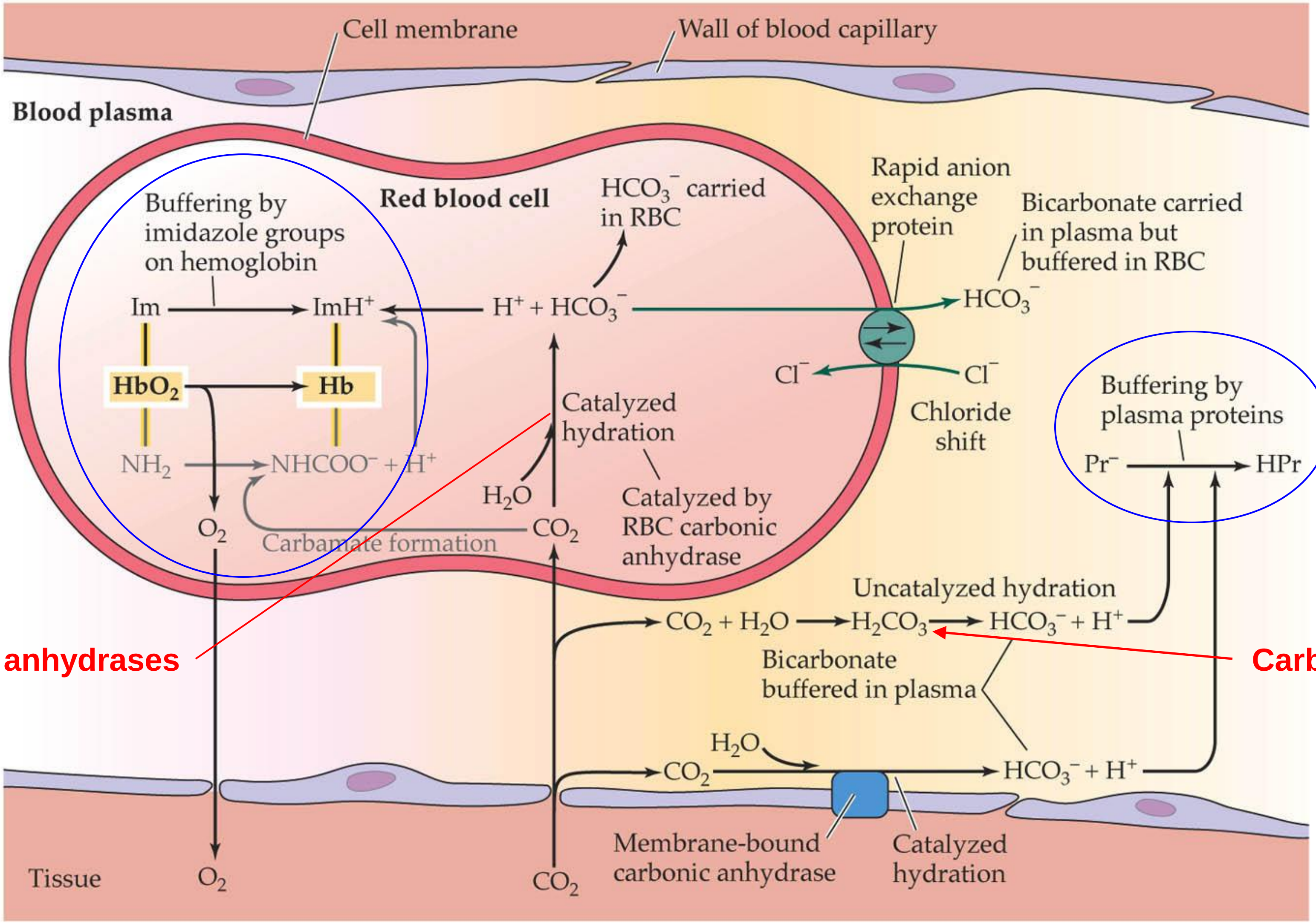
The relation between CO_2 partial pressure and total CO_2 concentration in blood.

Most CO_2 is **transported** as bicarbonate HCO_3^-

HCO_3^- **formation:** $CO_2 + H_2O \leftrightarrows HCO_3^- + H^+$

Processes of CO_2 uptake by the blood in a systemic blood capillary of a vertebrate



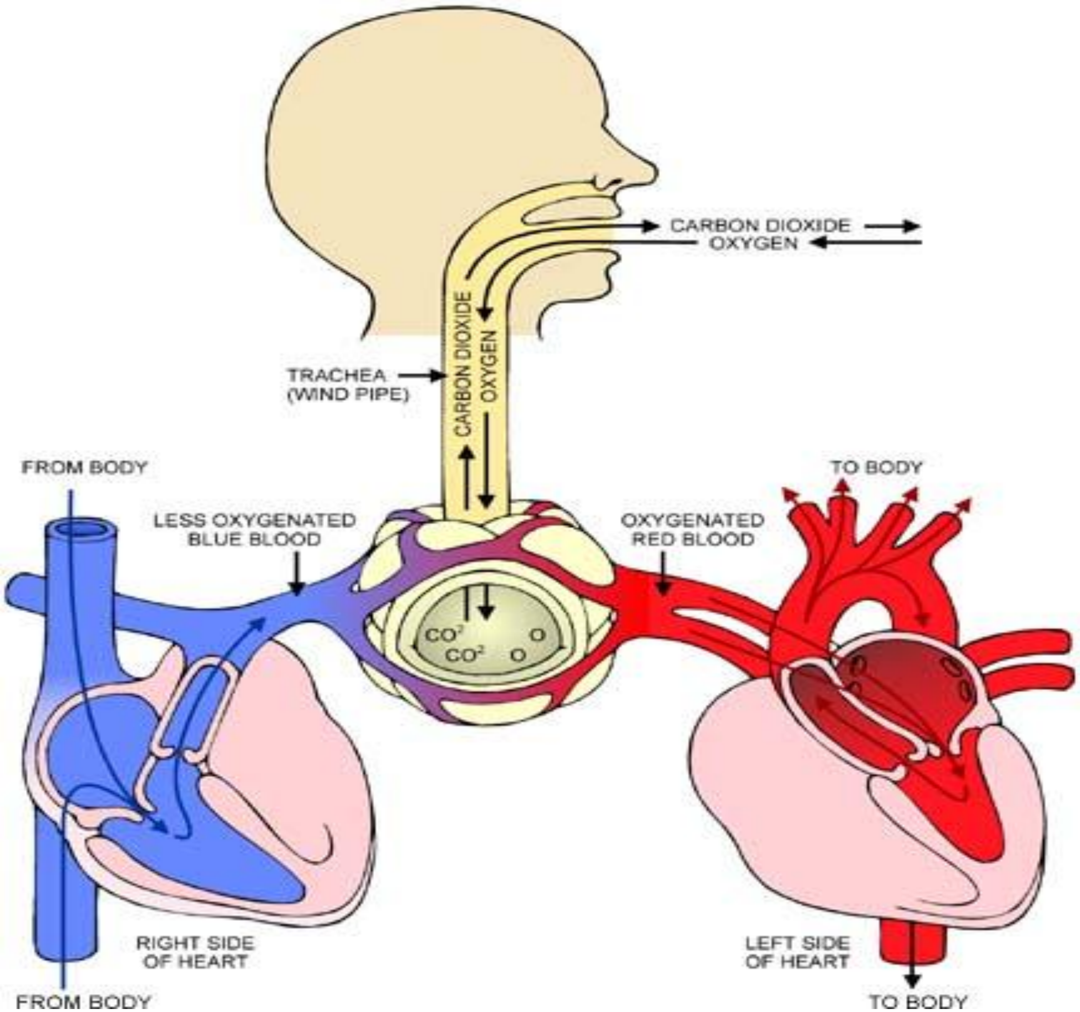


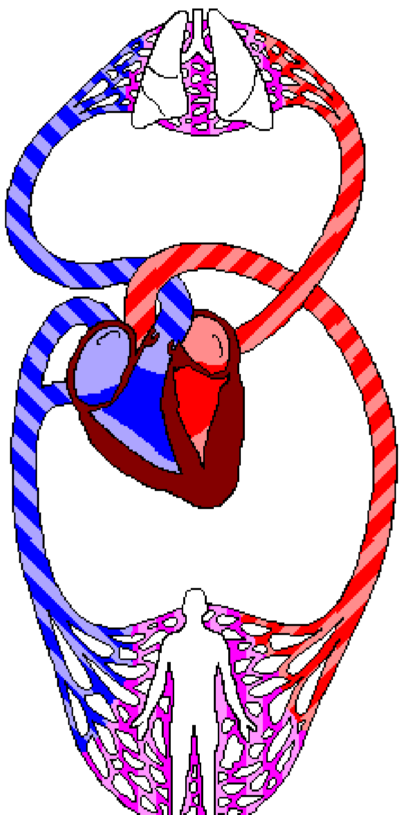
The extent of CO_2 transport depends on blood buffers

HCO_3^- **formation:** $CO_2 + H_2O \leftrightarrows HCO_3^- + H^+$

Circulation is a pressure-driven mass flow of **fluid** that rapidly **transports** O_2, CO_2, nutrients, organic wastes, hormones, agents of the immune system, heat, and other commodities throughout the body and that often provides a source of **hydraulic pressure** for organ function.

