Aquatic Animal Physiology

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What kinds of environments are “extreme”?

Some extreme environments that you may know about are deserts, caves, and frozen places like antartics. However, water can also be pretty extreme. The open ocean gets deep, dark, and cold as you descend and rivers rush tumbling over boulders and cliffs. How do creatures live there?

Factors which differentiating between aquatic environment and terrestrial environment

01 Density

02 Heat Capacity and conductivity

03 Osmotic pressure

04 Oxygen availability

05 Electrical conductivity

06 Viscosity

Most fish are stenohaline.
Stenohaline means organism that can’t tolerate a wide fluctuation in the salinity of water. Freshwater will die when living in the high concentration of salt, likewise marine water will die when living in the lower salinity of water.

What kind of adaptation they have?

Osmoregulation

Most marine inverts are *osmoconformers*: the concentration of solutes in their body fluid is the same as the surrounding sea water

- This means water enters and leaves equally, no overall change in water content of organisms

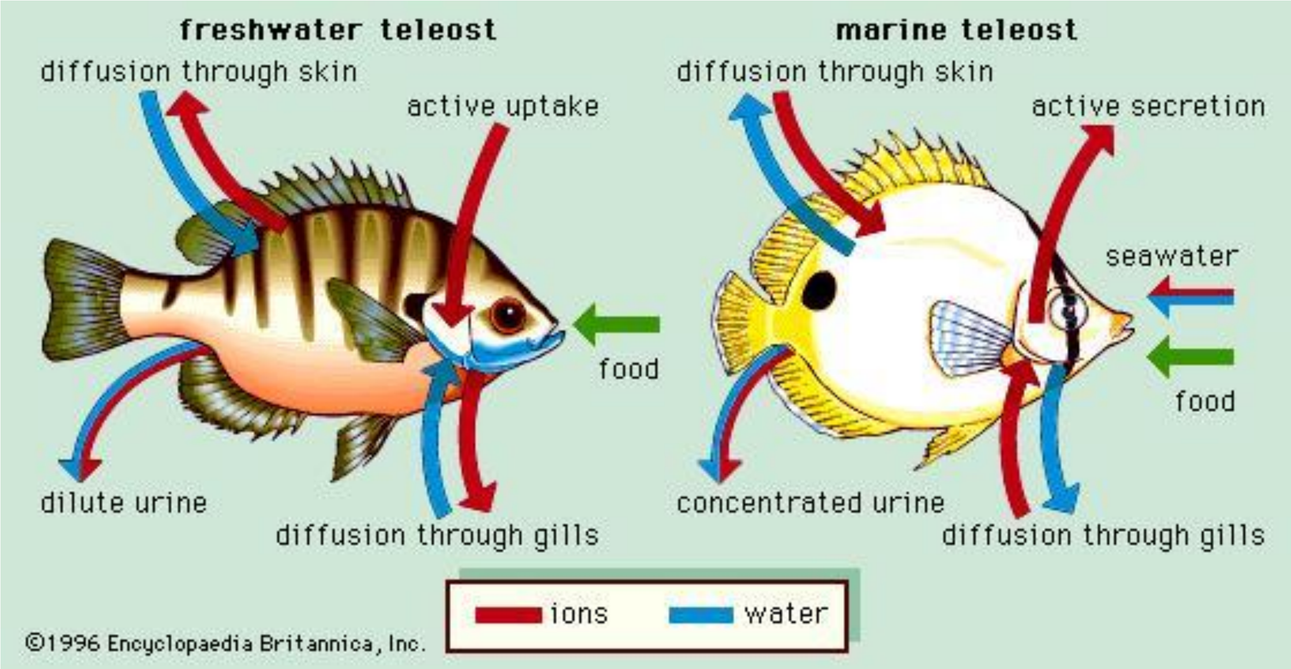
Marine verts with osmotic concentrations of solutes lower than that of seawater lose water by osmosis

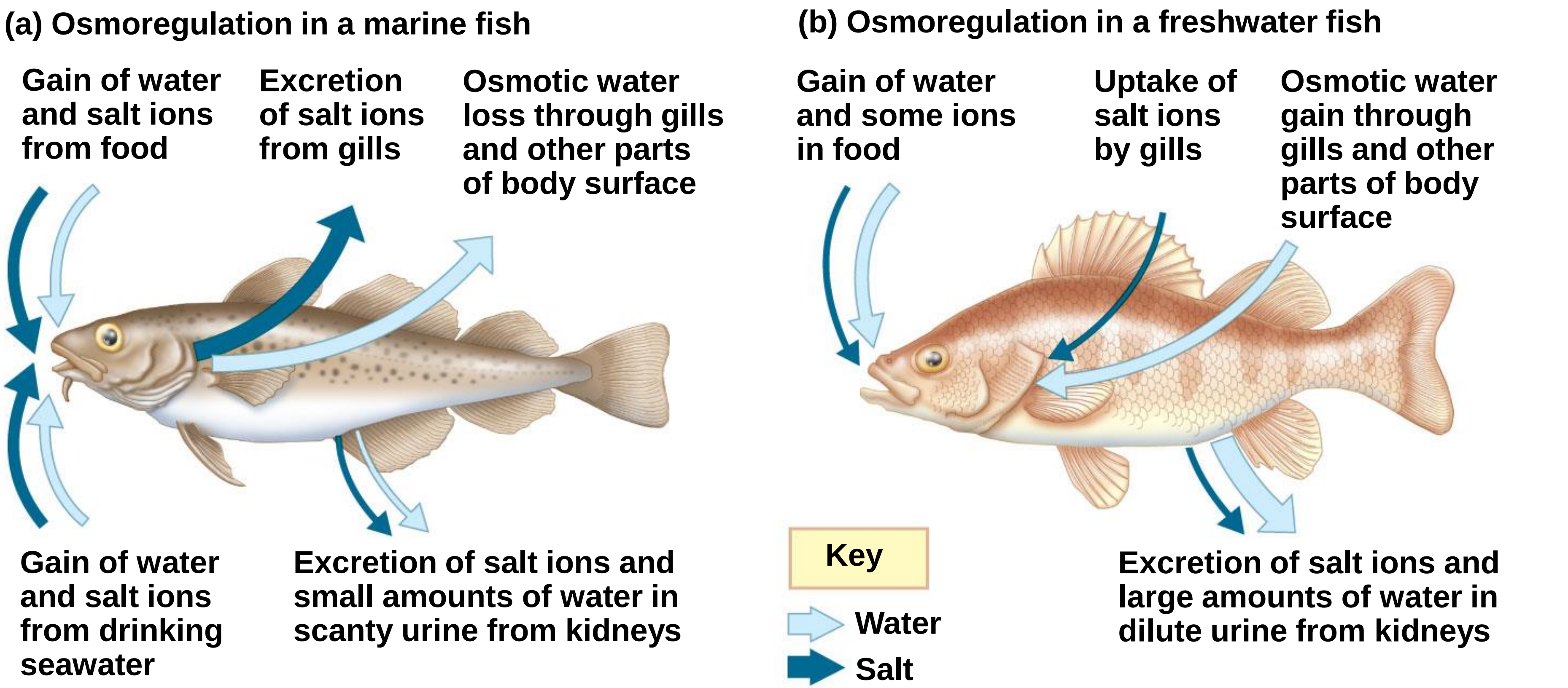
- Require mechanisms to maintain their body solute and water content

