

Gas Exchange in fish

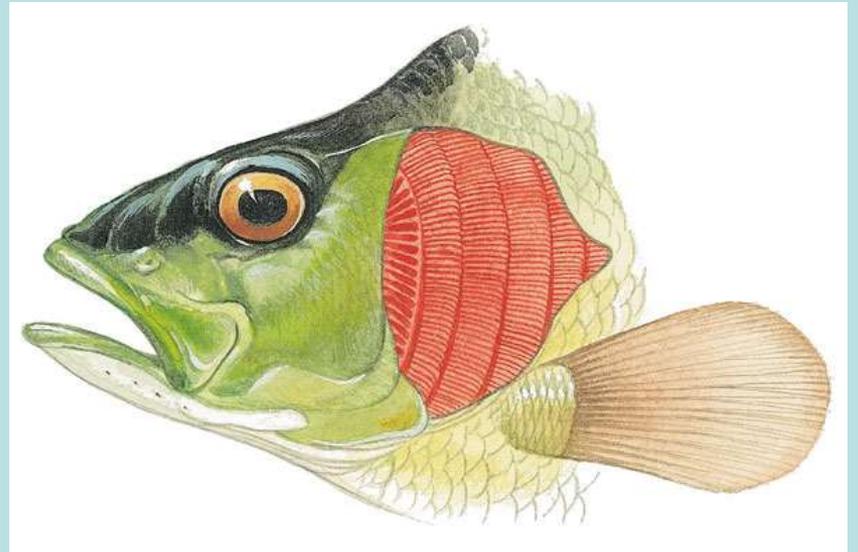


Gas exchange in fish - gills

- The gas exchange organs in fish are the **gills**.
- Like other animals, fish require a gas exchange surface that:
 - is **thin**, but well protected from damage.
 - is **moist**, so gases can dissolve before they diffuse. This is not a problem for fish as they live in water.
 - has a **large surface area** to meet their O₂ requirements.

Gas Exchange in Fish - gills

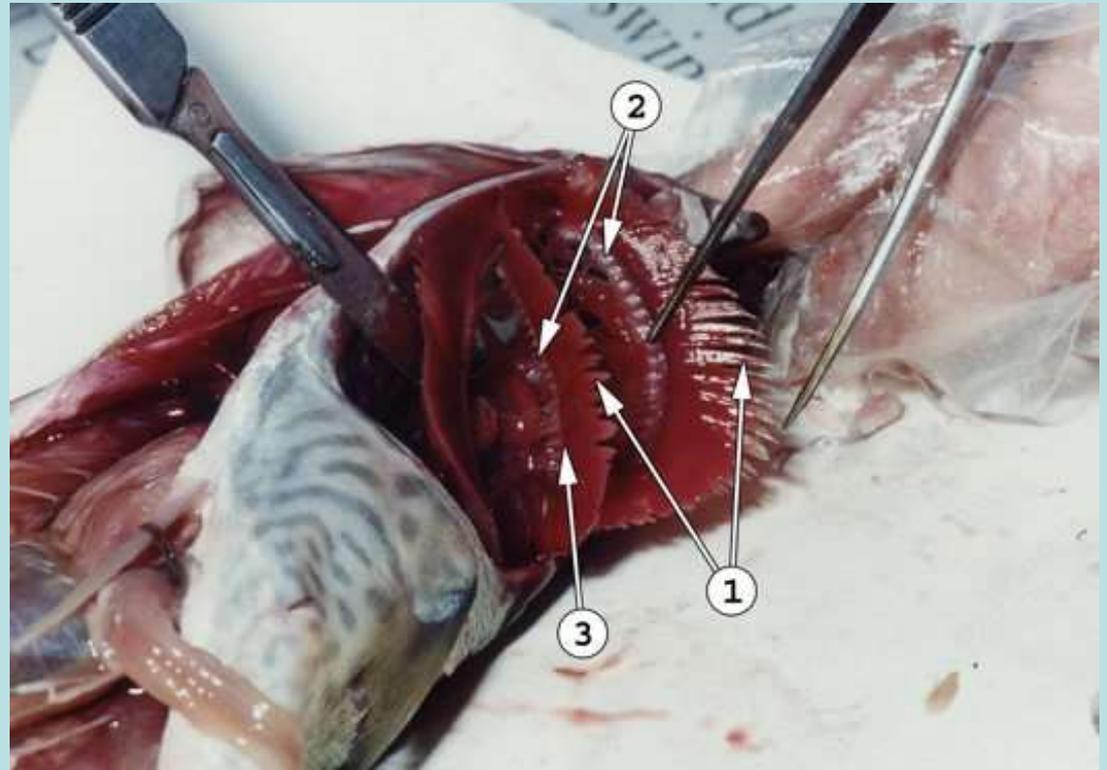
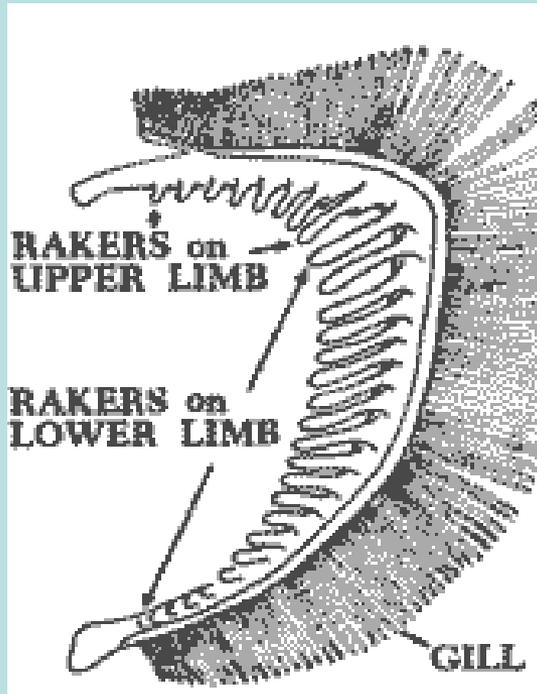
- Water contains a very low percentage of dissolved oxygen (1%) compared with air (20%), so fish require a gas exchange system with a **very large surface area** which is very efficient at extracting O_2 from the water.



Gas Exchange in Fish - gills

- Most fish have 4 pair of gills, located at the back of the mouth on both sides of the head. The gills are attached to **bony gill arches**.
- The gill arches have comb-like structures called **gill rakers** which trap dirt and debris in the water and prevent them from clogging up the gills.
- The gills are external to the body cavity and protected in most fish by a bony plate called an **operculum**.
- Sharks and other cartilaginous fish have **gill slits** instead of an operculum covering their gills.

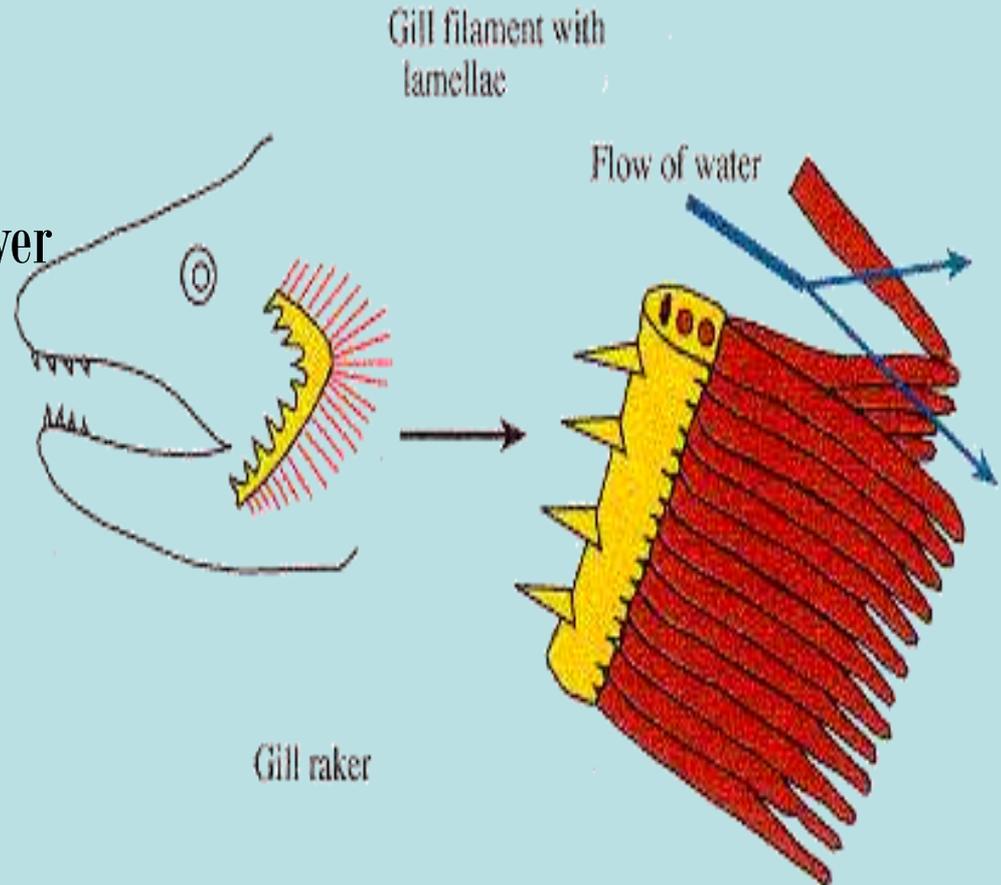
Bony gill arches with gills and gill rakers