Heart: discrete, localized pumping structure





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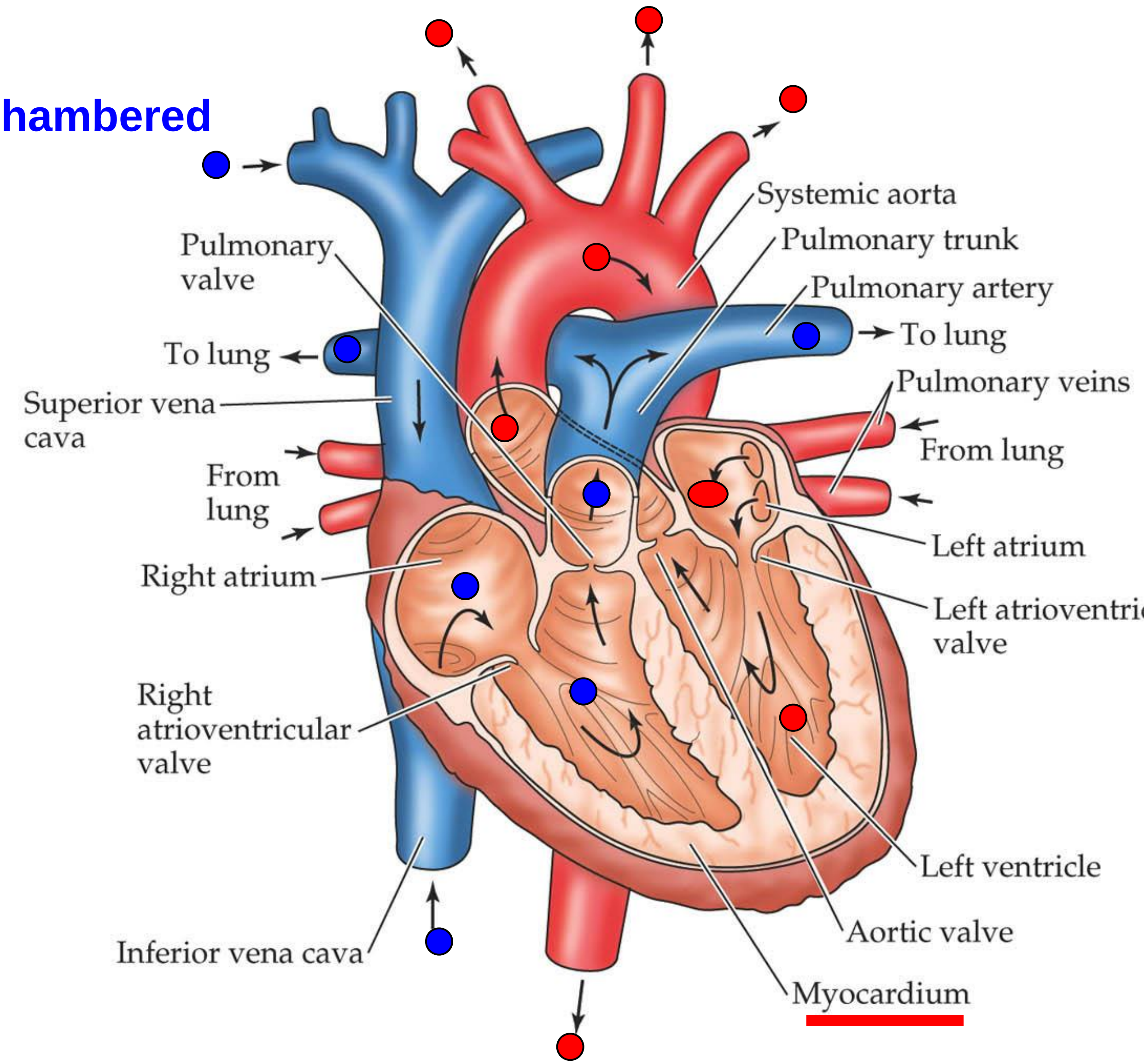
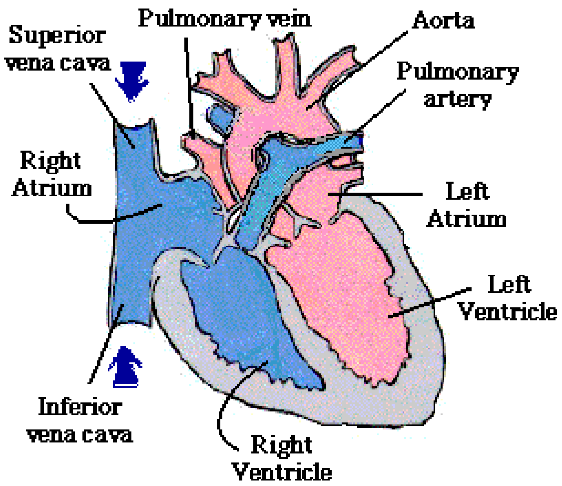
Heart: discrete, localized pumping structure

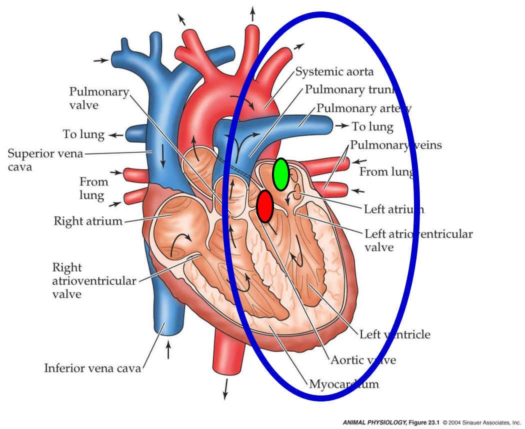
Chambered



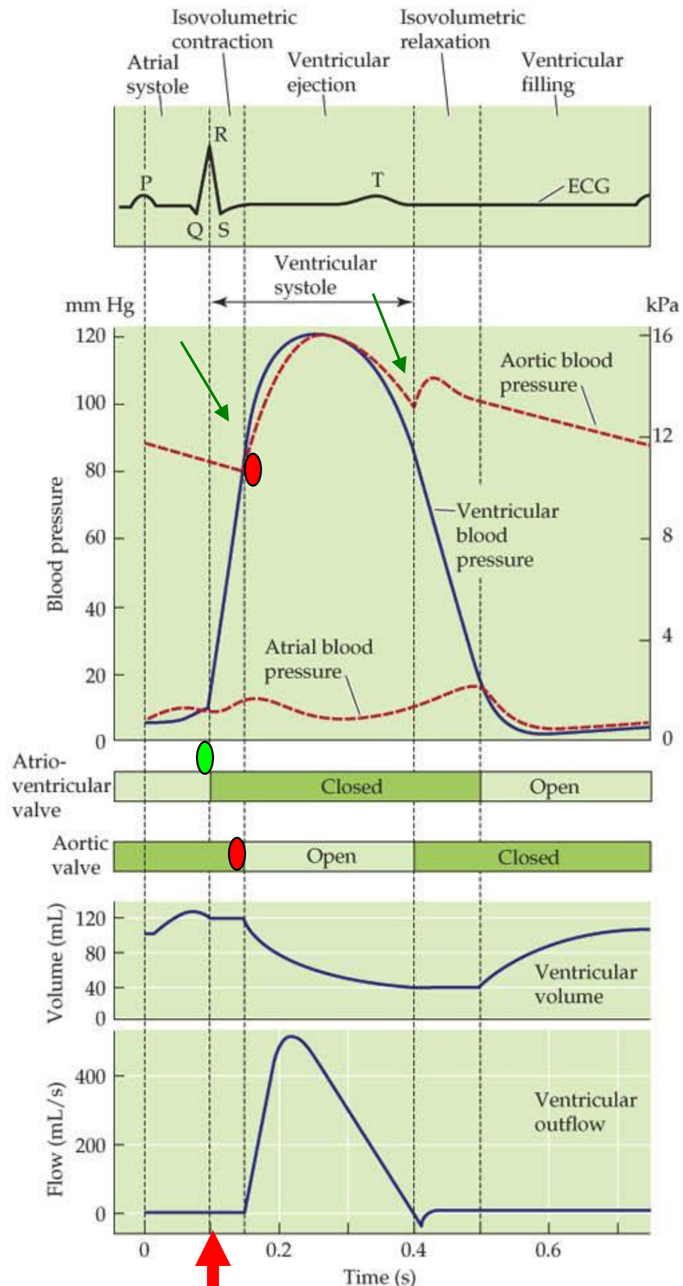


The heart as a pump: The dynamics of the left side of the human heart

1. Atrial systole
2. Isovolumetric contraction
3. Ventricular ejection
4. Isovolumetric relaxation
5. Ventricle filling.



Contraction: systole
Relaxation: diastole



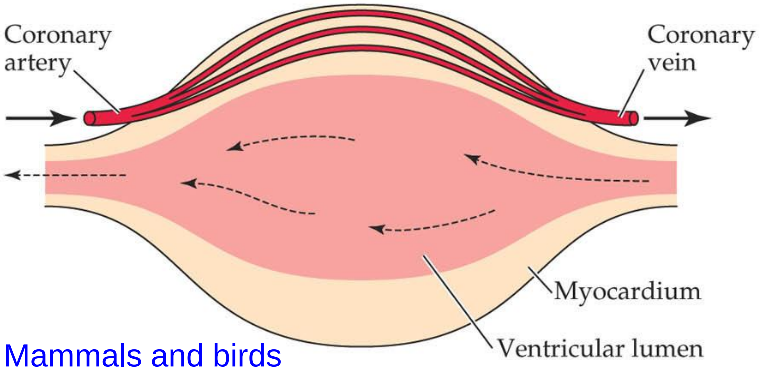
- **Pressure**

- **Volume**

- **Flow**

Different systems evolved by animals to supply O_2 to the myocardium

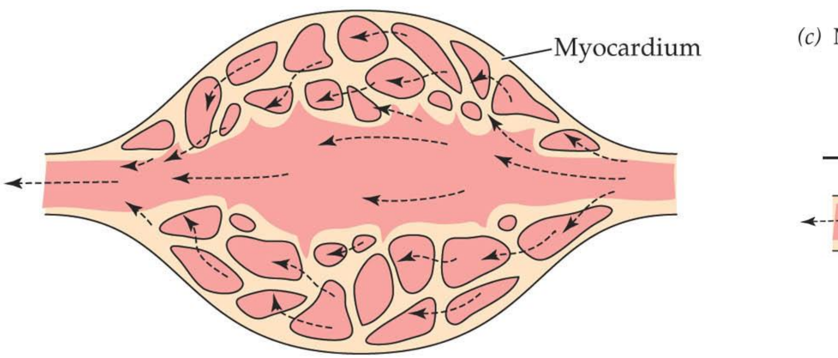
(*a*) Compact myocardium with coronary arteries and veins



Mammals and birds

O_2 MUST be delivered to the myocardium

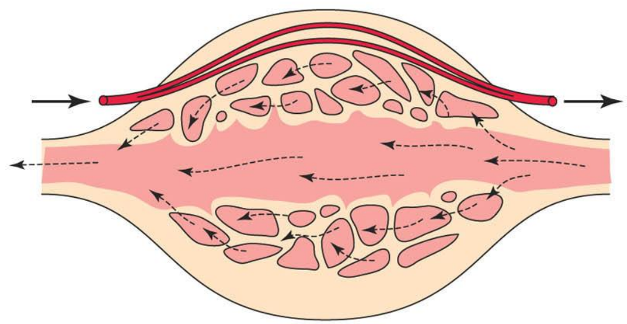
(*b*) Spongy myocardium with little or no development of coronary vessels



Teleost, amphibians, reptiles

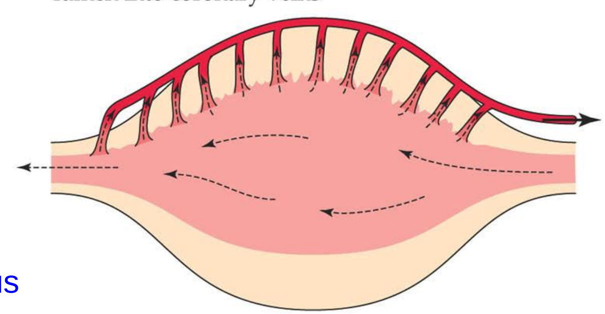
Tuna, some amphibians and reptiles

(*c*) Myocardium composed of outer compact tissue and inner spongy tissue

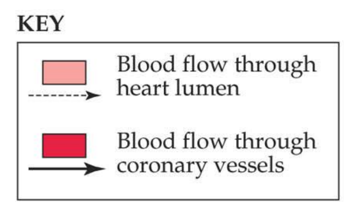


ANIM.