Osmoregulation

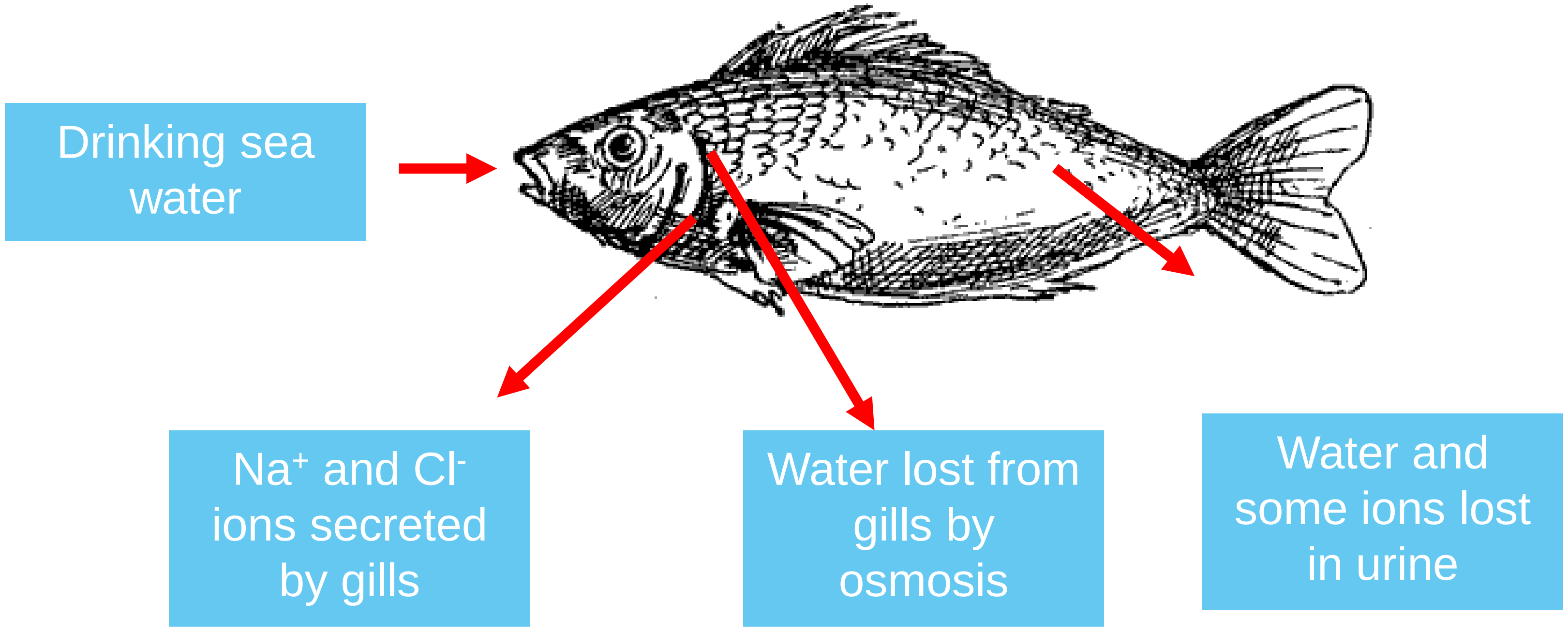
Osmoregulation: process by which living organisms maintain the solute and water content in their blood and body fluids

- Marine bony fish (teleosts) have an internal solute concentration approx 1/3 of sea water



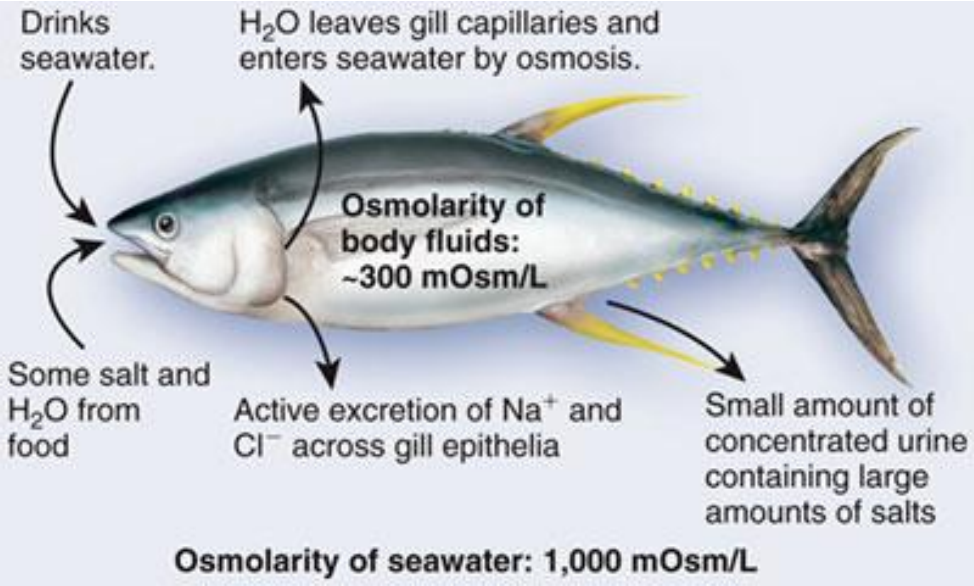

(a) Osmoregulation in a marine fish
Gain of water and salt ions from food
Excretion of salt ions from gills
Osmotic water loss through gills and other parts of body surface
Gain of water and salt ions from drinking seawater
Excretion of salt ions and small amounts of water in scanty urine from kidneys
(b) Osmoregulation in a freshwater fish
Gain of water and some ions in food
Uptake of salt ions by gills
Osmotic water gain through gills and other parts of body surface
Excretion of salt ions and large amounts of water in dilute urine from kidneys
Key
Water
Salt

Osmoregulation in Marine Bony Fish



Osmoregulation in Marine Bony Fish

- Marine bony fish drink sea water
  - Excess salts in water are absorbed in intestine
  - Sodium and chlorine ions are actively secreted by chlorine secretory cells (present in gills)
  - Process requires energy (provided by respiration)



Density and viscosity of water permits animals to float, reducing metabolic requirements at rest. To optimize the ability to float, animal density should be equal to that of water. But since most animals contain some dense material (bone, shell, etc), the rest of the tissue must have a density lower that that seawater

How can this be done?