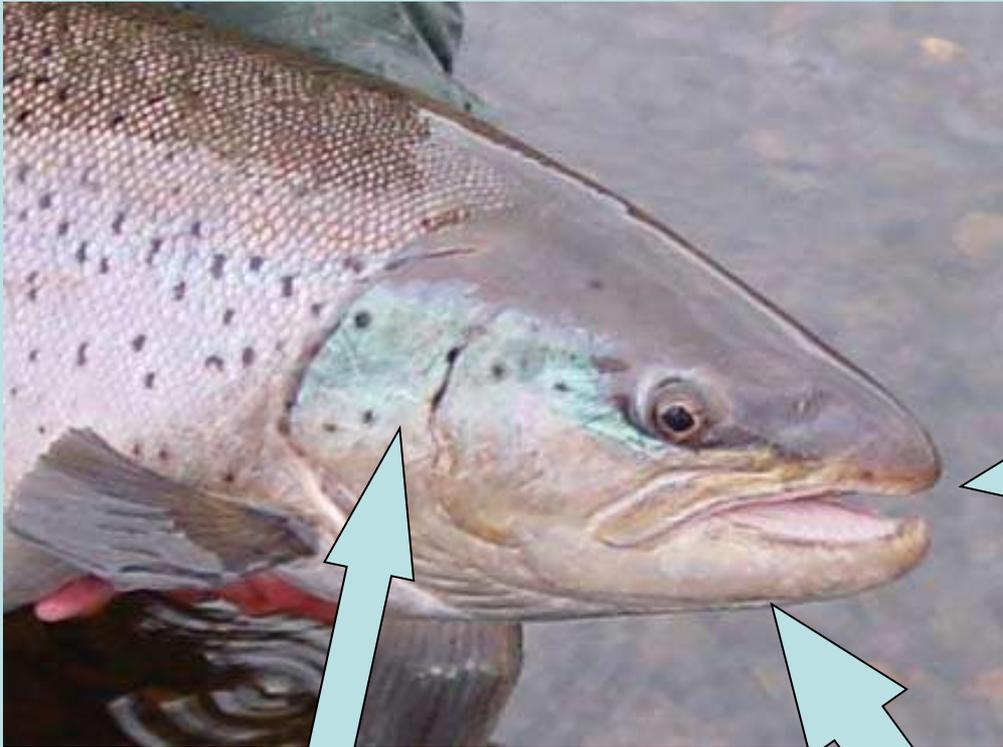
Fish have gills over which water **continually** flows.

Gills are supported by water flowing over them, so are unsuitable for life on dry land.

The water has oxygen dissolved in it.



Fish Anatomy



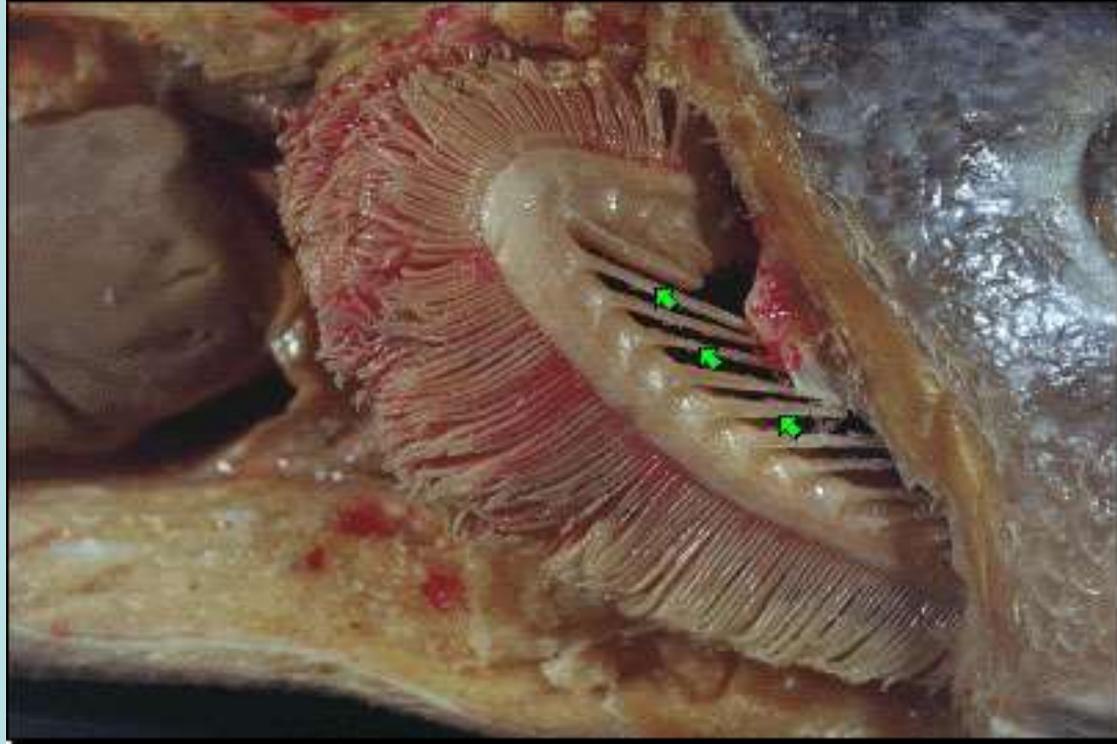
Mouth (Buccal Cavity)