(*d*) Myocardium of mixed structure with blood flowing from lumen into coronary veins

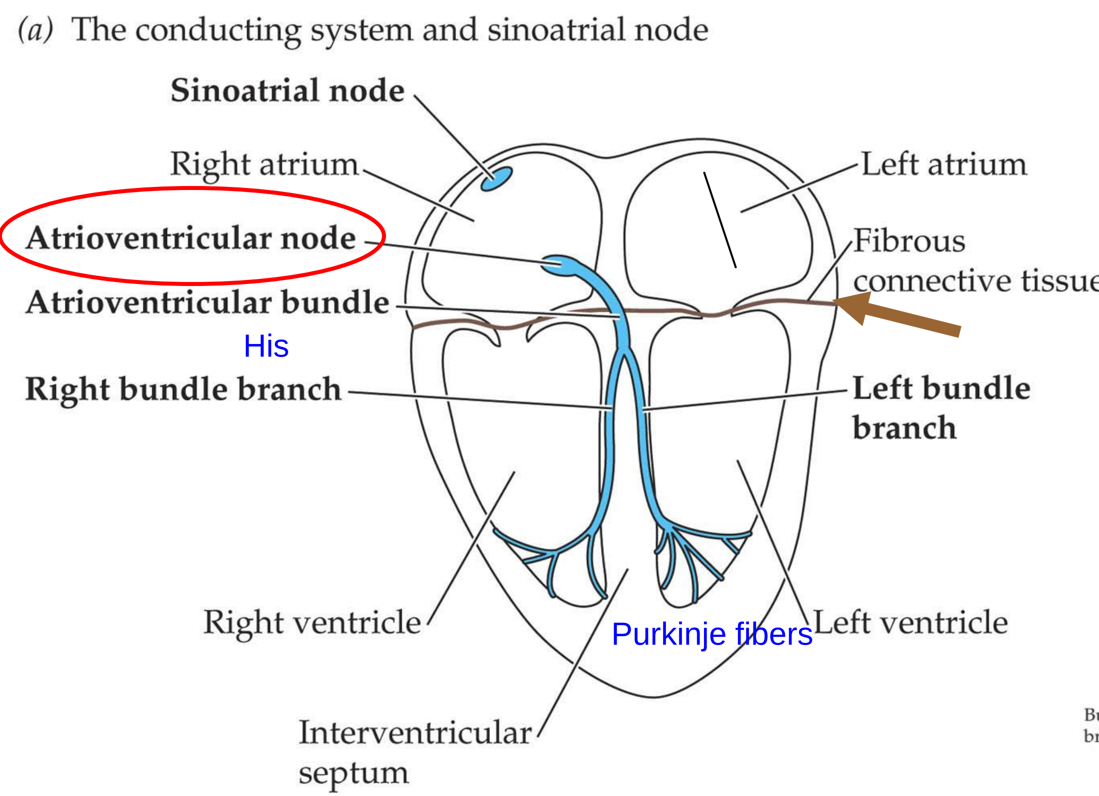


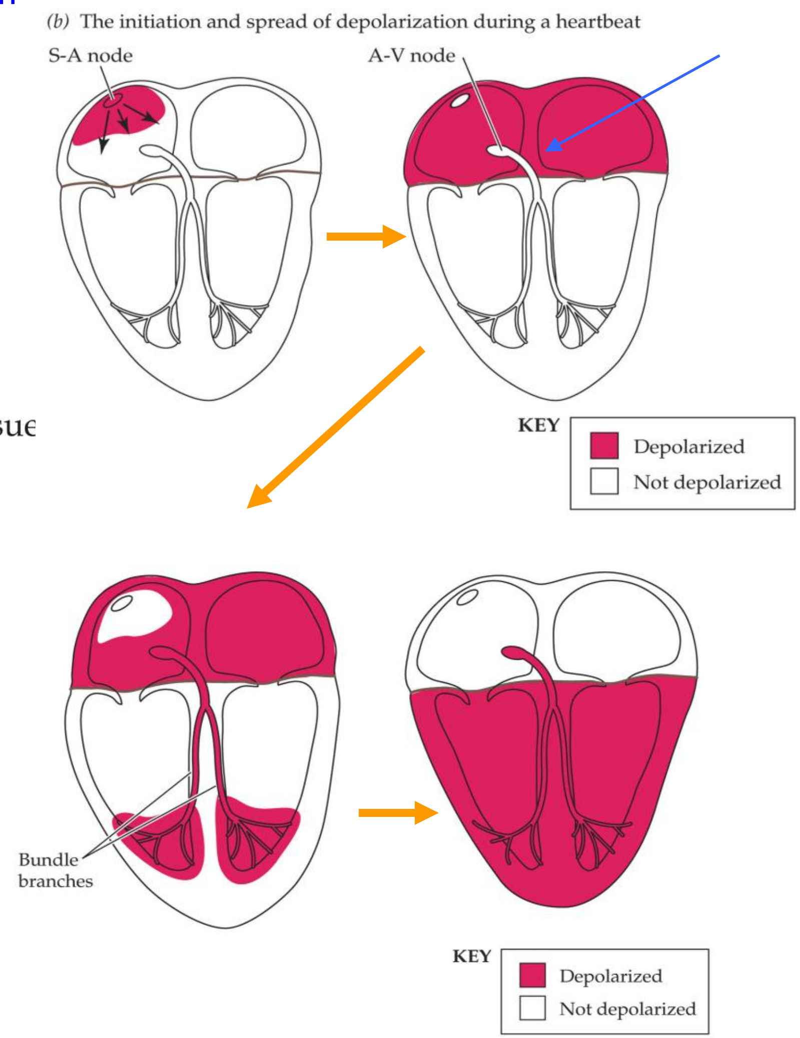
octopus



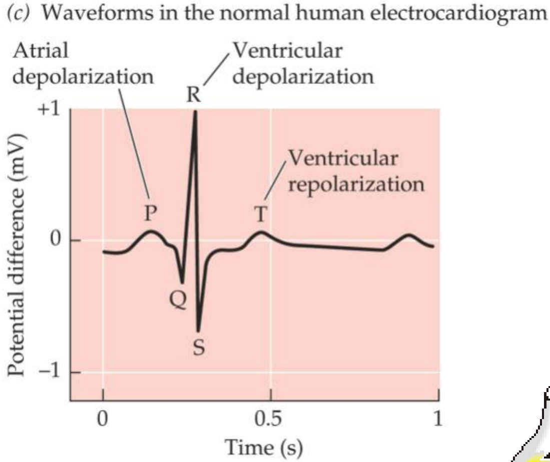
The conducting system and the process of conduction in the mammalian heart (MYOGENIC)

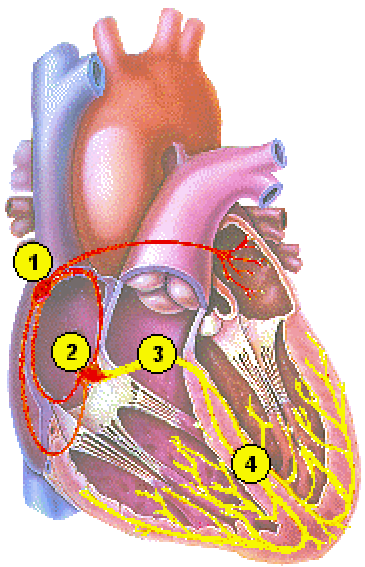
- Rhythmic contraction reflects rhythmic depolarization of cell membranes of the muscle
  - **Pacemakers** **spontaneously** initiate depolarization
  - Cells are electrically coupled, depolarization spread
  - Depolarization in the **AV node** travels slow.
  - Depolarization travels fast in the conduction system