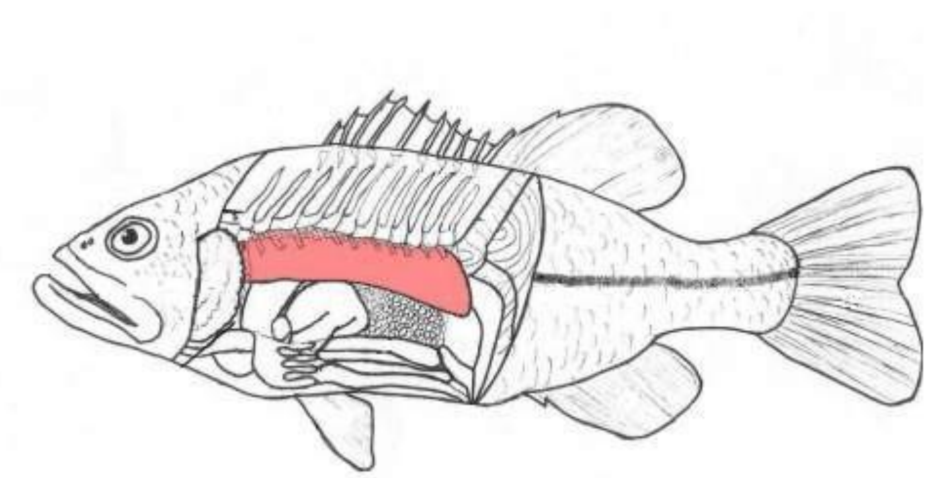
Buoyancy

- Maintaining vertical position in the water column
  - potentially energetically costly
- Many primitive fishes had lungs
  - in more advanced lineages, lost respiratory function
  - become gas bladder

Buoyancy : Swim Bladder

- Used to regulate buoyancy as well as sound production and detection in some fishes
  - respiratory function in primitive fishes

Swim Bladder in a Fish



U.S. Fish and Wildlife Service

Buoyancy : Swim Bladder

Gas retention : the blood supply to the swimbladder is double. A dorsal vessel serves only to remove gas prom the swimbladder when required. The major suplly is at the gas gland (gas-secreating gland, where the rete mirabile is found). The blood supply in the capillaries of the rete ae countercurrent in flow. Thus, gas is retained passively

Buoyancy : Swim Bladder

Gas secretion : the major obstacle is the secretion of gas from blood, with a total partial pressure of <1atm, into the swimbladder, with total partial pressures reaching >100 atm in some cases

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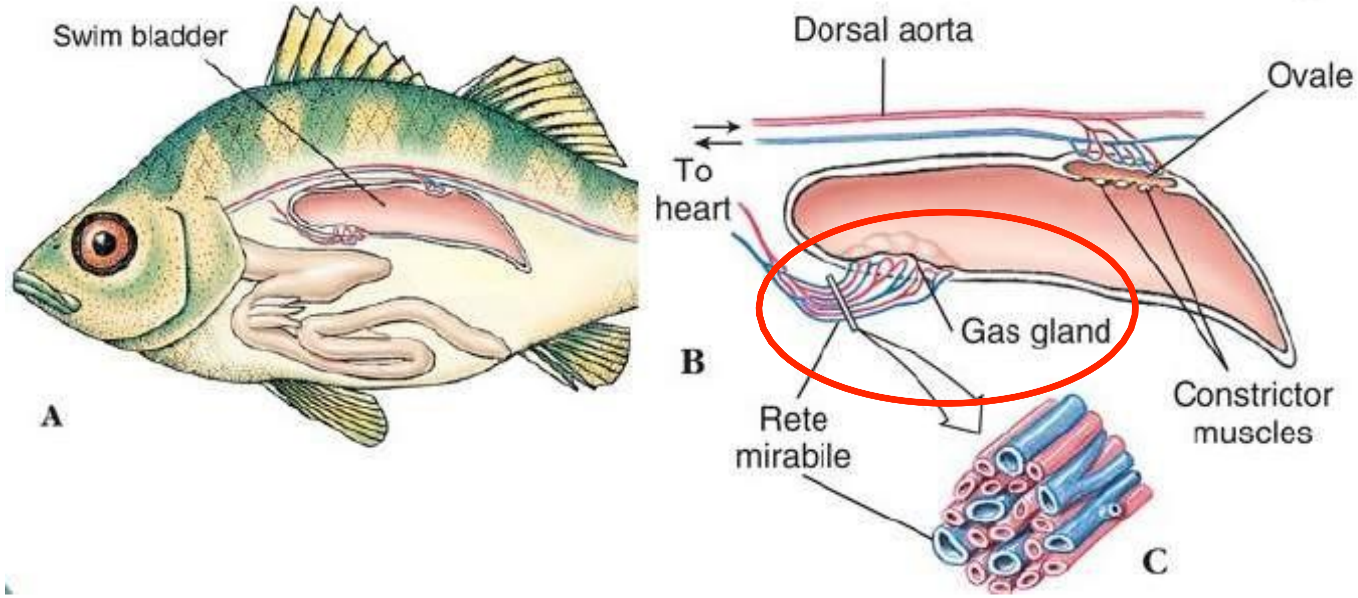
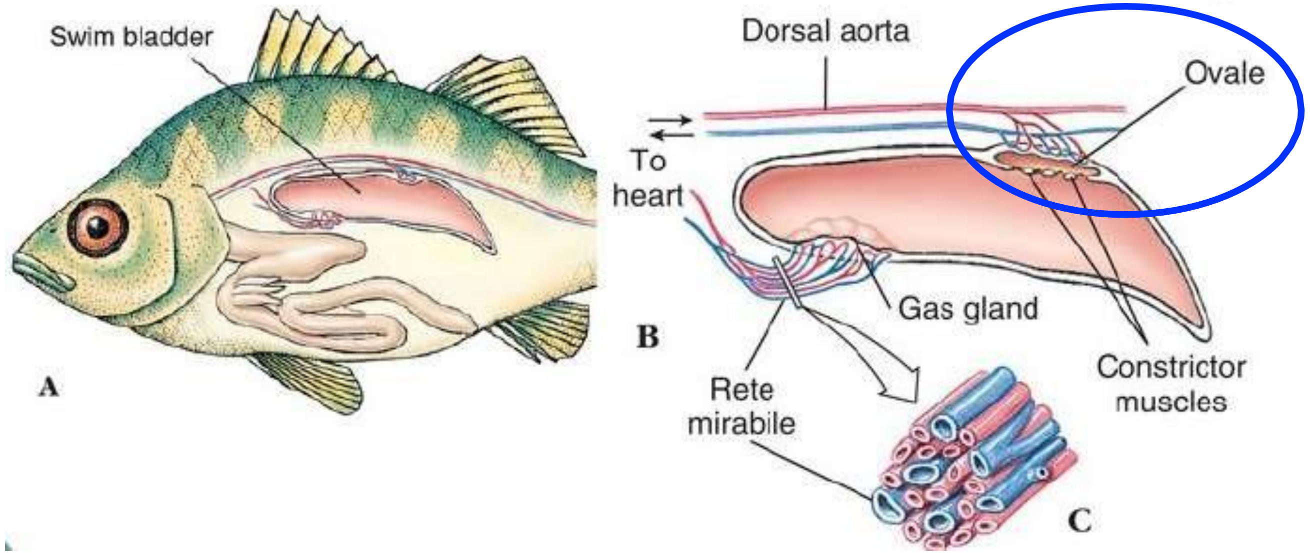