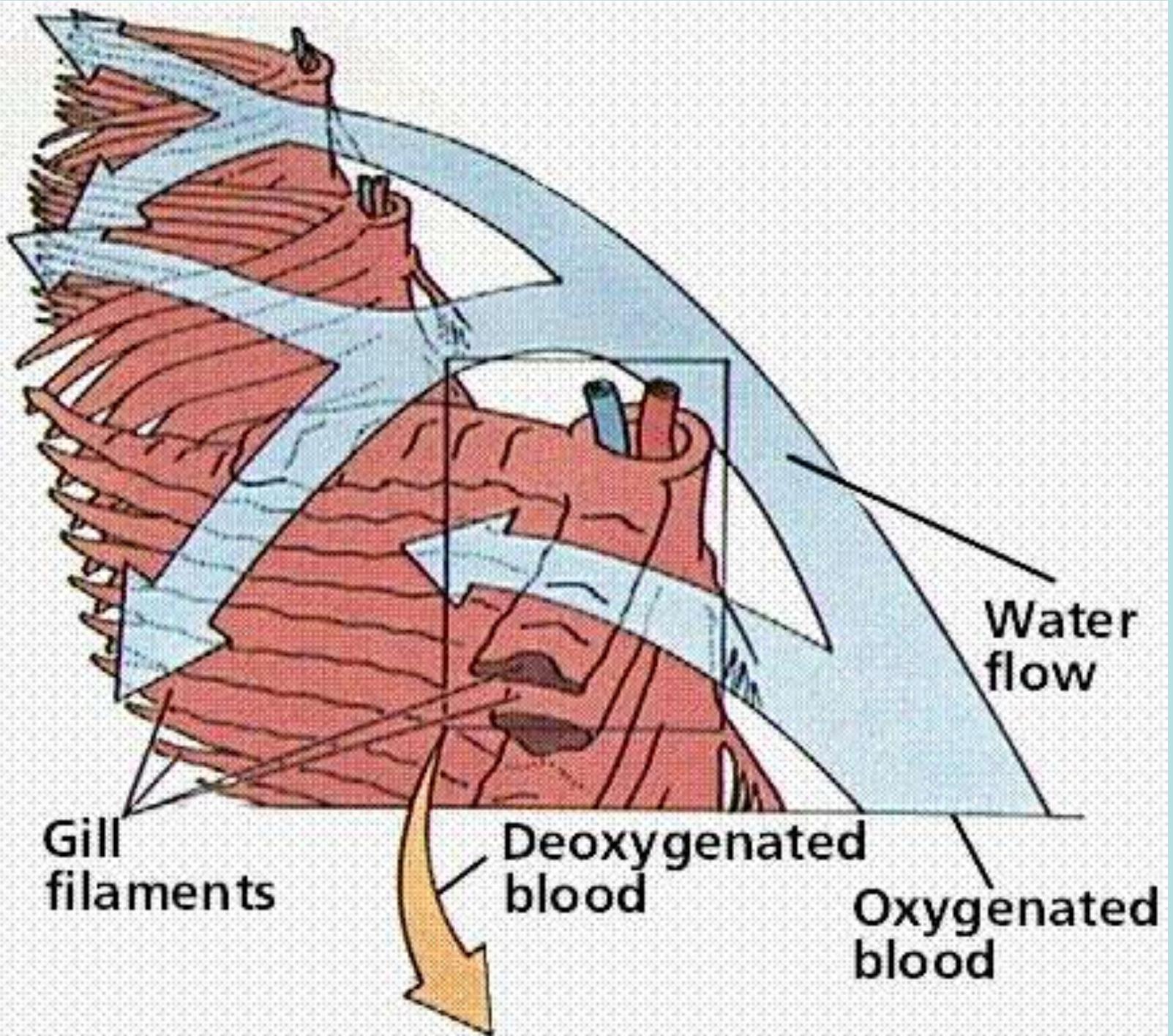
Operculum

Buccal Floor

Gill Structure

- Gill arches
- Gill filaments
- Lamellae



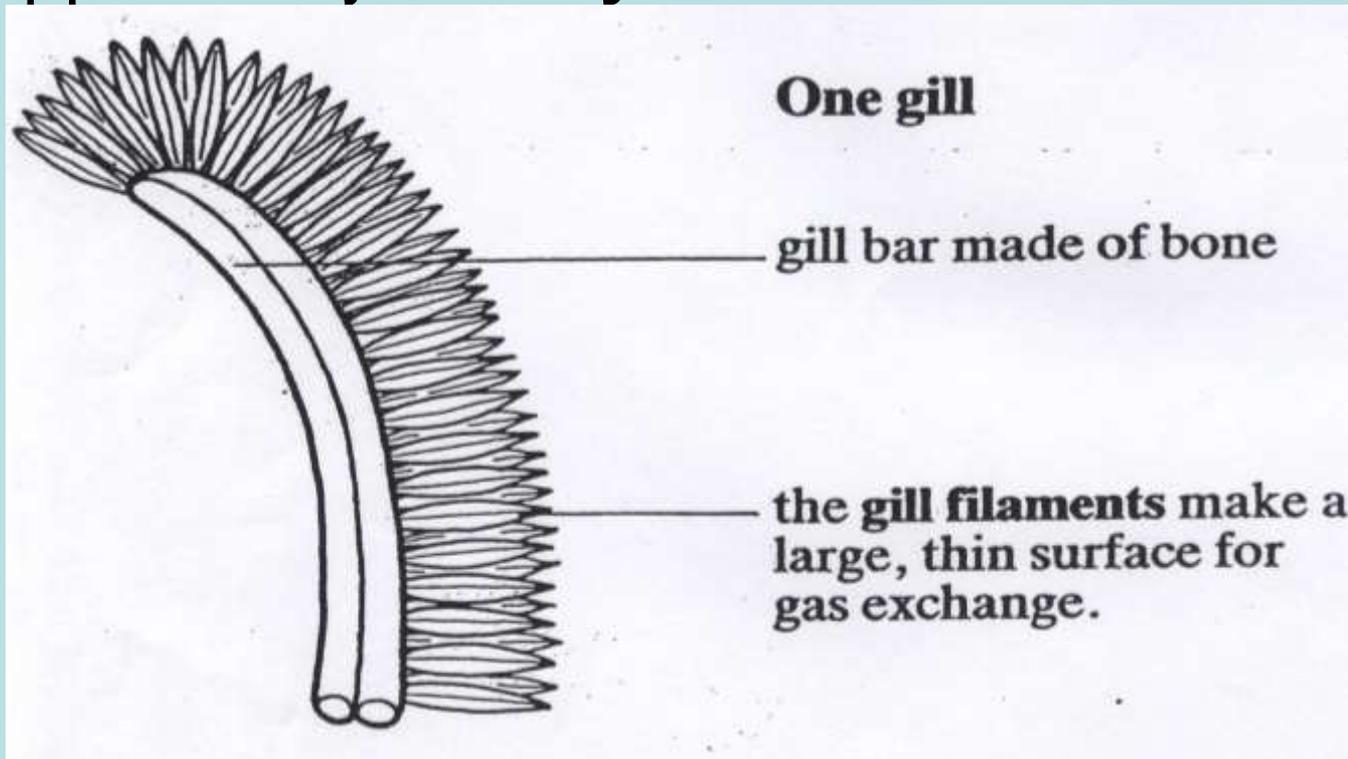


Adaptations of the gills for efficient gas exchange

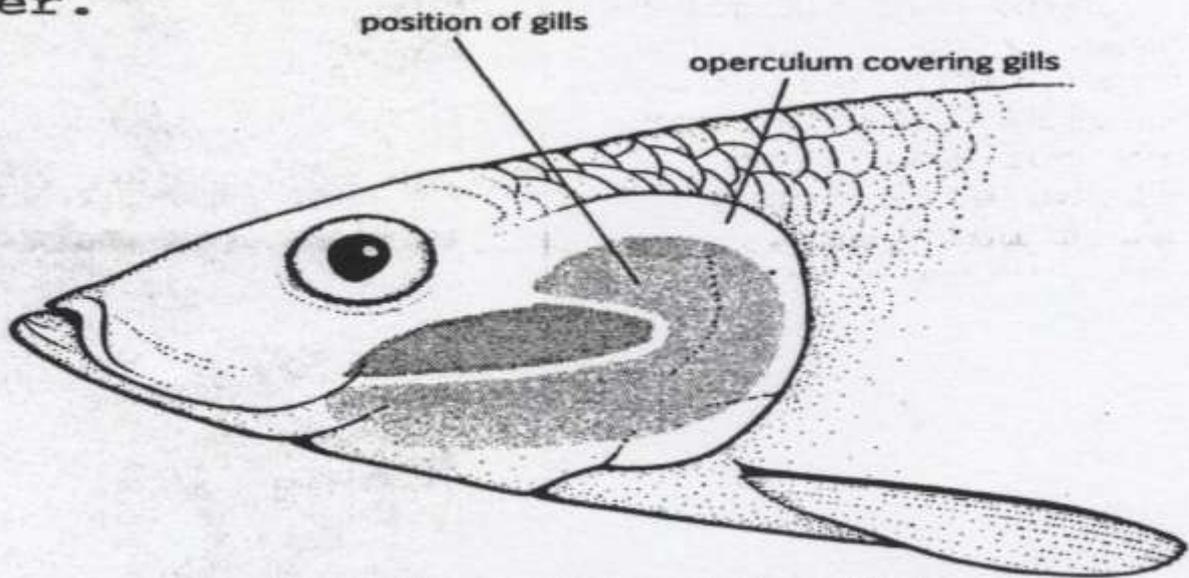
- Large surface area : volume
 - allows more diffusion of gases
- Permeable membranes
 - allows gases to diffuse through tissues
- Thin (flattened cells)
 - short diffusion distance
- Good vascular (blood) supply –
 - maintains concentration gradients

Structure of Gills

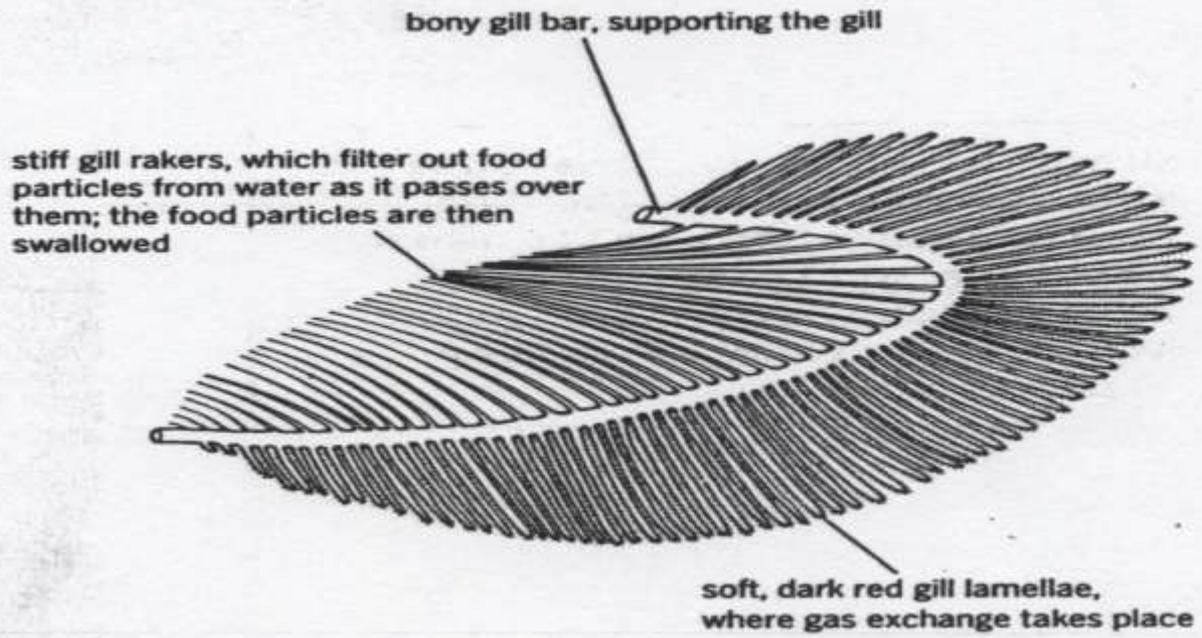
- The **gills** are made of numerous thin **filaments** supported by a **bony arch**.