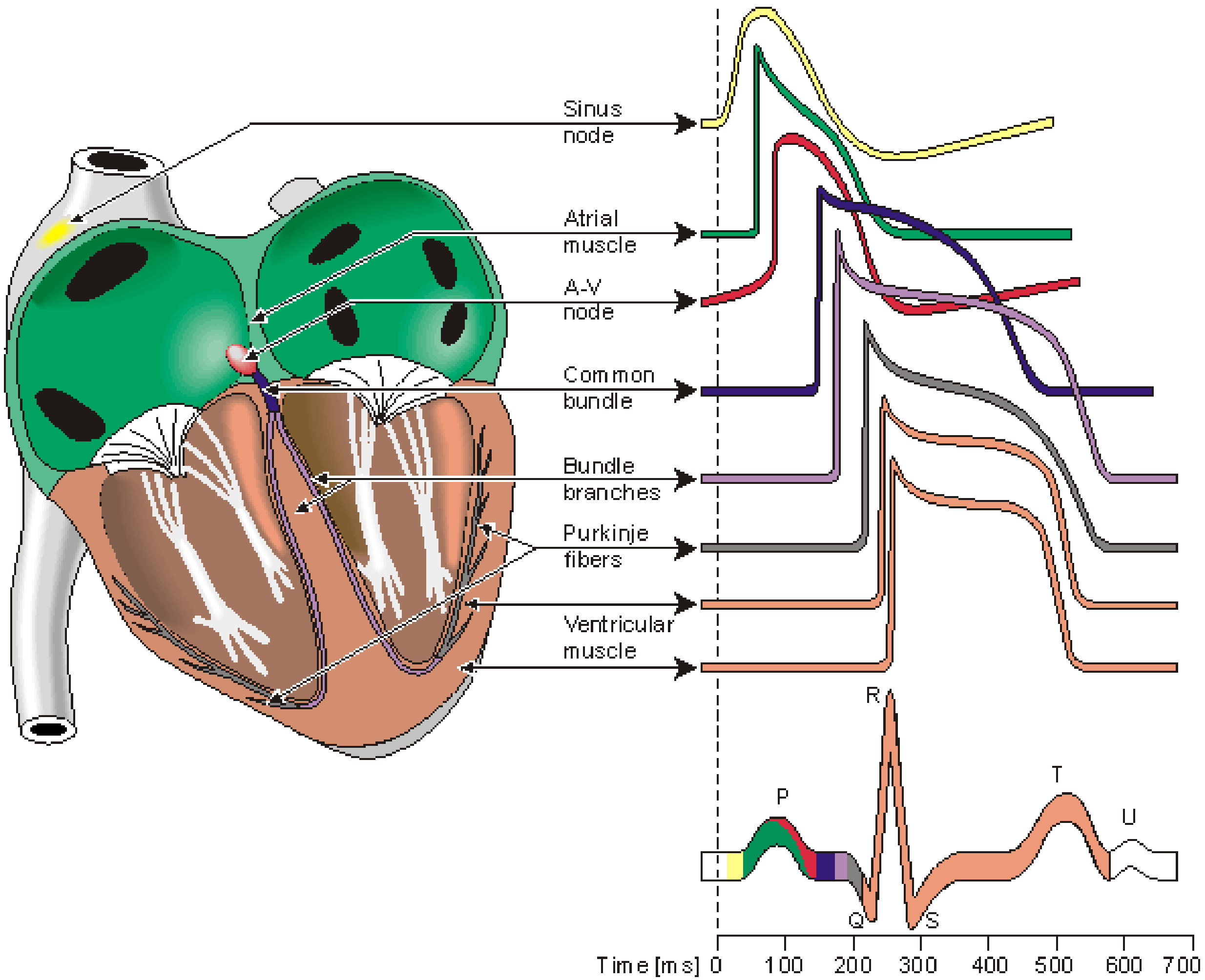




The conducting system and the electrocardiogram





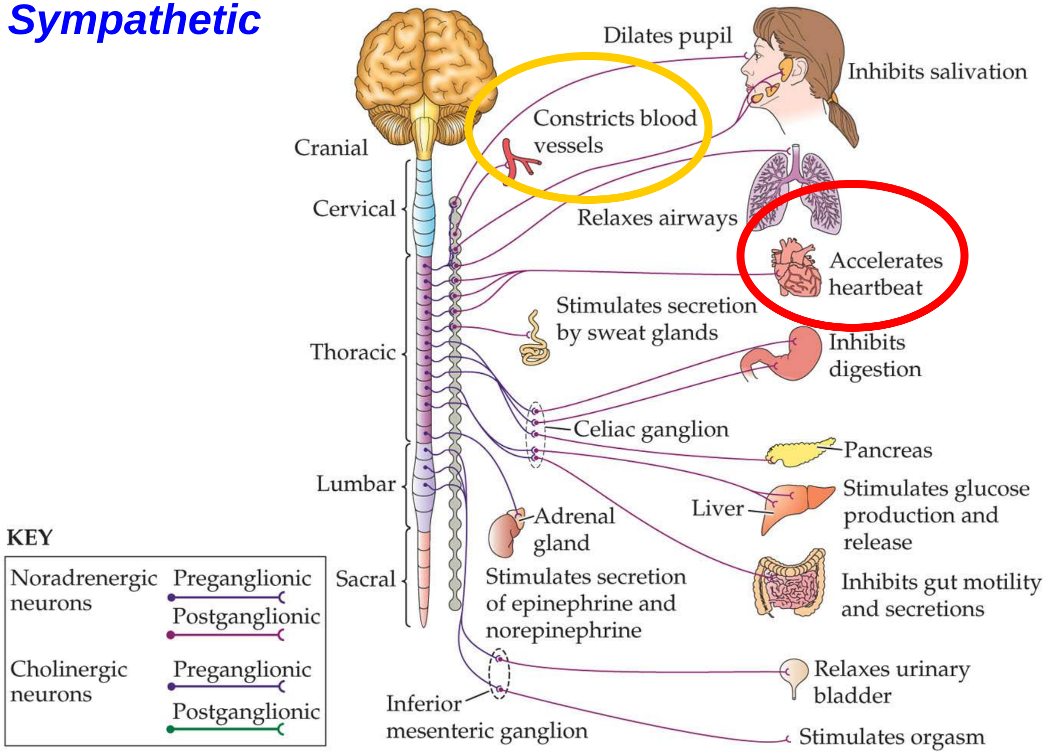


Parasympathetic and sympathetic divisions of autonomic nervous system

Stress

Sympathetic

Parasympathetic



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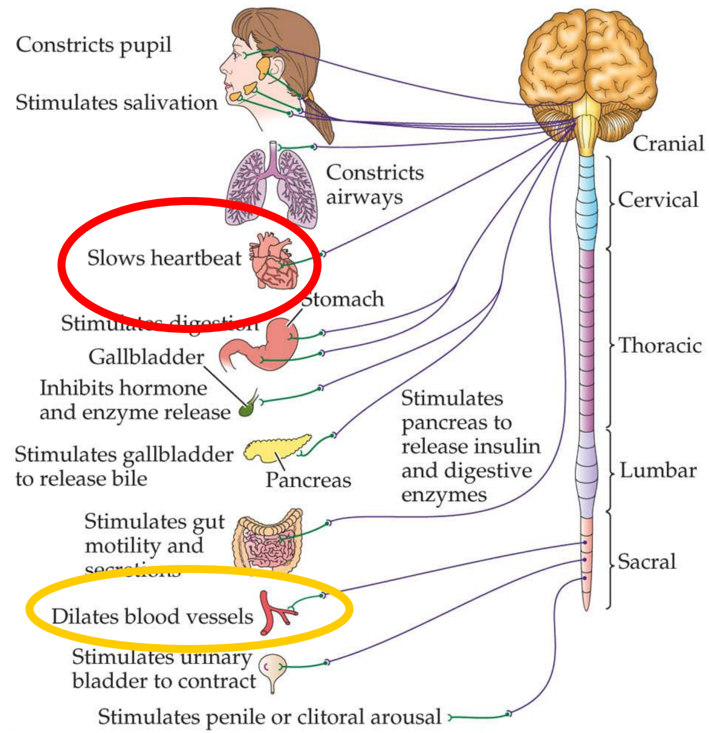

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Adrenergic

Mobilize energy

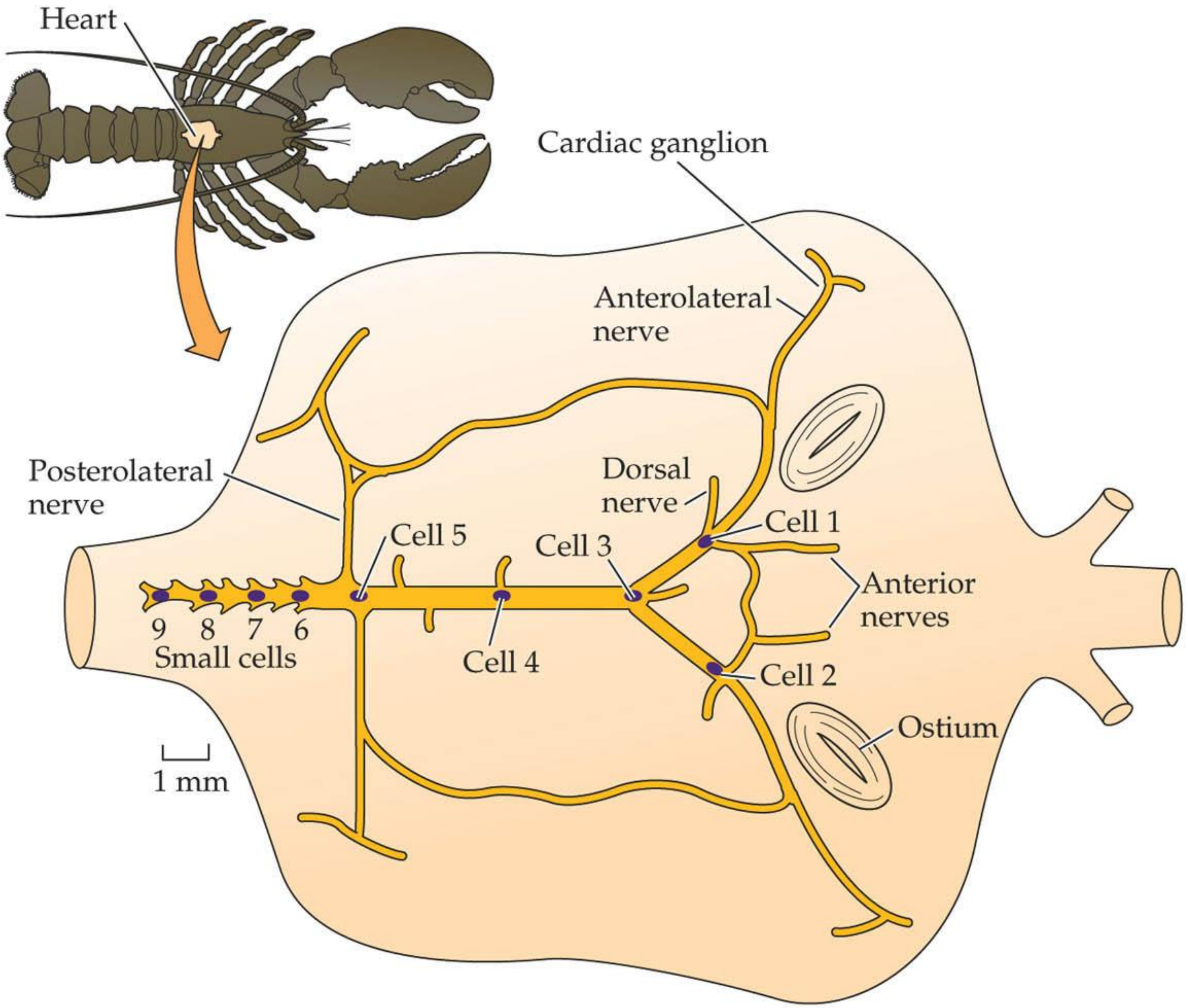
Fight or flight

Cholinergic

Restore energy

Rest and Digest

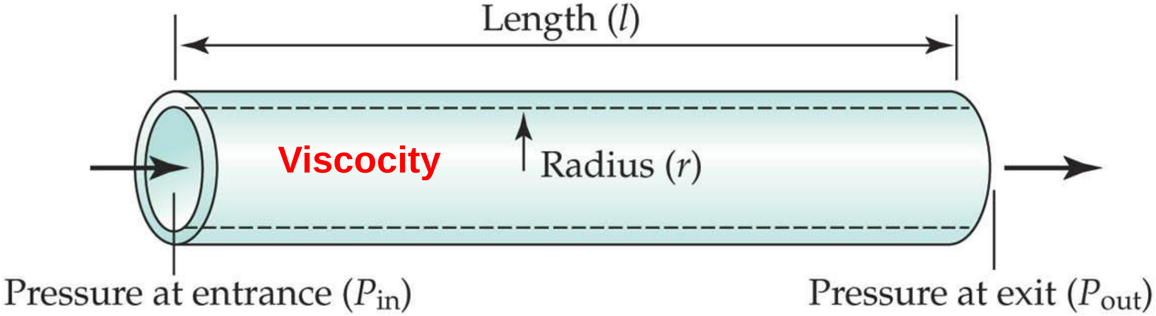
The **neurogenic** heart of a lobster



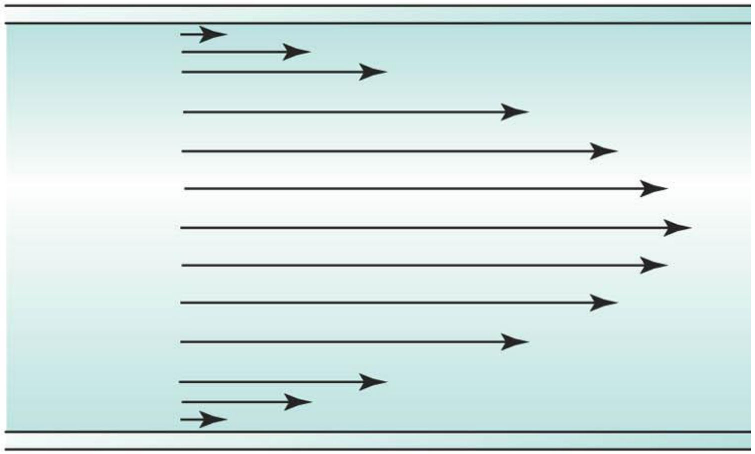
Blood pressure is the principal factor that causes blood to flow

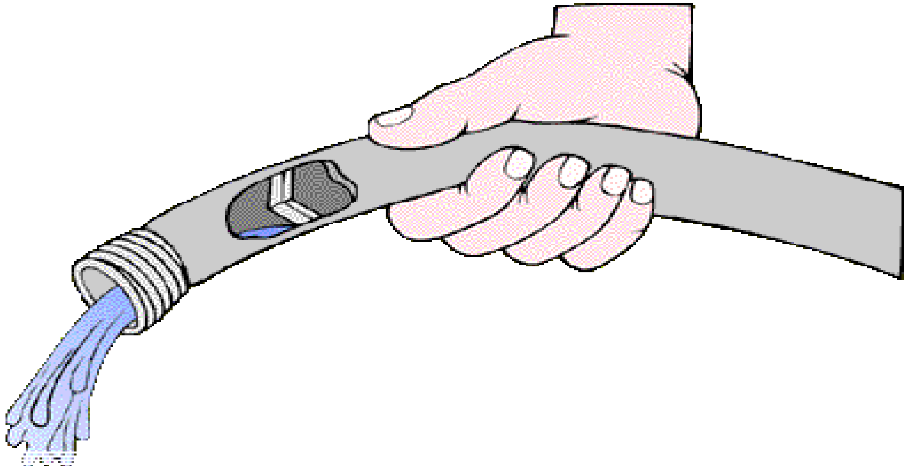
- **Blood Flow** is proportional to the difference in pressure
- Flow is inversely proportional to the radio of the vascular tube.
- As blood flows pressure decreases. Kinetic energy is converted into heat.