Swim bladder
Dorsal aorta
Ovale
To heart
Gas gland
Rete mirabile
Constrictor muscles
A
B
C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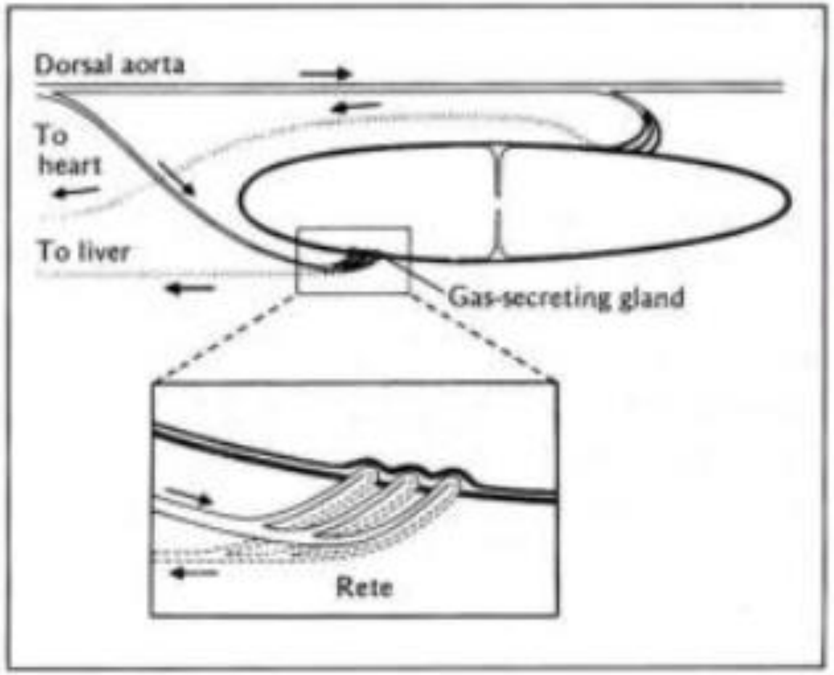
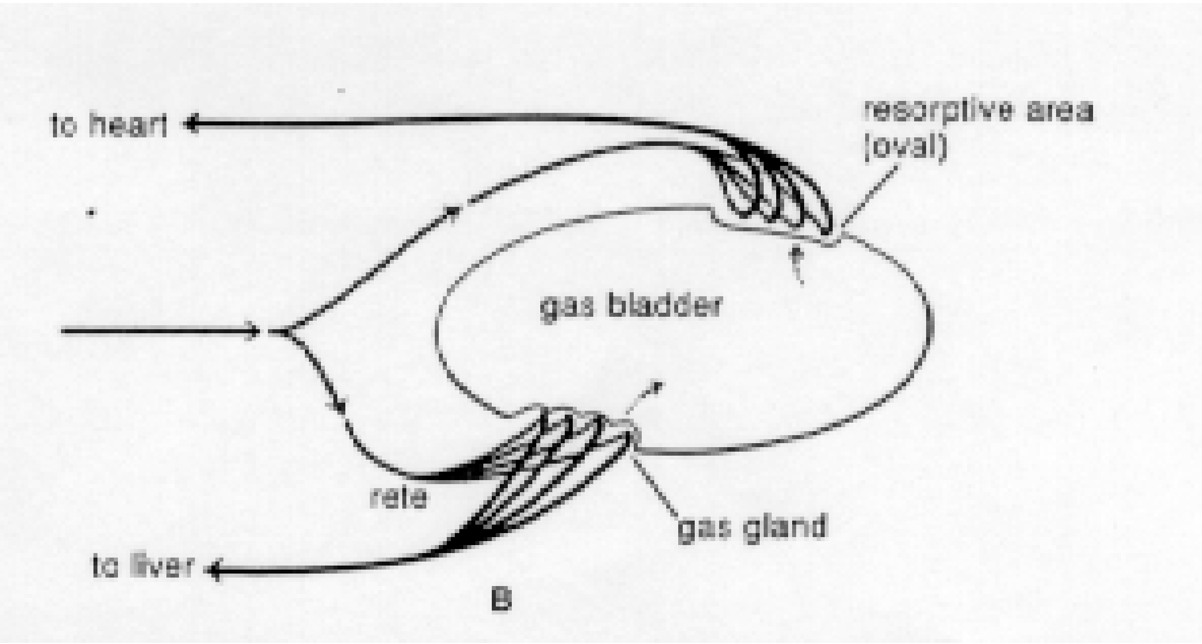
Buoyancy : Swim Bladder