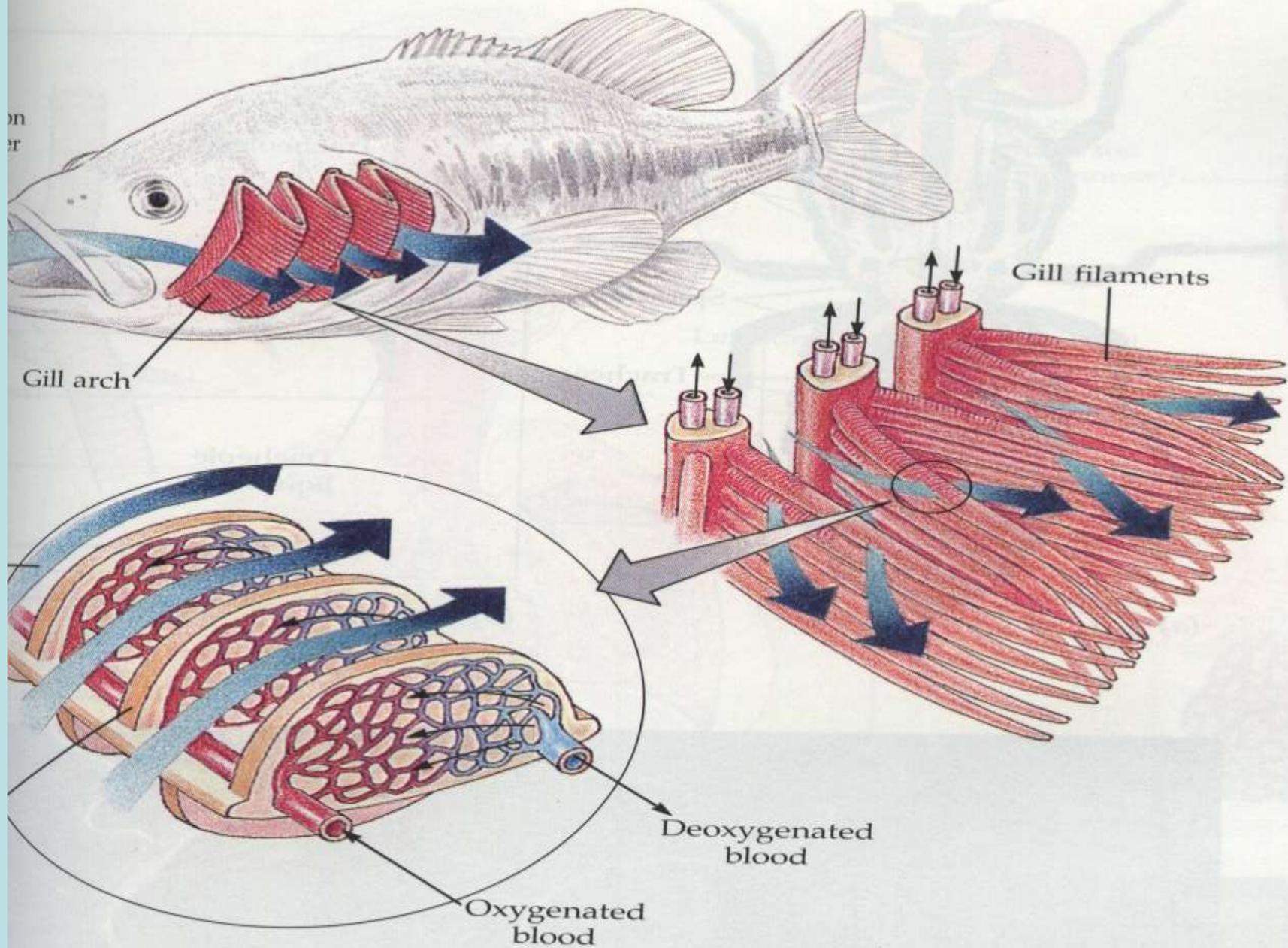


cer.



Head of herring, to show position of gills







Gill slits



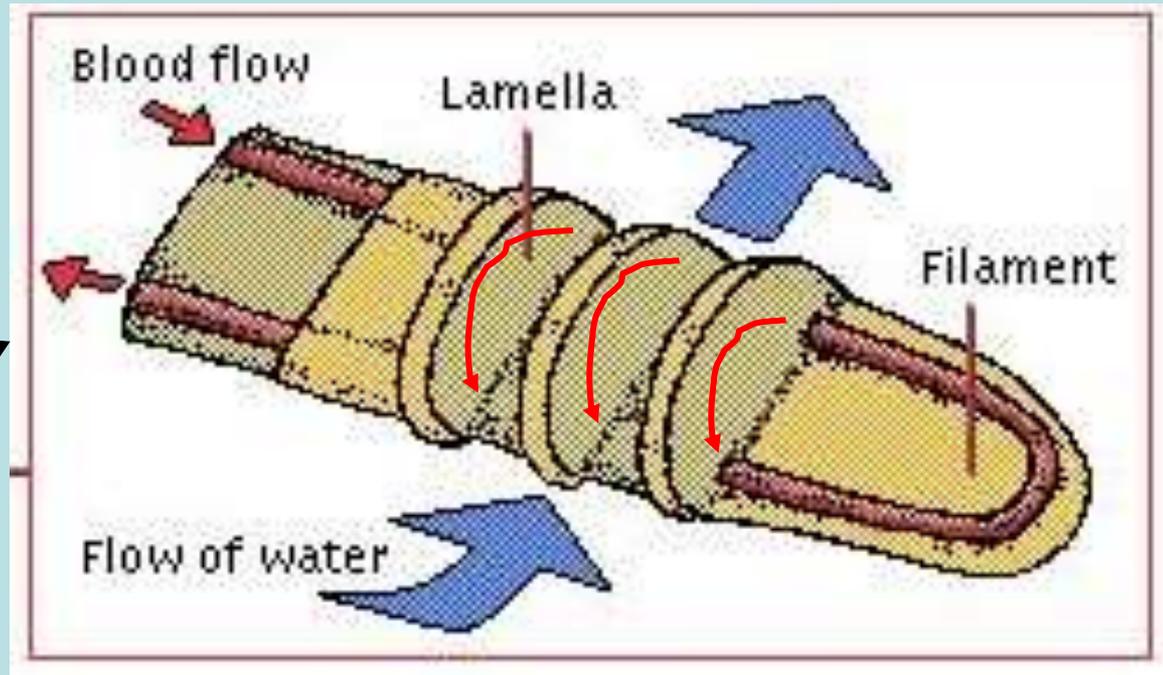
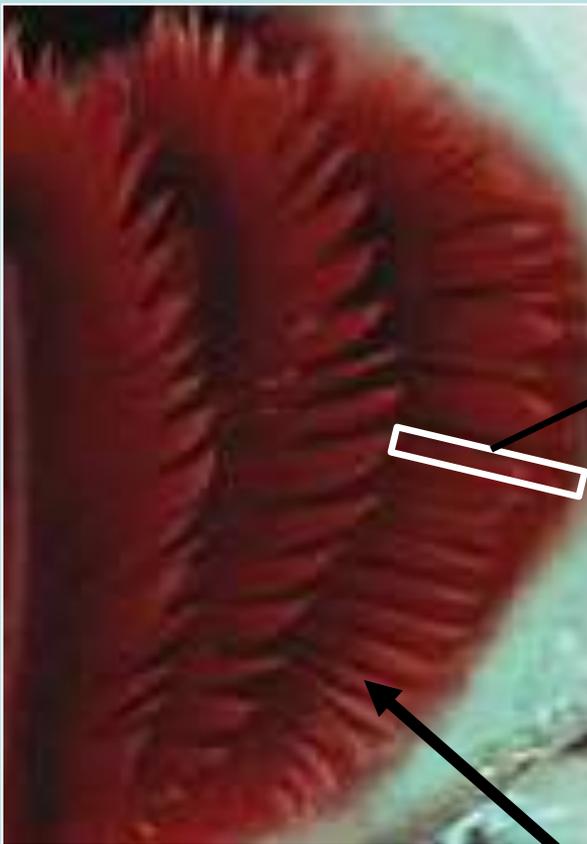
Operculum



Features of the gills

- **Operculum** – gill cover that protects the gills in bony fish. It opens to the outside at its back edge and helps to pump water across the gills.
- **Gill filaments** – very finely divided membranes that make up the gills. Each gill consists of two rows of gill filaments.
- **Lamellae** – tiny ridges or folds on each gill filament. The lamellae folds contain a network of fine blood capillaries for picking up O_2 from the water.

The lamellae are the gas exchange surfaces in the gills, and the blood capillaries they contain give the gills their bright red colour.



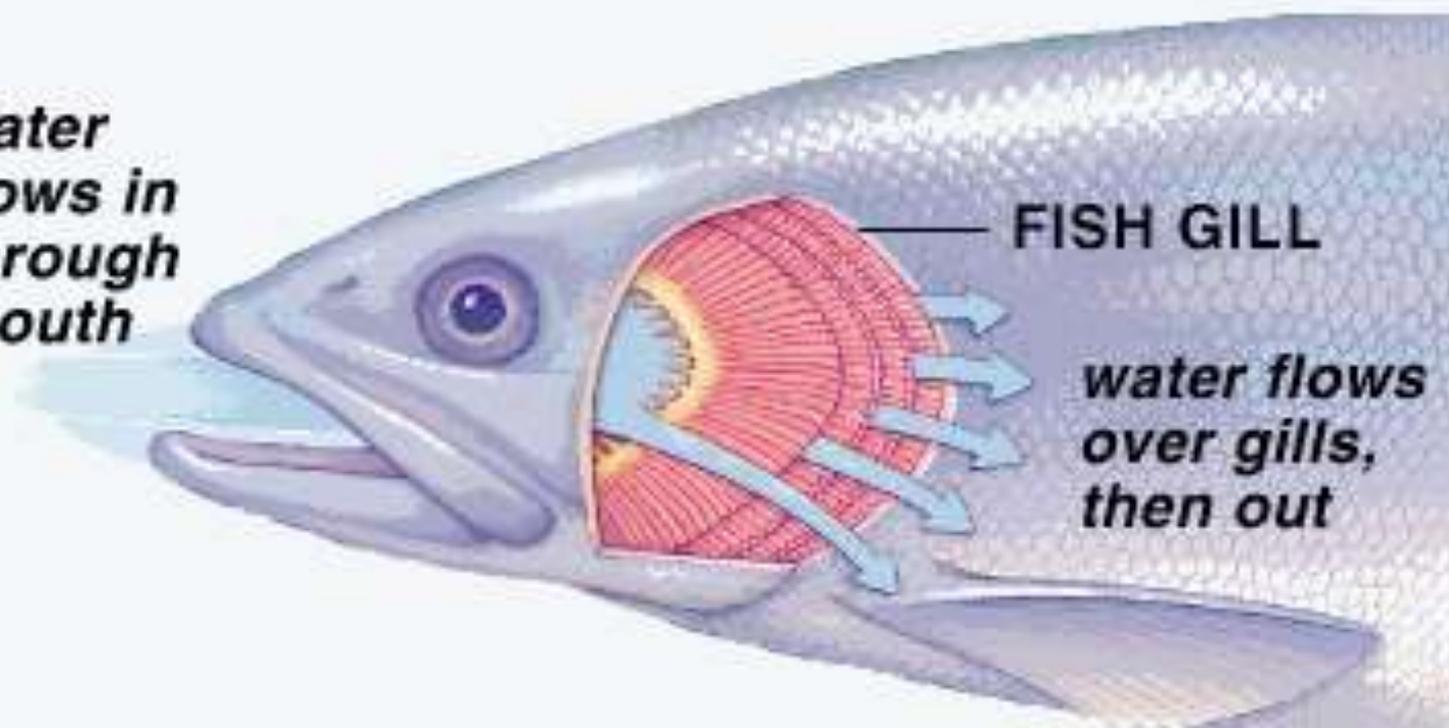
Gill filaments

The gills with their finely divided gill filaments and lamellae provide a very large surface area for gas exchange – about 60 times larger than the body surface of the fish.