(*a*) Pressures and dimensions that affect the rate of flow



(*b*) The velocity profile of laminar flow





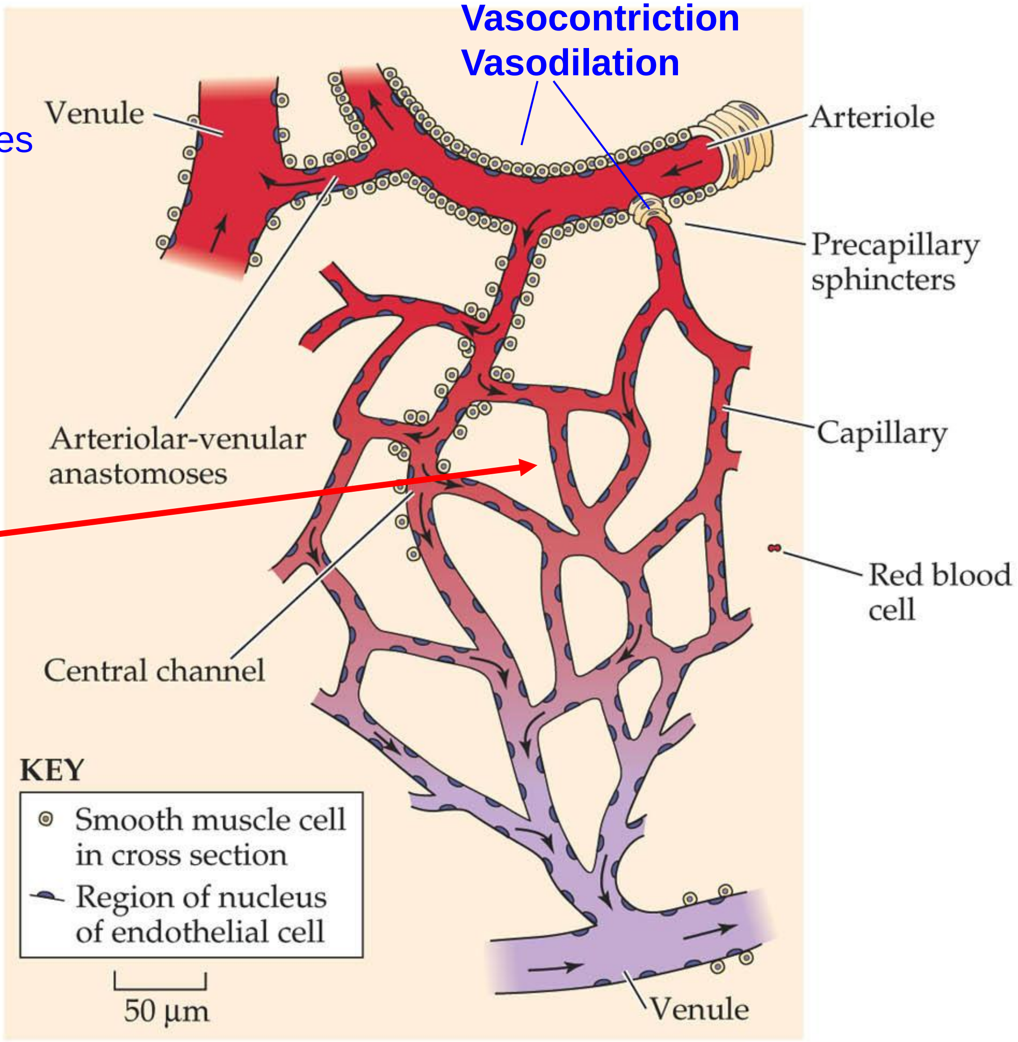
Vascular system

Arteries:
Elastic
1)eliminate pressure oscillations.
2) Maintain a pressure reservoir between systoles

A microcirculatory bed

Extremely large **exchange surface**
of gas and nutrients in the capillary beds

Vasocontriction
Vasodilation

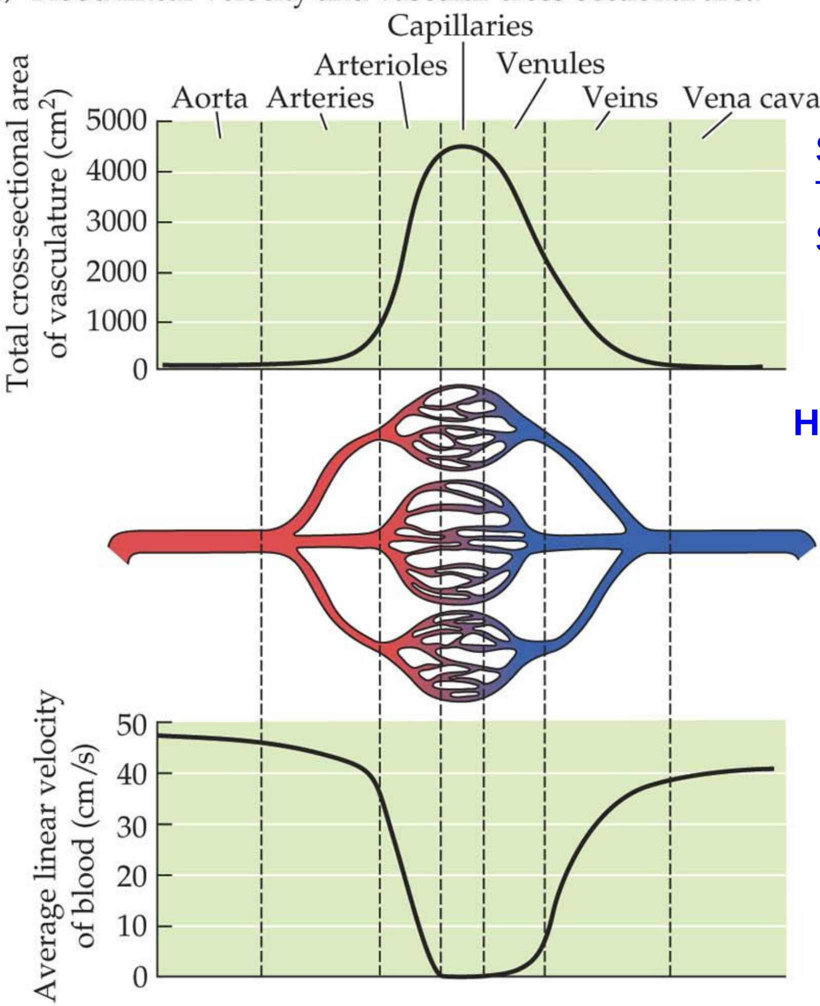


Veins: thin walls and valves to avoid reverse flow

Regulation of skin blood flow to thermoregulate
Regulation of muscle circulation during exercise
Regulation of erection of sexual organs

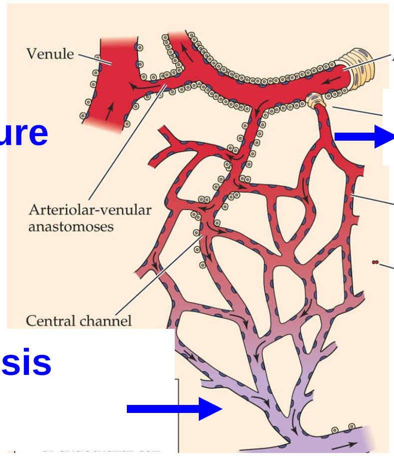
Blood flow in the human systemic vasculature

(a) Blood linear velocity and vascular cross-sectional area



System has high resistance
The area of the vascular system increases
Speed blood flow reduces in capillary: favor exchange

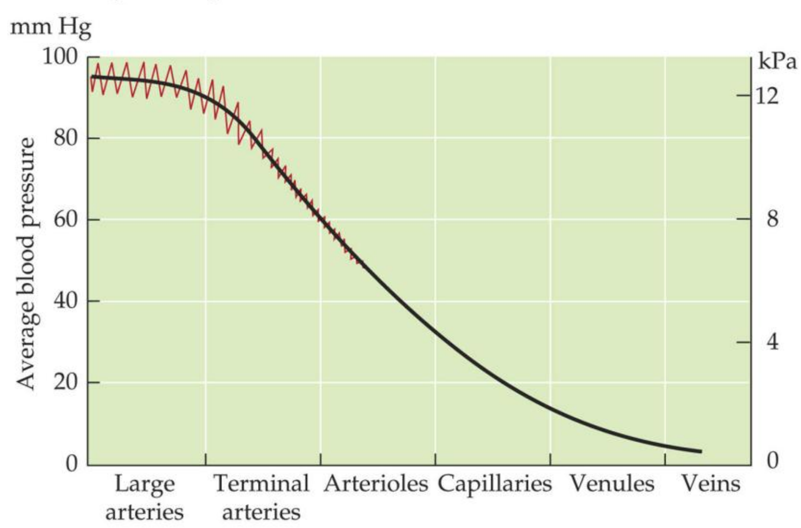
Hydrostatic pressure



Ultrafiltration

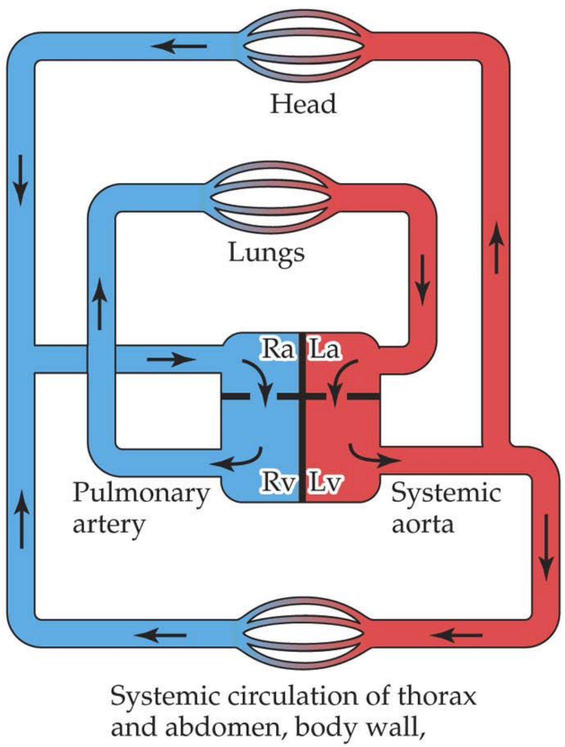
Osmosis

(b) Average blood pressure

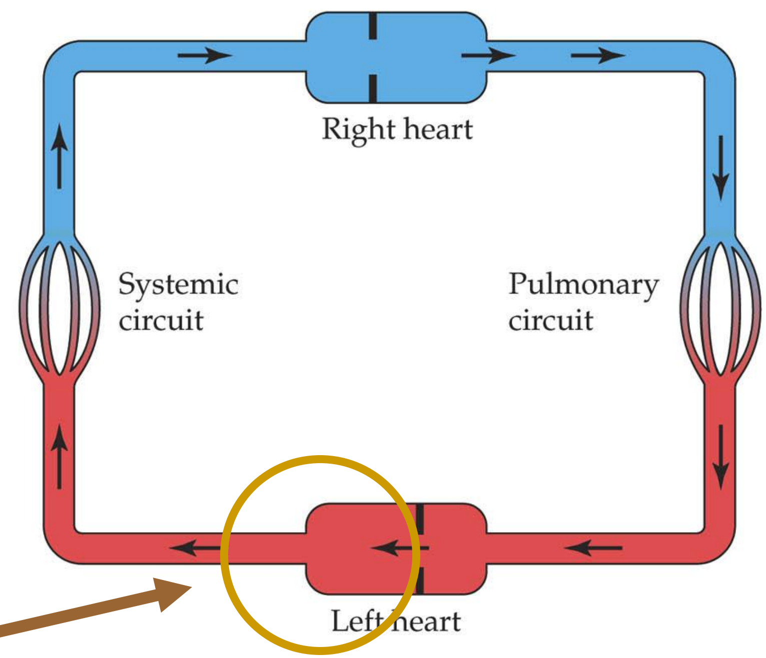


Closed circulatory system

(a) The circulatory plan



(b) A schematic of the circulatory plan emphasizing that the systemic and pulmonary circuits are connected in series