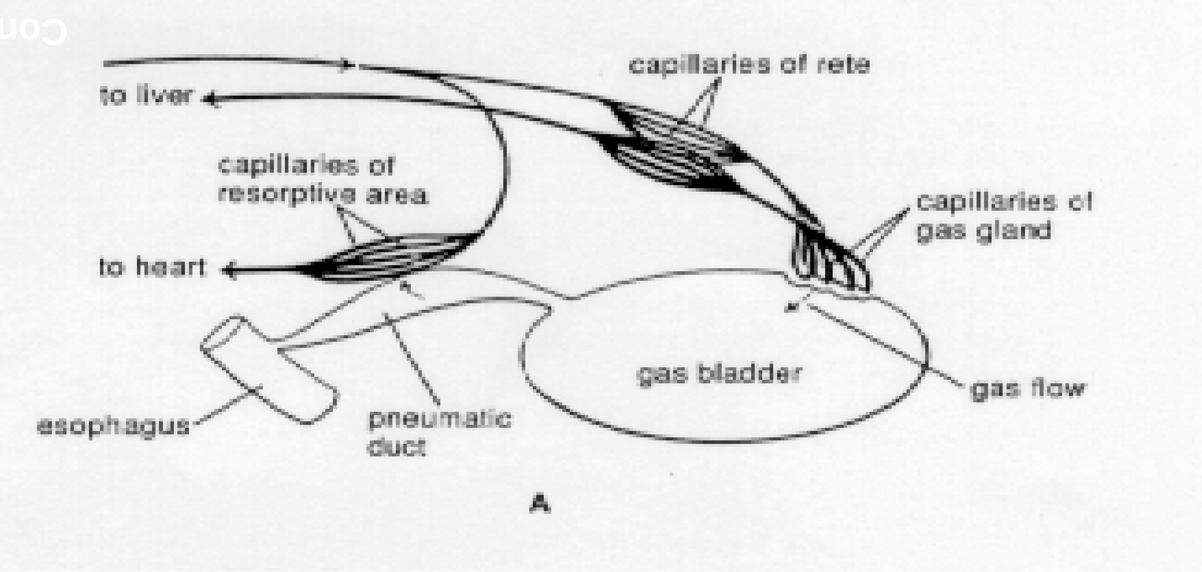
Diagram of the circulation to the swimbladder of a fish. Blood may reach the swimbladder either through a set of parallel capillaries, the rete, which supplies the gas gland, or through a vessel to the posterior portion where fine blood vessels that spread over the wall can serve to absorb gases rapidly. When gas is being secreted, the gas-absorption vessels are closed and carry no blood.



Buoyancy :
Gas Bladder Components

- **Gas gland : **inflates gas bladder by diffusion
- **Rete mirabile : **looping bundle of arterial and venous capillaries generates concentration gradient
- **Oval/pneumatic duct : **removes gas





Buoyancy
Bohr & Root Effects

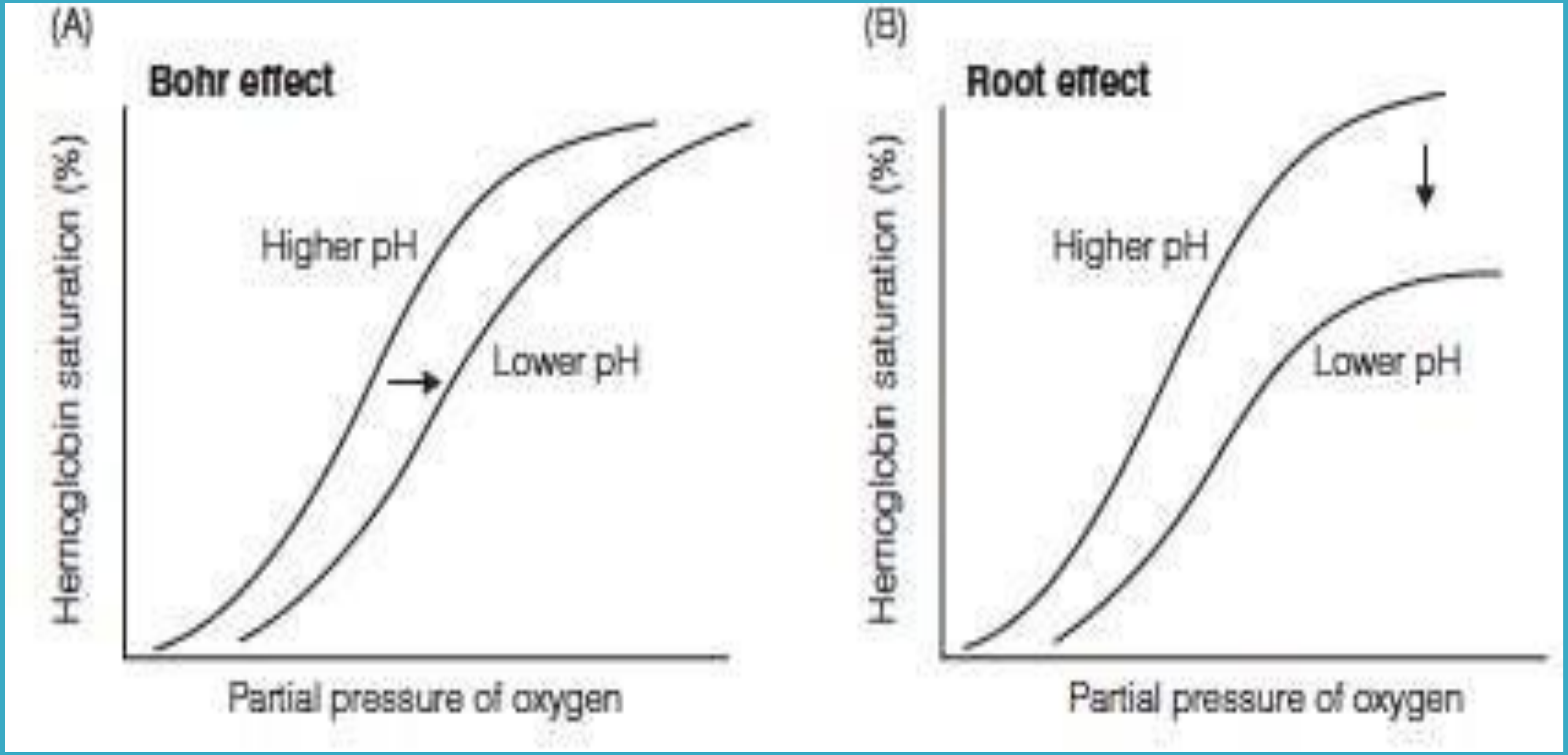
hemoglobin's affinity for oxygen is inversely related to acidity and CO_2 concentration