Ventilation of the gills

- Fish continually pump water over their gills. This process is called **ventilation**. It ensures that the gills always receive a fresh supply of oxygenated water.
- Steps involved in ventilation:
 1. The fish opens its mouth, expands its buccal (mouth) cavity and closes its opercula, which draws water into the mouth.
 2. The fish closes its mouth, contracts its buccal cavity and opens its opercula, which forces water out across the gills.

*water
flows in
through
mouth*



FISH GILL

*water flows
over gills,
then out*

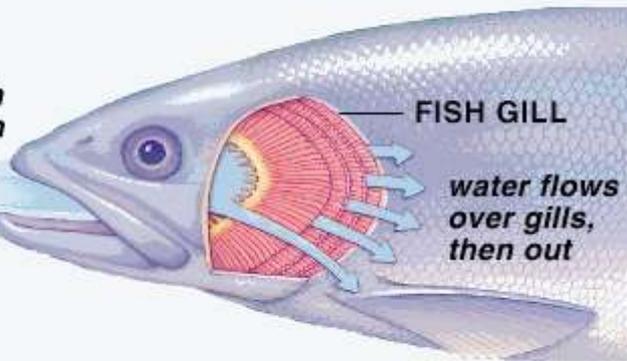
Tropical Fish

- The O_2 concentration of water varies. Warm or polluted water holds less O_2 than cold or clean water.
- Tropical fish compensate for the lower solubility of O_2 in warm water by having larger gills with a greater total surface area.
- Fish also increase their rate of ventilation as the O_2 level of the water declines.

Gas exchange in the gill lamellae

- The gas exchange system is linked to the blood transport system in fish.
- As water passes across the gills, O_2 from the water diffuses through the lamellae folds and into the blood capillaries inside.
- The blood then carries O_2 from the gills to all of the body cells and CO_2 from the body cells back to the gills.
- CO_2 then diffuses from the blood capillaries in the lamellae out into the water.

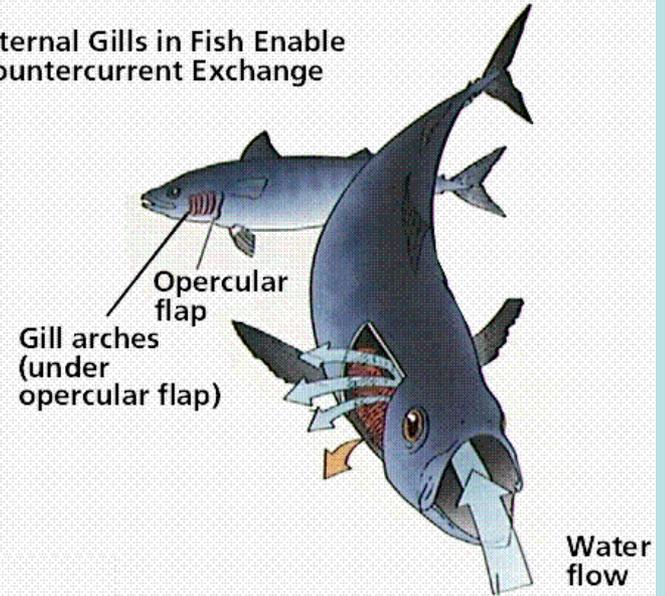
water flows in through mouth



FISH GILL

water flows over gills, then out

Internal Gills in Fish Enable Countercurrent Exchange



Opercular flap
Gill arches (under opercular flap)

Water flow

Gill chamber

Pharynx

Water out

Microsoft Illustration

Water in

Gill filaments

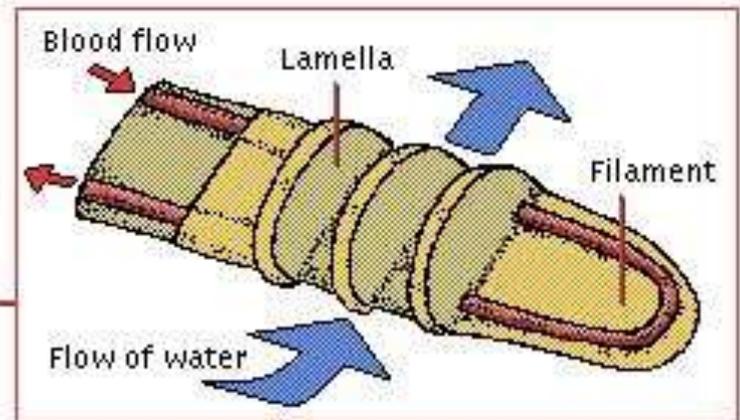
Gill cover (operculum)

Blood flow

Lamella

Filament

Flow of water



Counter-current exchange

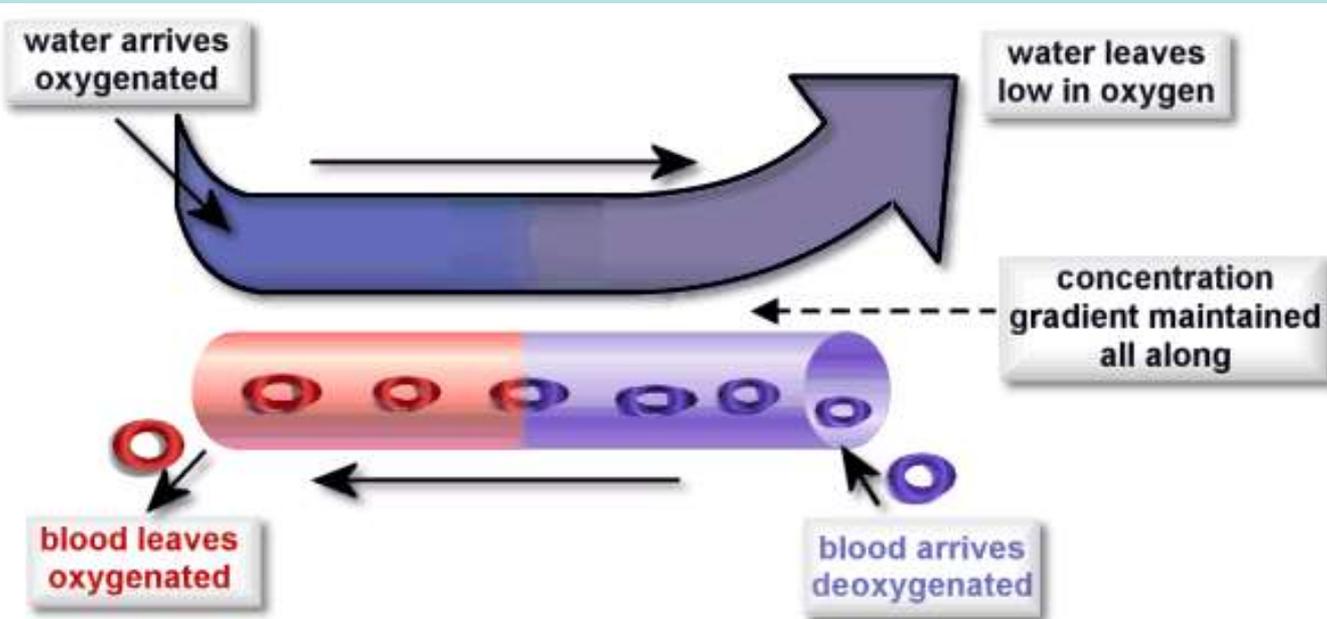
- Gas exchange in fish gills is very efficient because the flow of water over the gills is in the opposite direction to the flow of blood through the capillaries in the lamellae. This is called **counter-current flow**.
- Because of counter-current flow, blood flowing in the capillaries always meets water with a higher oxygen concentration, which allows diffusion to occur all the way along the lamellae.
- This results in over **80%** of the available oxygen being extracted from the water as it flows over the gills.