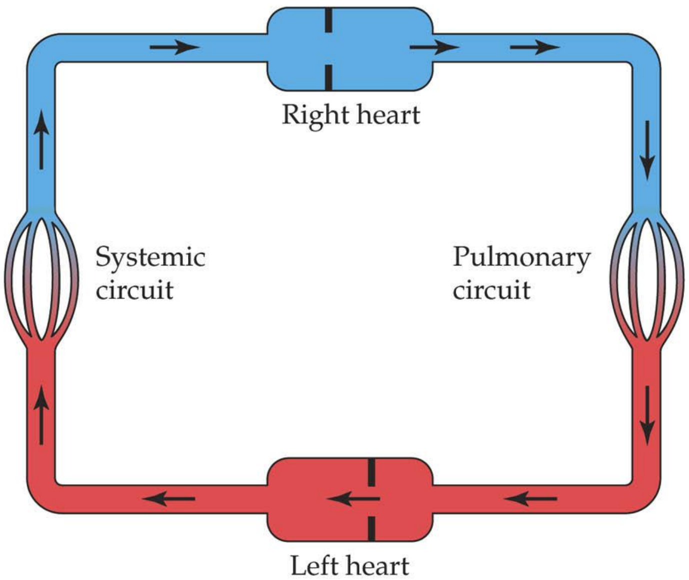


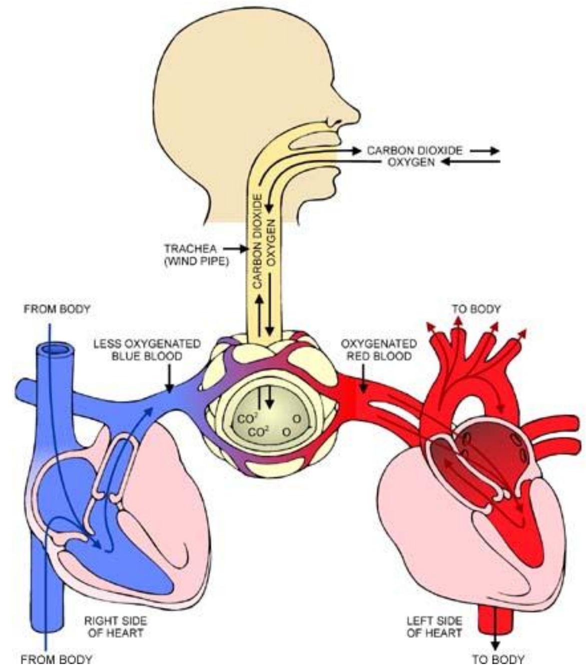
Maximize delivery of oxygenated blood to systemic tissues

Pulmonary circuit

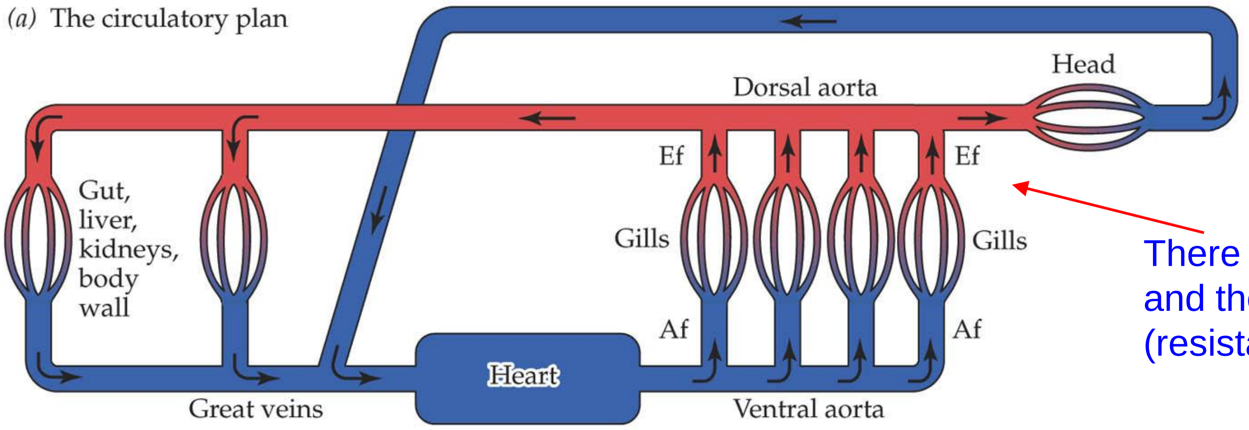
The pulmonary circuit is a **low resistance** and **low pressure** system to prevent pulmonary edema.

(b) A schematic of the circulatory plan emphasizing that the systemic and pulmonary circuits are connected in series

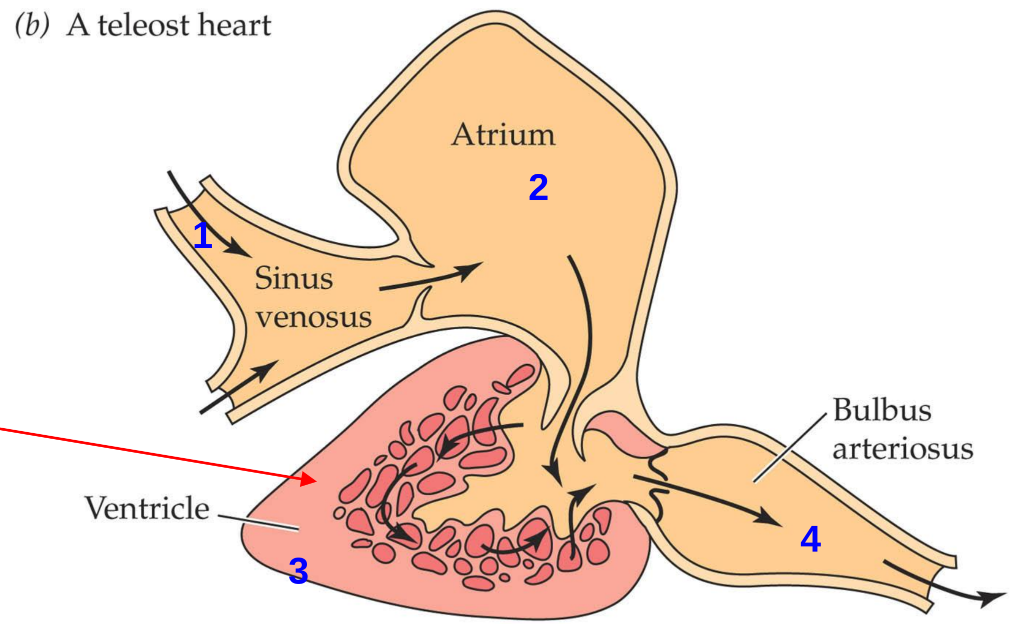




The circulatory plan in **gill-breathing fish** is also in **SERIES** with the systemic tissues



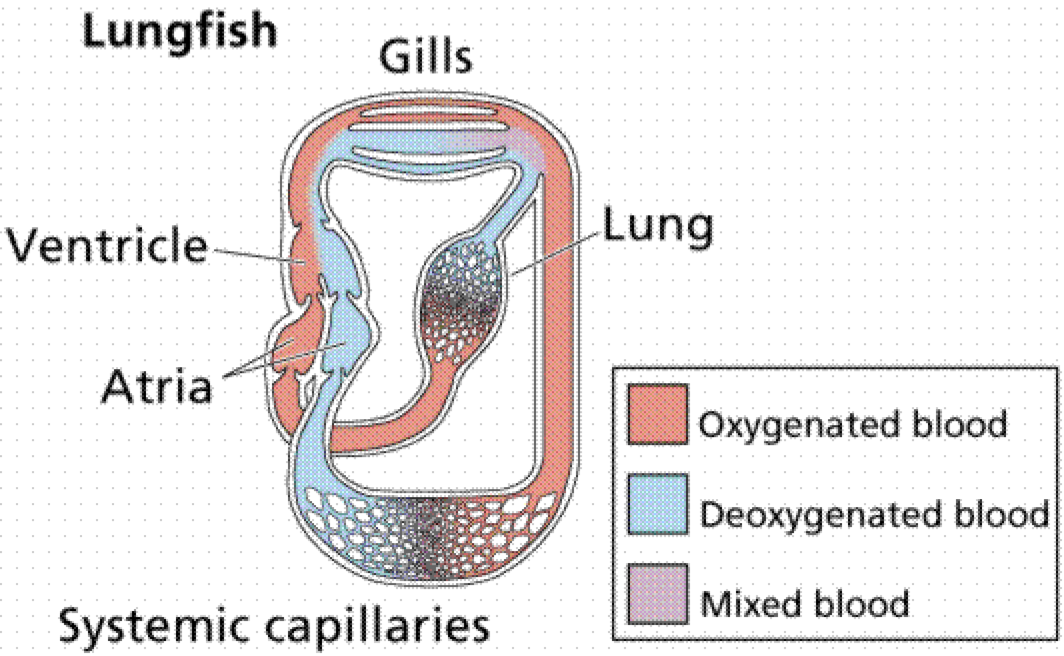
There is not heart between the gills and the systemic circulation (resistance)

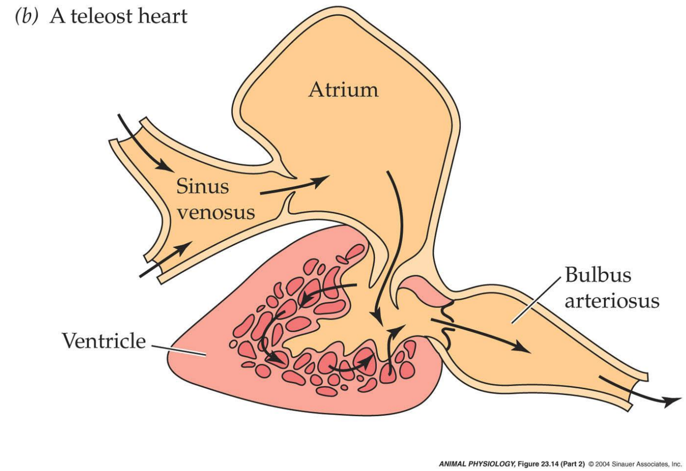


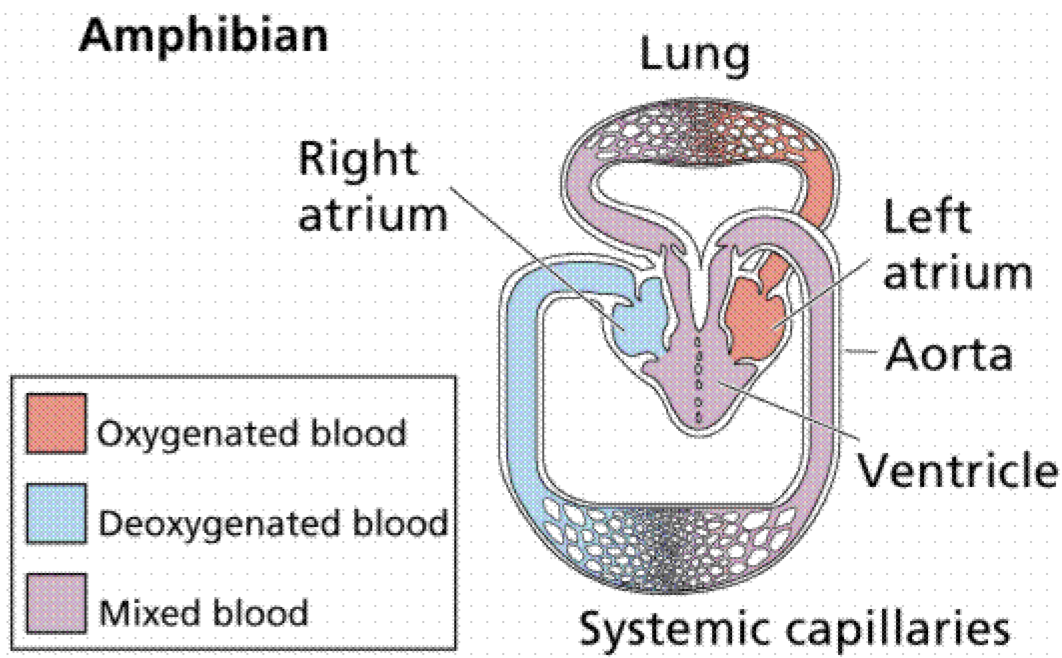
The spongy heart is oxygenated by **systemic** blood.