Bohr Effects

Root Effects

hemoglobin dumps O_2 quickly in acidic environment but rebinds O_2 relatively slowly when the pH increases

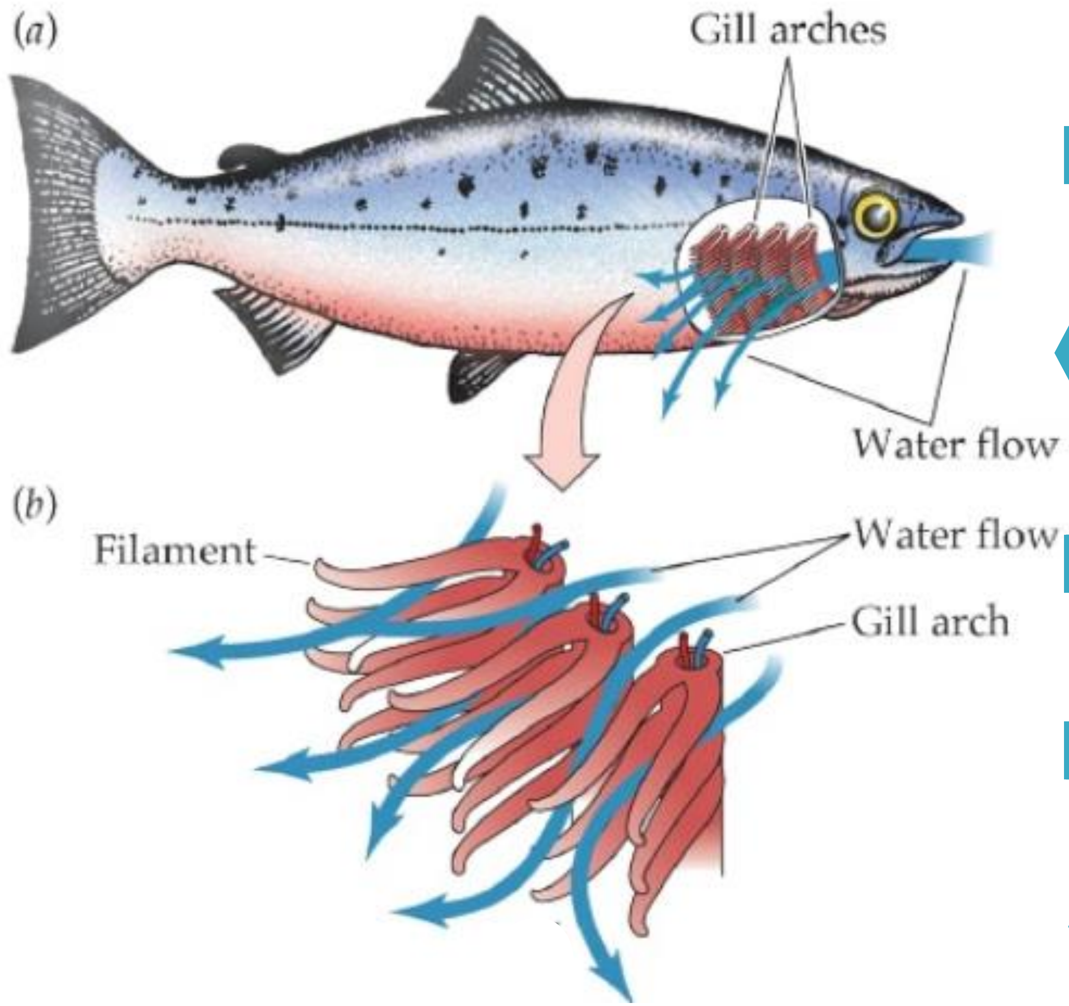
Buoyancy
Bohr & Root Effects



Respiration

O2 concentrations in water are low, especially in warmer and/or saltier water. So, the gas exchange must be efficient to get enough oxygen for respiration.

Aquatic animals use gills to obtain oxygen in water

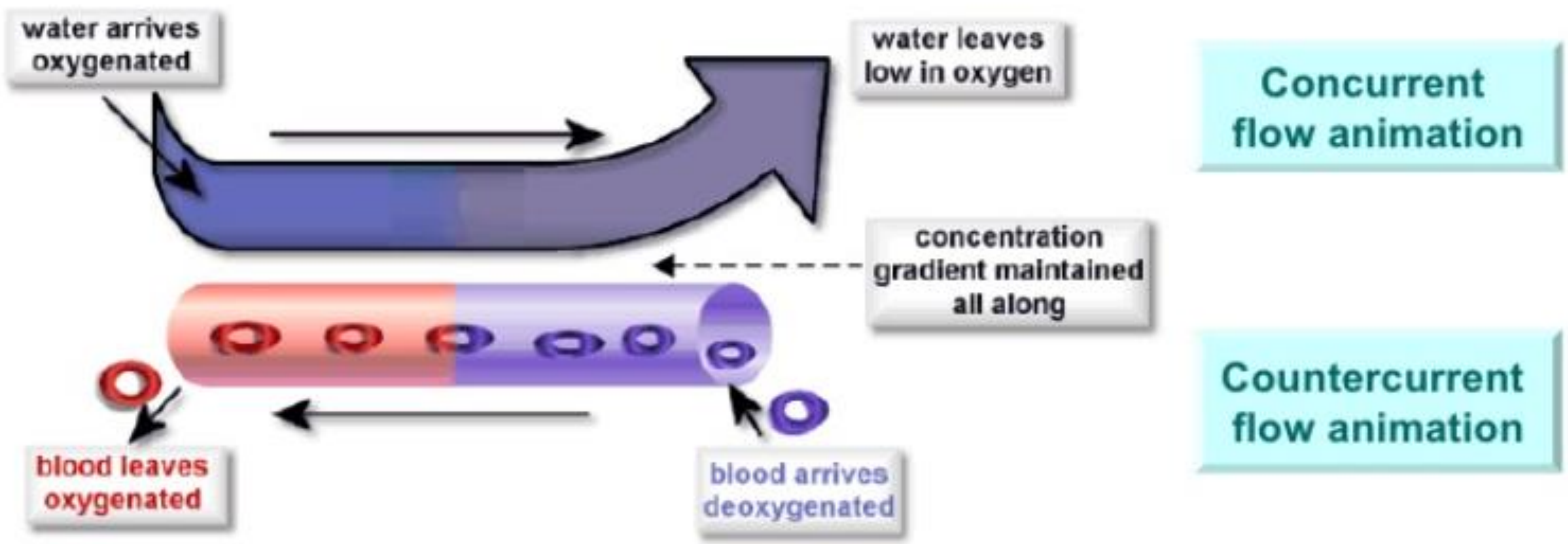


Each gill made of four bony gill arches

Gill arches lined with hundreds of gill ffilaments that very thin and flat

Gill filaments have fold called lamellae that contain a network of capillaries

Blood flows through the blood cappilaires in the opposite direction to the flow of water