ENHANCING THE EFFICIENCY OF FISH GILLS

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

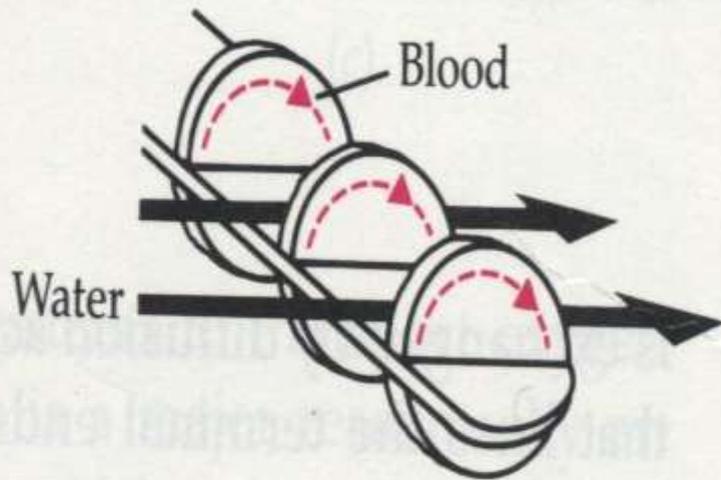
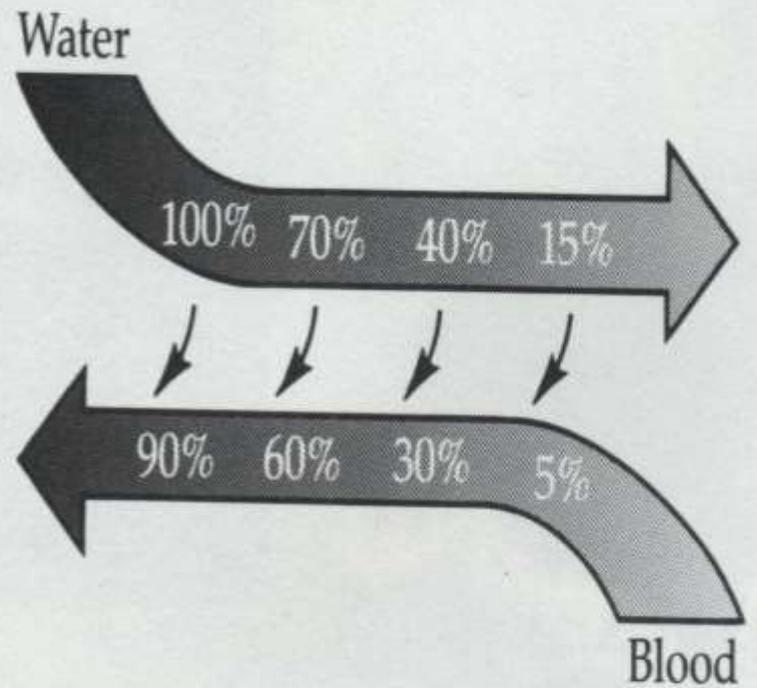
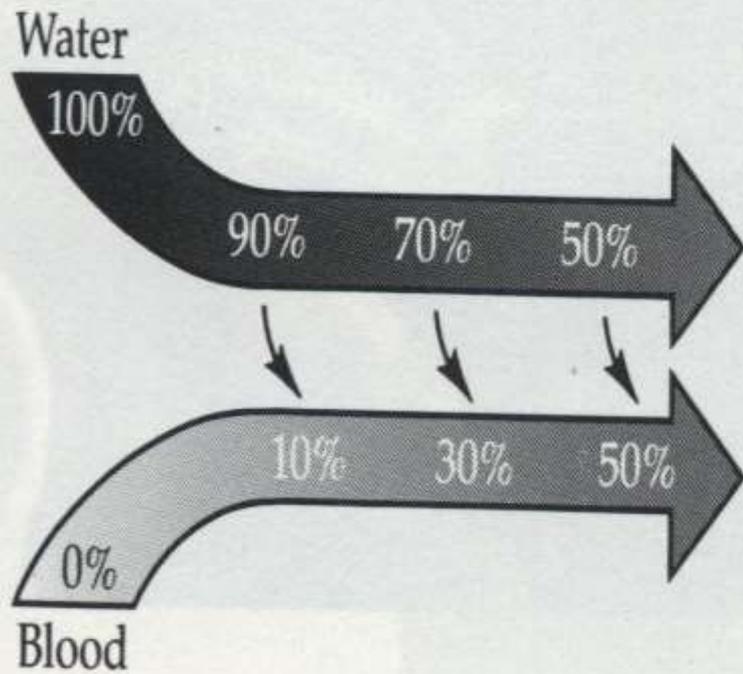
COUNTER-CURRENT FLOW: water and blood in the gills flow in **opposite directions**

→ maintains a **favourable concentration gradient** for diffusion of both gases

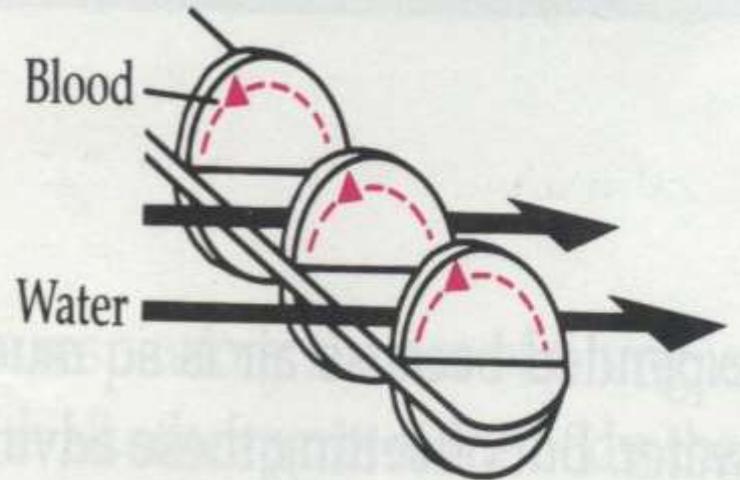


**Concurrent
flow animation**

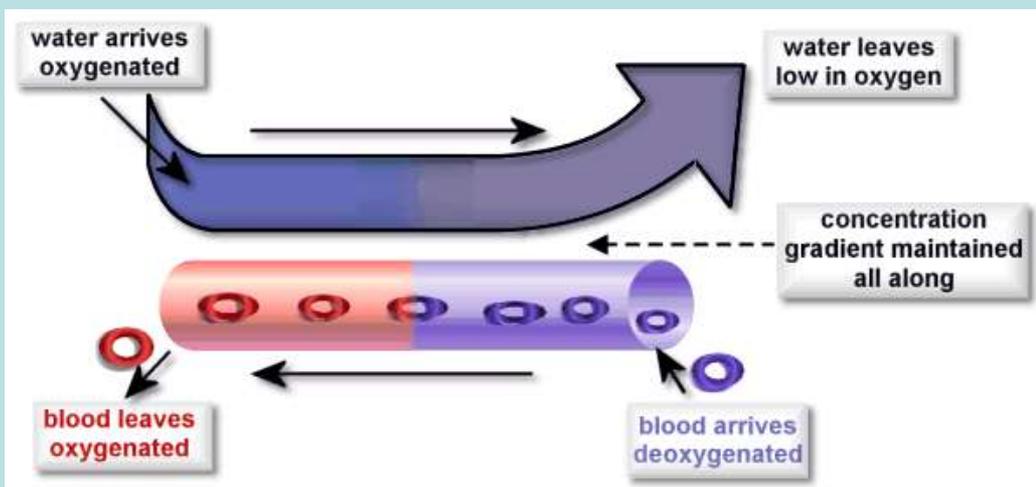
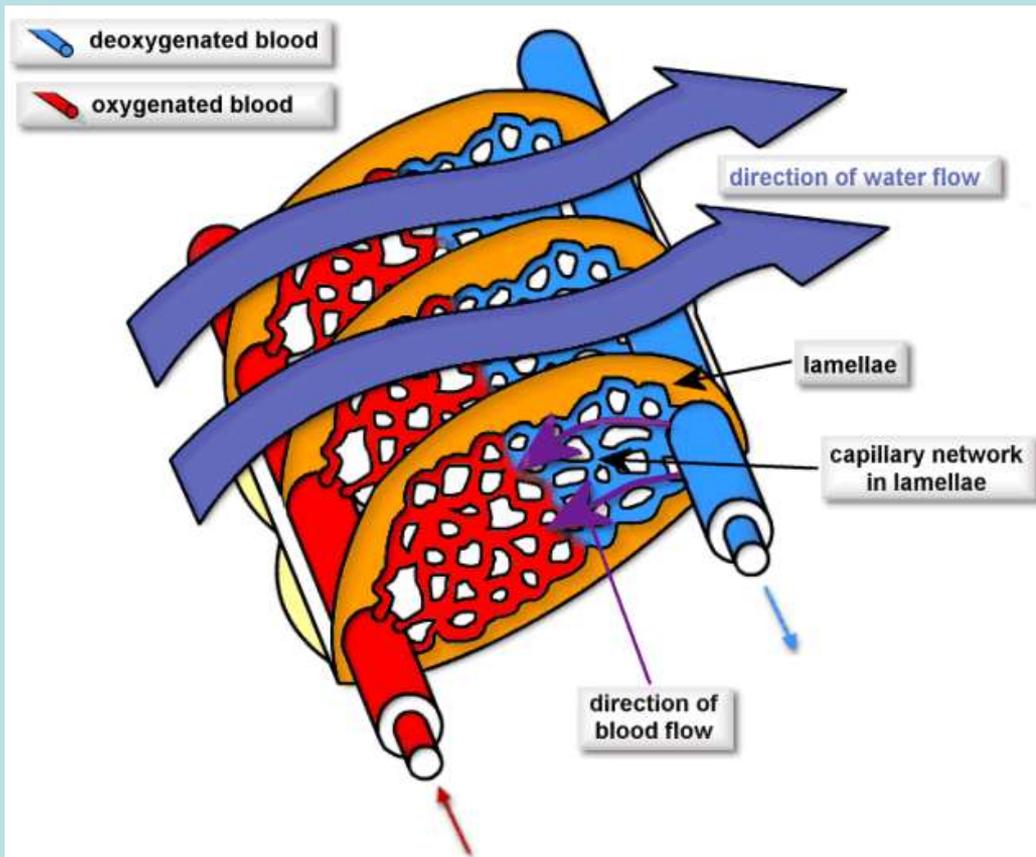
**Countercurrent
flow animation**