Lower metabolism
Lower pressure
exercise--increase

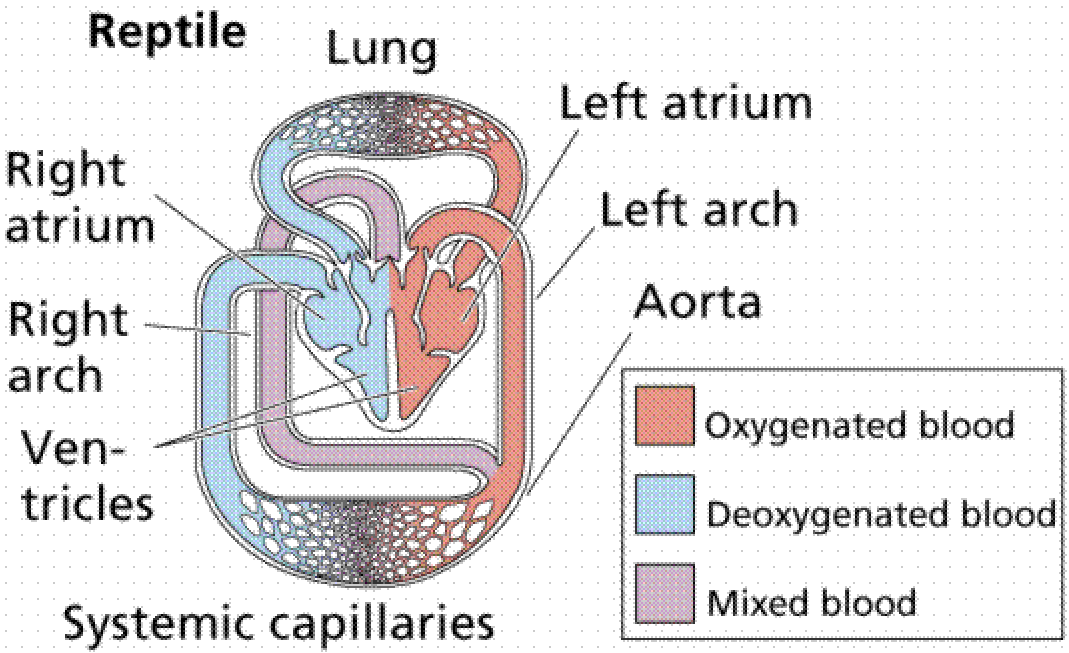
The circulatory plans of lungfish and amphibians