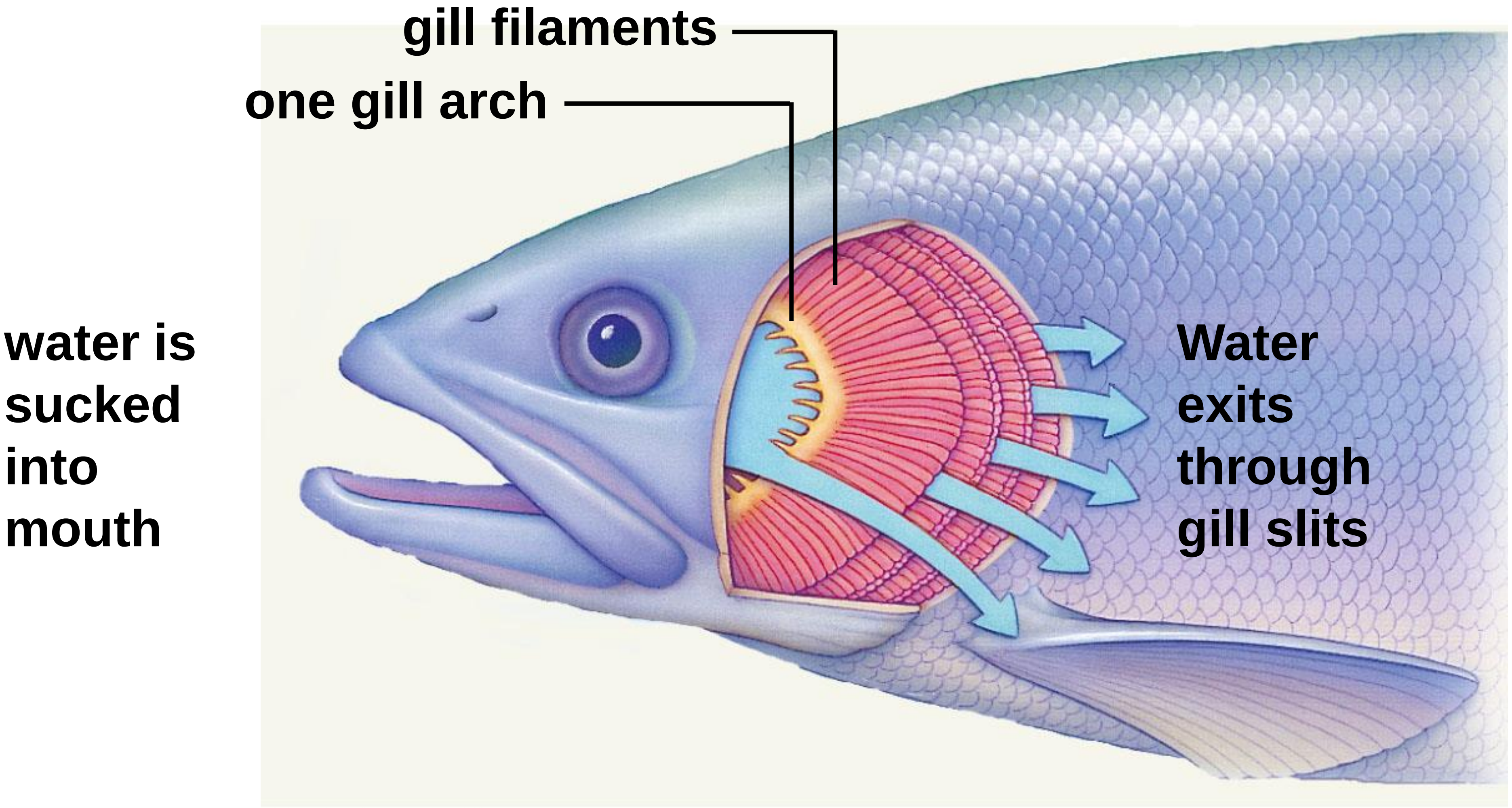


Fresh water flows over gills in ***one direction.***

Counter-current flow : water and blood in the gills flow in ***opposite directions***