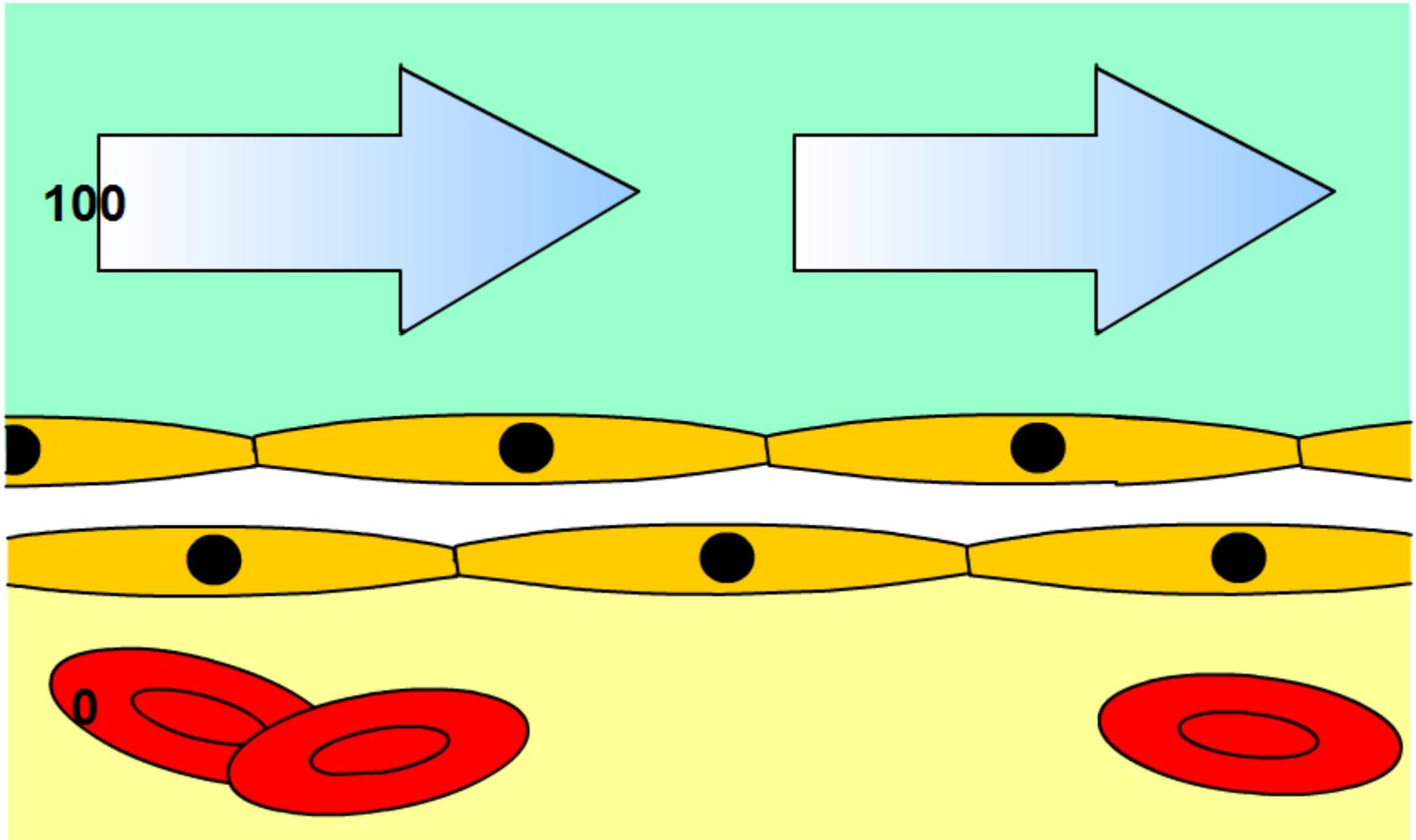
(a) Concurrent flow



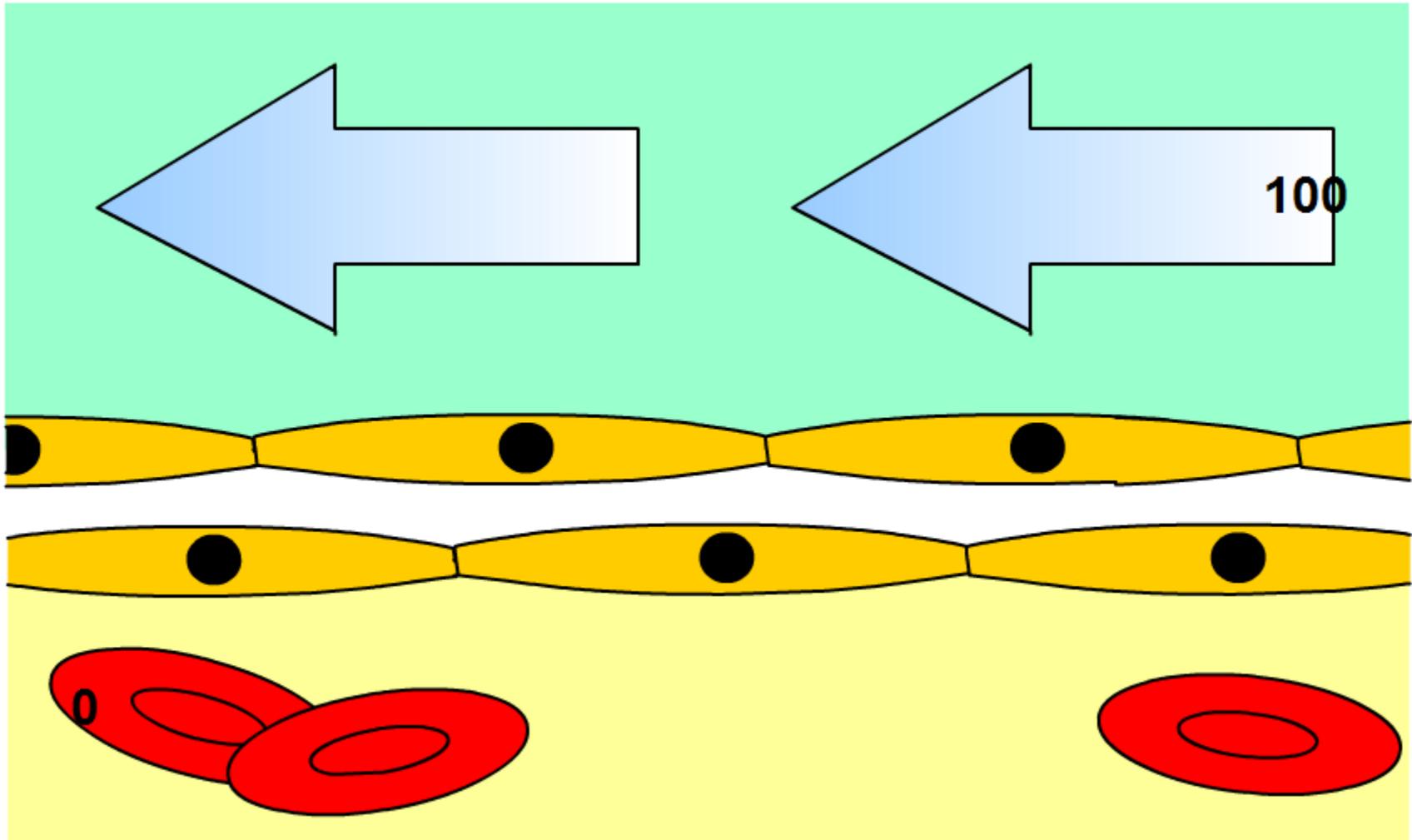
(b) Countercurrent flow



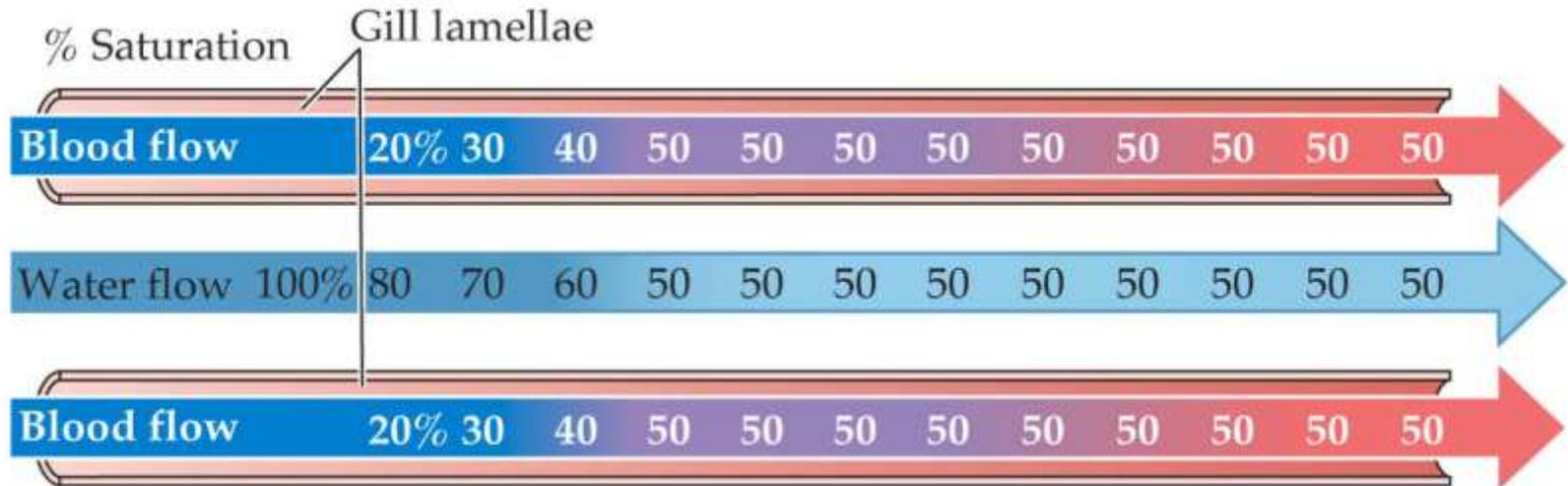
CONCURRENT FLOW



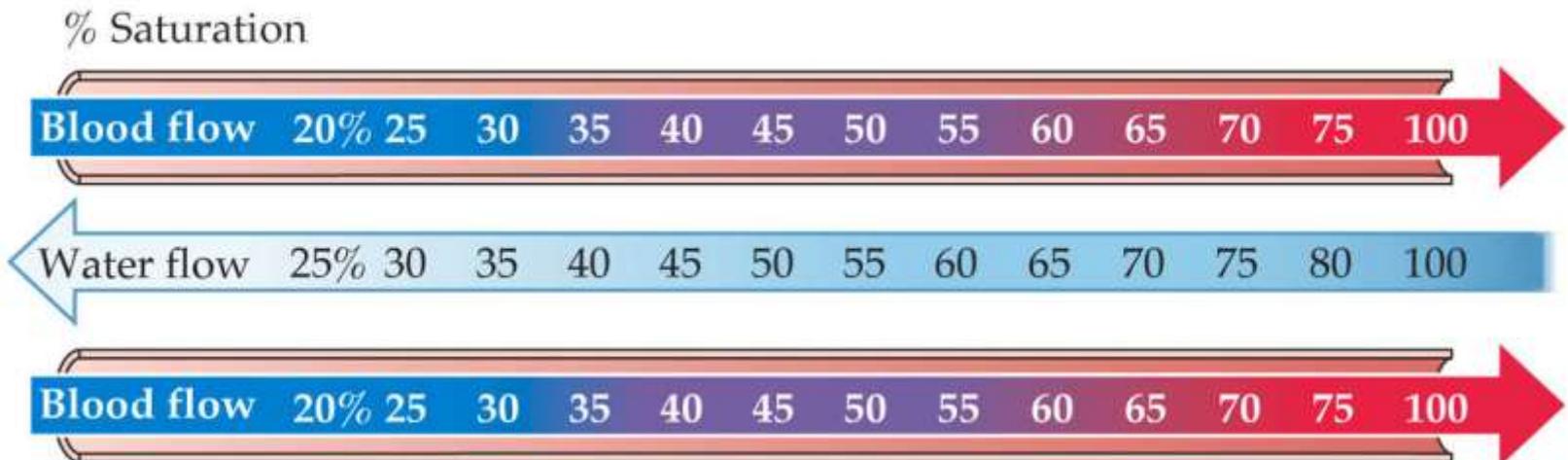
COUNTER-CURRENT FLOW



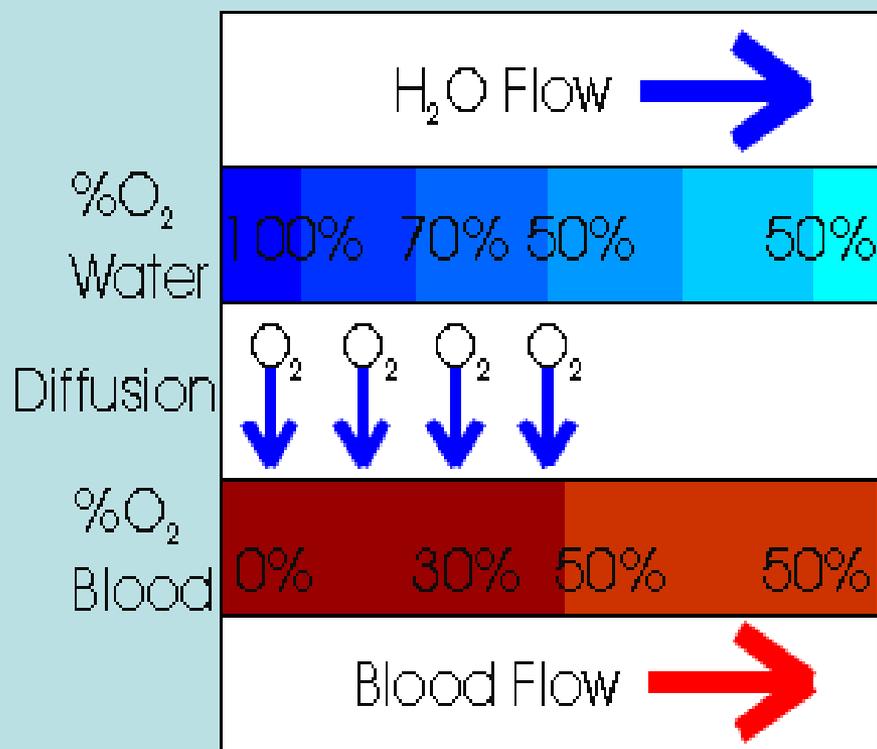
(a) **Concurrent flow**



(b) **Countercurrent flow**

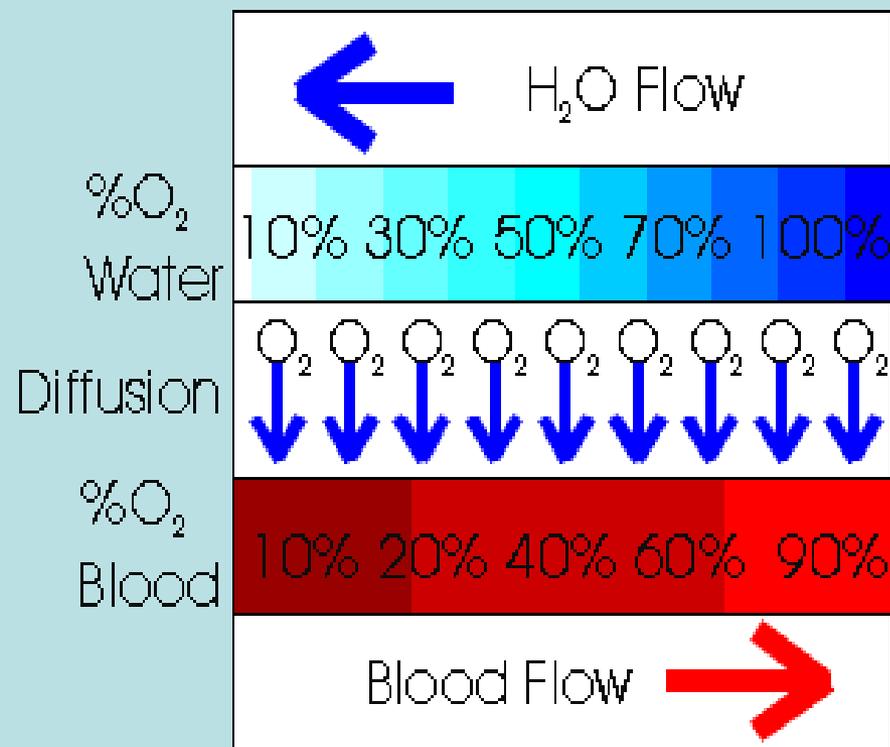


Same current



Equilibrium is reached,
diffusion stops

Counter current



Equilibrium not reached,
diffusion is constantly
taking place

The advantages of gills for gas exchange in water

- Fish gills are external to the body cavity but because they are surrounded by water they do not require special adaptations to keep their gas exchange surfaces moist.
- Water provides buoyancy and support for the gills and keeps the gill filaments separated so that they can maintain a large surface area for absorbing O_2 from the water.
- The gill filaments with their lamellae folds provide a very large surface area for gas exchange (60x larger than the fishes body surface). This is important because water contains much less O_2 than air.
- Gill filaments need to be very thin for gas exchange, but they are well protected from damage by the operculum and by gill rakers.

Advantages continued ...

- Fish transport oxygen in their blood using the respiratory pigment haemoglobin in their red blood cells.
- Having the gas exchange surfaces linked to the blood transport system makes gas exchange highly efficient and allows fish to be very active and to have larger body size than insects.
- Ventilation of the gills combined with counter-current flow allows maximum extraction of O₂ from the water (80%), compared with uptake from the air by mammals (20%).

Limitations of gills for gas exchange

- Gills are only suitable for gas exchange in water. On land, gills lose their support, collapse and quickly dry out so they can no longer function for gas exchange.

Useful websites for further info.

- <http://futurescientists.tamu.edu/lesson11/page2.html>
- <http://www.sci.sdsu.edu/classes/bio100/Lectures/Lect16/lect16.html>
- http://www.examtutor.com/biology/resources/studyroom/organs_and_systems/gas_exchange/exchange_fish.php
- http://www.geocities.com/aquarium_fish/how_fish_breathe.htm