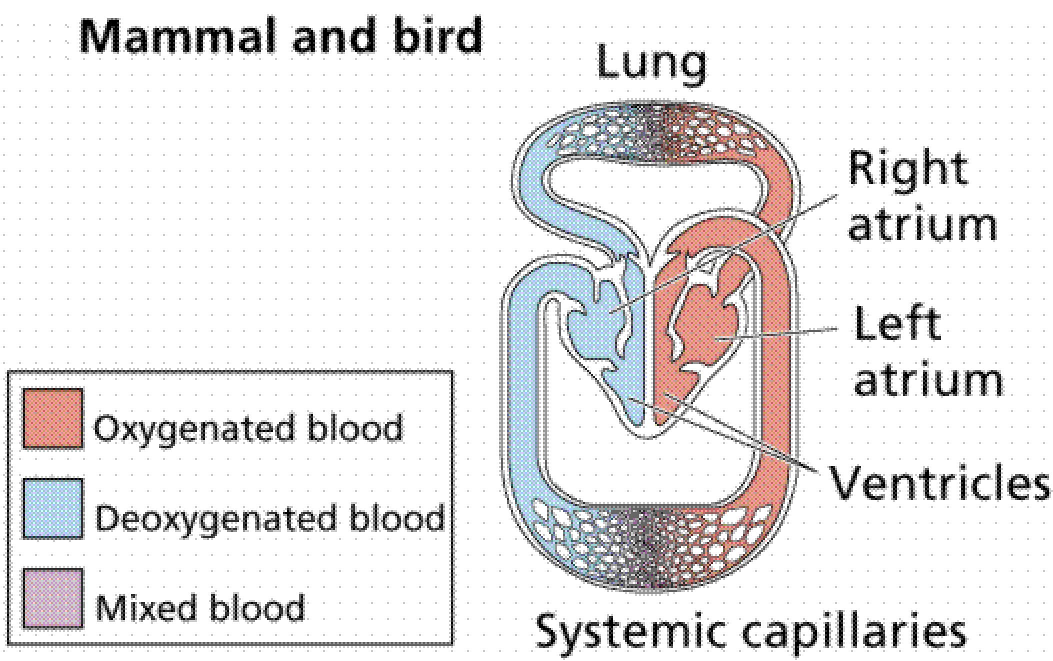




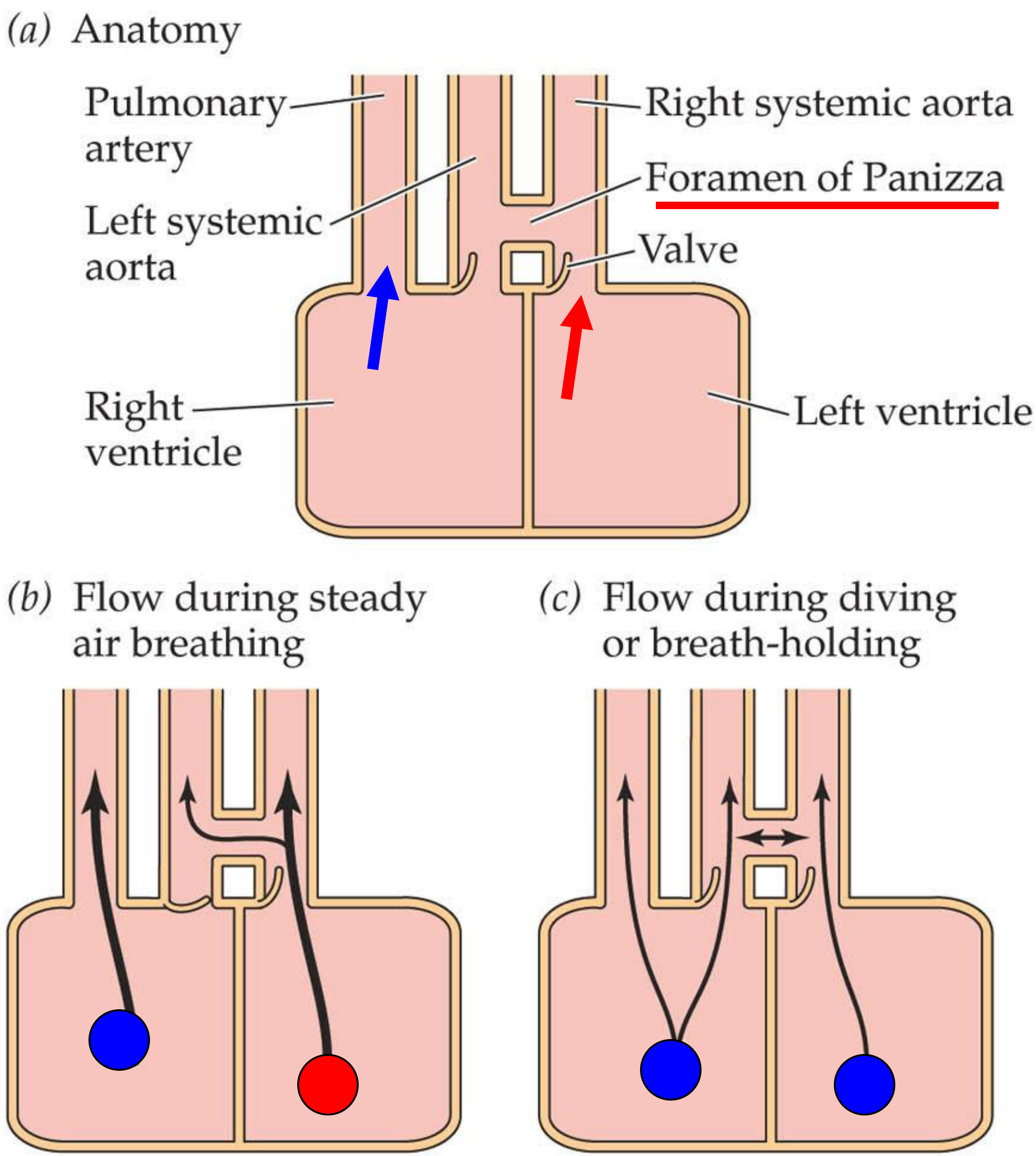


The circulatory plans of reptiles



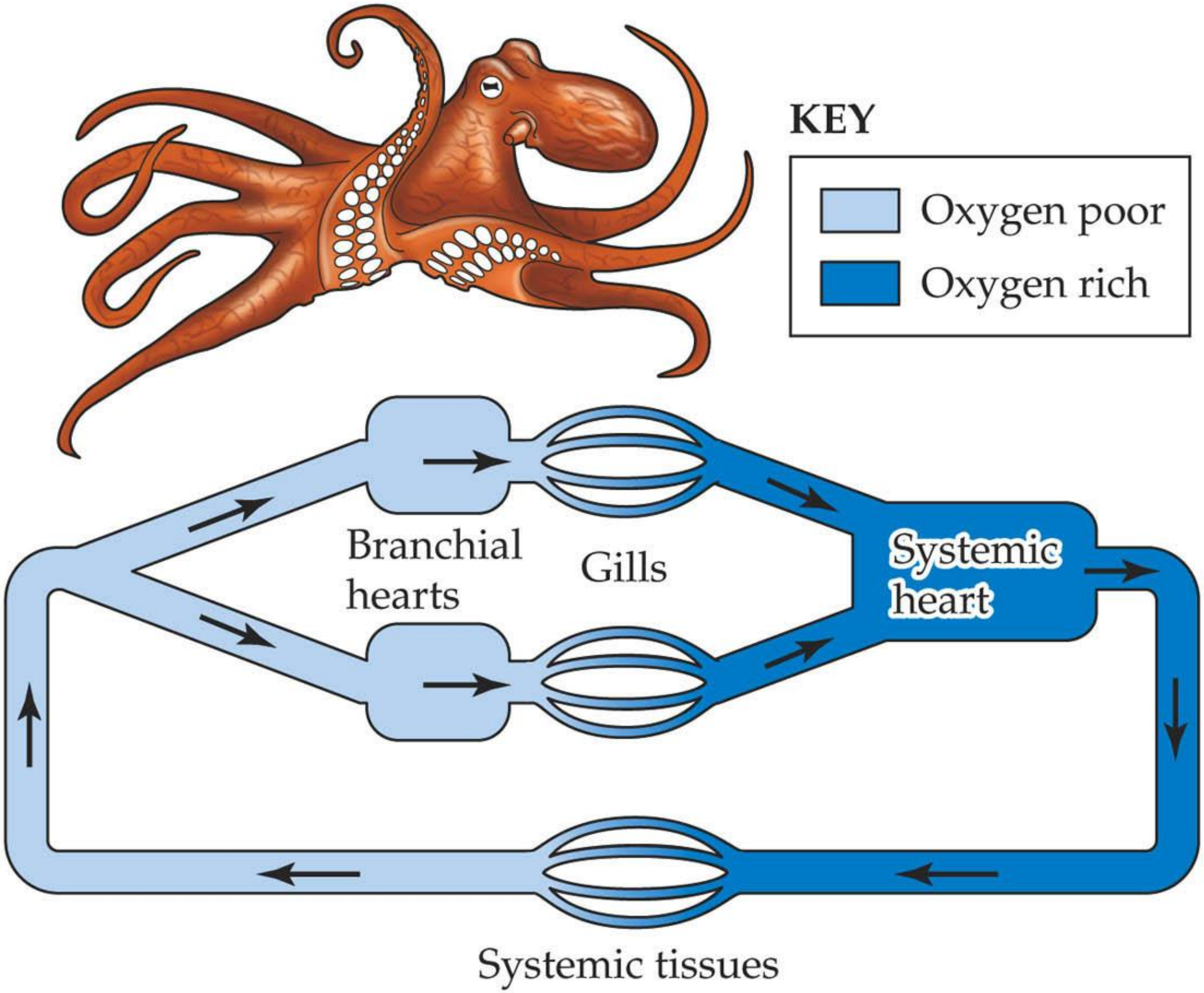


Blood flow in heart ventricles and systemic and pulmonary arteries of crocodilians

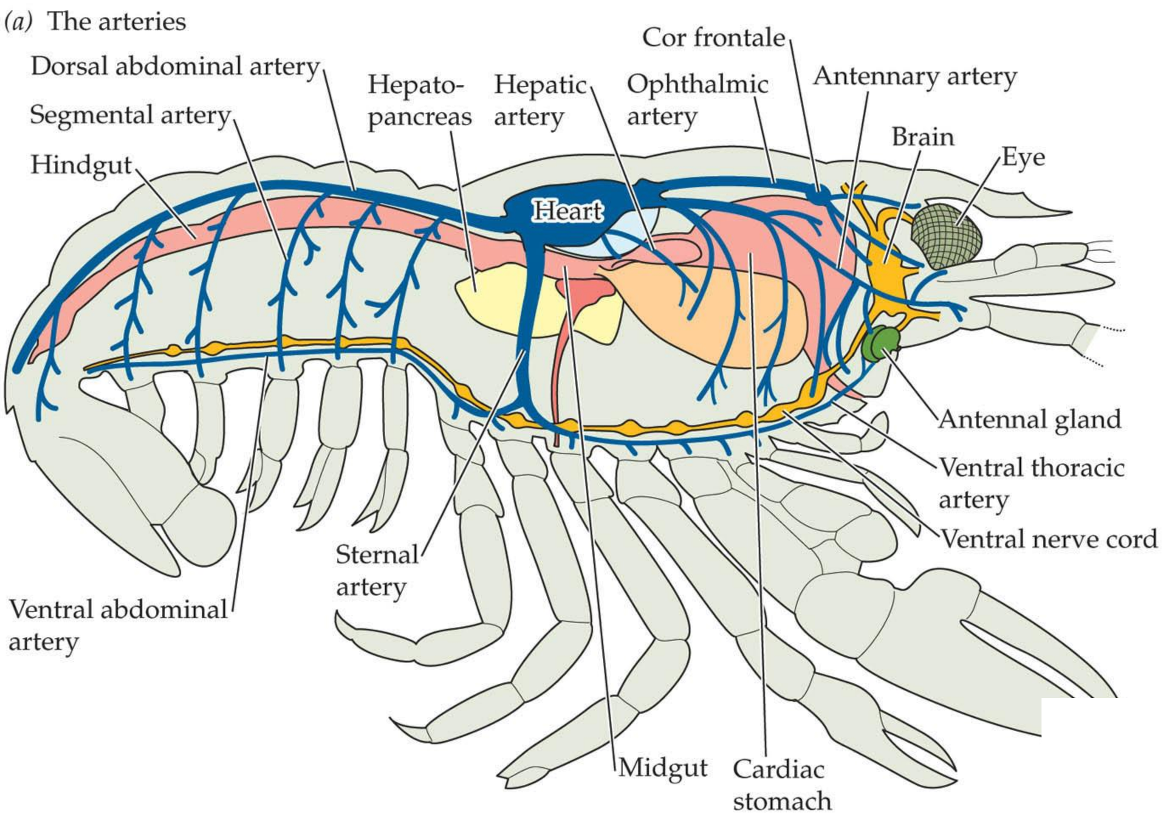


The closed circulatory plan of squids and octopuses

(*a*) The circulatory plan



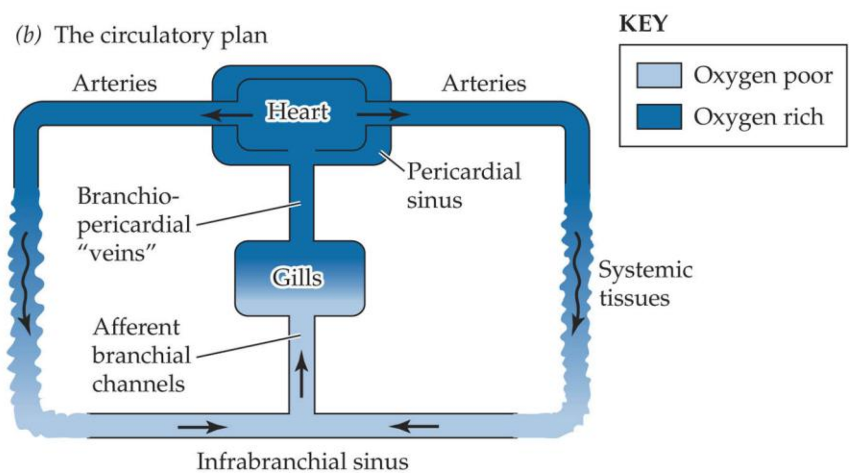
Open circulatory system of a crayfish or lobster



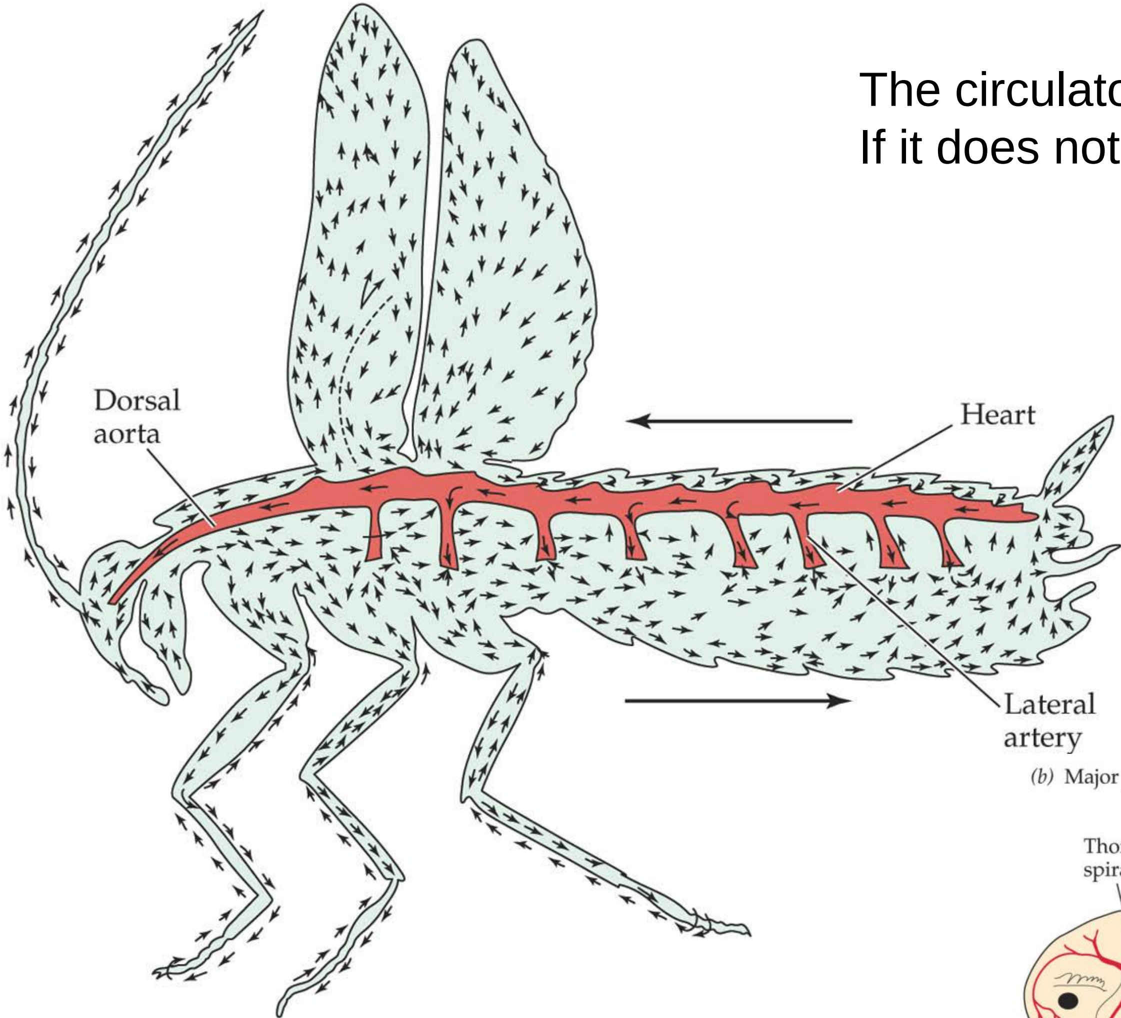
Lacunae (small) (capillary)
Sinus (large)

Low pressure

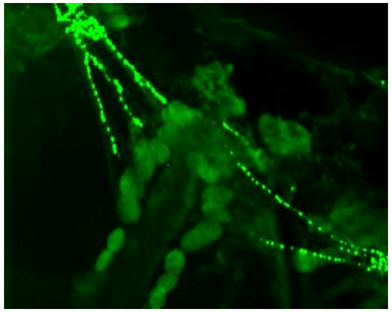
Hemolymph



Blood flow through the tissues of an insect is principally through lacunae and sinuses



The circulatory system can be simple
If it does not need to transport O_2



(b) Major parts of the tracheal system in a flea