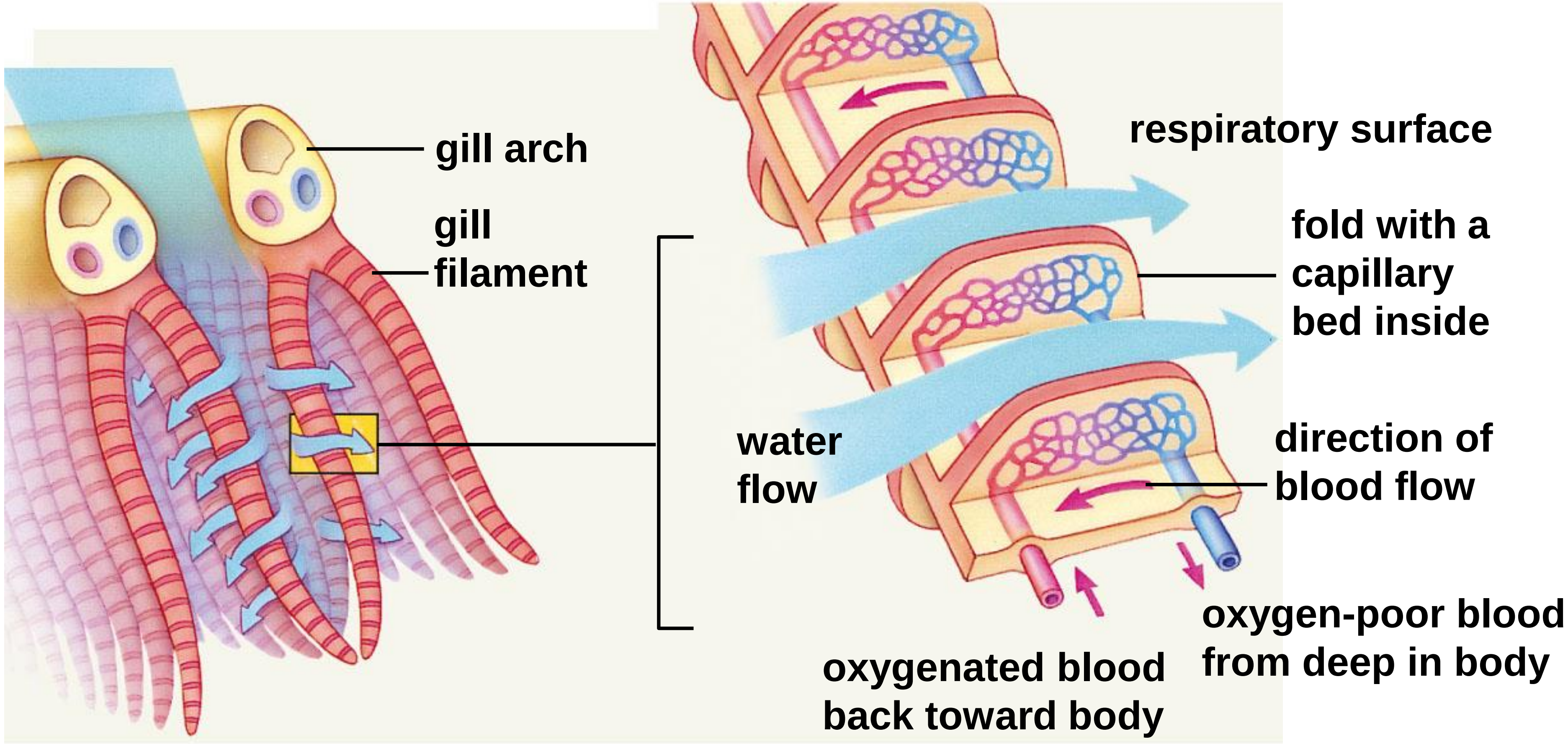
- Maintains a ***favourable concentrayion gradient*** for diffusion of both gases

Countercurrent Flow



A A bony fish with its gill cover removed. Water flows in through the mouth, flows over the gills, then exits through gill slits. Each gill has bony gill arches to which the gill filaments attach.

Fig. 39-10a, p. 686



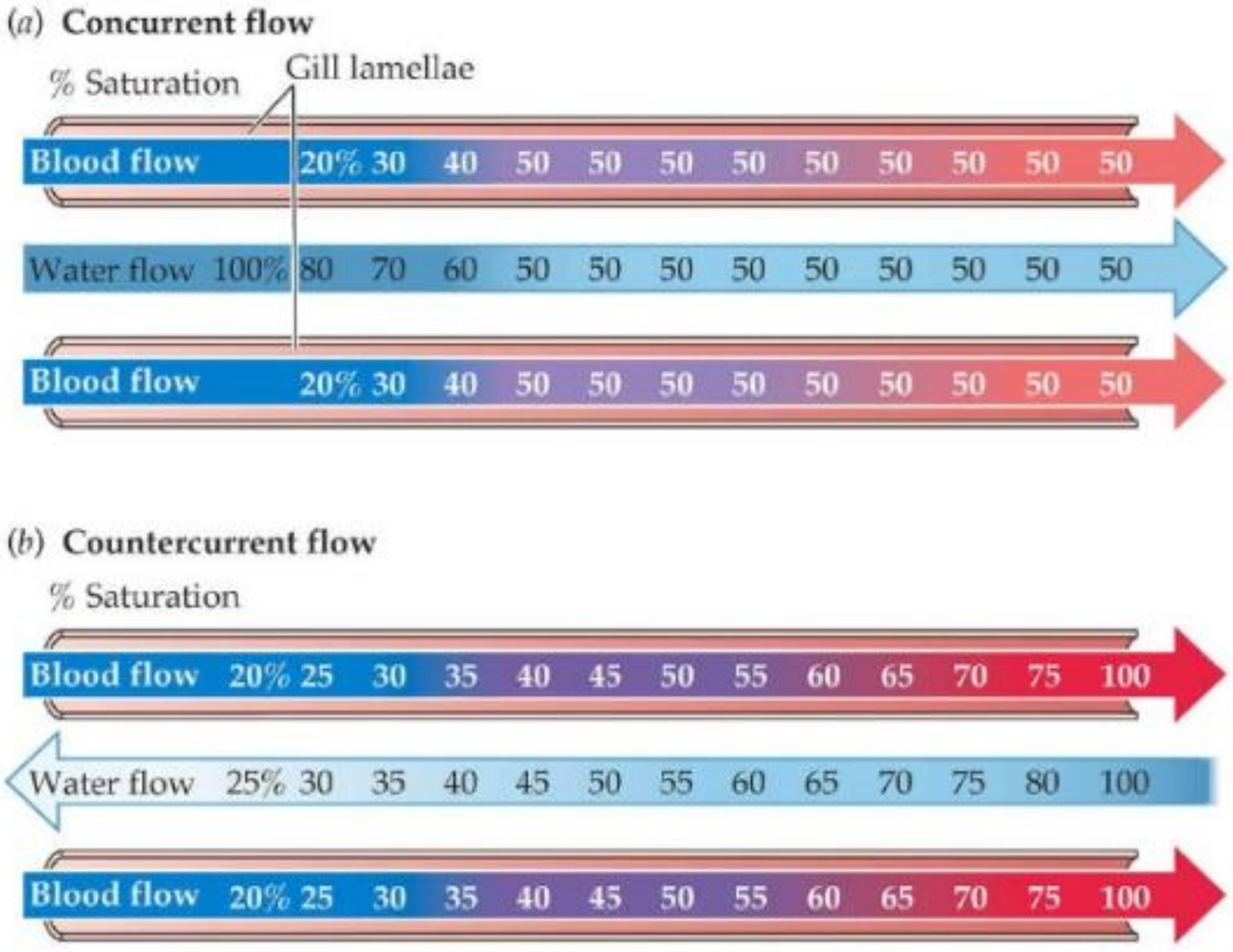
B Two gill arches with filaments

C Countercurrent flow of water and blood

Fig. 39-10 (b-c), p. 686

Respiration

Countercurrent exchange



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 48.6 Countercurrent Exchange Is More Efficient than Concurrent Exchange


Thank You