Gas Exchange in Fish

How do fish breath?
BONY FISH

Diagram of fish gills and blood flow:
- Water flow through the gill arches.
- Oxygen-poor blood entering the gill arch.
- Oxygen-rich blood exiting the gill arch.
- Countercurrent exchange at the lamellae for efficient oxygen uptake.

Key parts labeled:
- Gill arch
- Operculum
- Blood vessel
- Gill filaments
- Water flow over lamellae showing % O₂
- Blood flow through capillaries in lamellae, showing % O₂
How is the structure of the gills related to its function?

Think:

- Specialised exchange surface
- SA/V ratio
- Fick’s Law
- Gas Exchange
- Blood flow
BONY FISH

Blood flows between gill plates under pressure in opposite direction of blood in capillaries. As blood always meets water with higher O₂ content it removes 80% of O₂ from water.

Water flows past the gills in the opposite direction to the blood (countercurrent flow) – so they can extract oxygen at 3xs the rate a human can. 

http://www.s-cool.co.uk/a-level/biology/gas-exchange/revise-it/gas-exchange-in-fish
Fish head dissection

http://www.youtube.com/watch?v=pNZQEmGpuuk

A Carp with the Operculum removed to show the Gills
How many filaments?

- You will have to work out how many filaments a fish has in your Unit Standard

How will you do it?

Step 1: count the number of filaments in a cm piece of gill arch

Step 2: ....
Aim

To understand the physiological adaptations of fish for gas exchange

In depth – Bony fish
General – Cartilaginous fish
A Fishy Issue
Problem of water as an exchange medium

Problems:

- Water has ~20x less oxygen per cm³ than air
- Water is denser/more viscous (777 x’s) than air

So fish need.....

- An efficient *surface* to obtain oxygen
- Mechanisms to maximise water movement over the surface
There are 2 different types of fish:

Do you know the differences?

Cartilaginous

Bony

© D. Randle 2002
<table>
<thead>
<tr>
<th>CARTILAGINOUS</th>
<th>BONY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have a skeleton made up of cartilage.</td>
<td>Are by far the most numerous.</td>
</tr>
<tr>
<td>Most live in the sea.</td>
<td>Live in both fresh and salt water.</td>
</tr>
<tr>
<td>Blood travels through the gills in the SAME direction as the water: <strong>PARALLEL FLOW</strong></td>
<td>Blood in the gill capillaries flows in the OPPOSITE/ACROSS direction to the water flowing over the <em>gill plates</em> in COUNTER-CURRENT FLOW.</td>
</tr>
</tbody>
</table>
BONY FISH

The ventilation mechanism for forcing water over the gill is:
Water flows in:

<table>
<thead>
<tr>
<th>Structure</th>
<th>What is does</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td></td>
</tr>
<tr>
<td>Operculum</td>
<td></td>
</tr>
<tr>
<td>Buccal cavity floor</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td></td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
</tr>
</tbody>
</table>
BONY FISH

The ventilation mechanism for forcing water over the gill is:

Water flows in:

<table>
<thead>
<tr>
<th>Structure</th>
<th>What does it do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>Opens</td>
</tr>
<tr>
<td>Operculum</td>
<td>Closes</td>
</tr>
<tr>
<td>Buccal cavity floor</td>
<td>Lowered (making cavity larger)</td>
</tr>
<tr>
<td>Volume</td>
<td>increases</td>
</tr>
<tr>
<td>Pressure</td>
<td>decreases</td>
</tr>
</tbody>
</table>

Animation of process
GETTING OXYGEN FROM WATER: FISH GILLS

- Gills covered by an *operculum* (flap)
- Fish *ventilates* gills by alternately opening and closing mouth and operculum
  - water flows into mouth
  - over the gills
  - out under the operculum
- Water difficult to ventilate
  - gills near surface of body
TO TAKE IN WATER
Pressure within the mouth decreases when:

The mouth opens and the floor of the mouth cavity is lowered increasing the size of the mouth

The OPERCULUM (gill cover) closes the opening at the back of the throat (pharynx)

Water rushes into the mouth
FOR WATER TO PASS OUT:-

Pressure within the mouth decreases when:

The mouth closes and the floor of the mouth cavity is raised decreasing the size of the mouth

The OPERCULUM (gill cover) opens and due to the increase in pressure, the water flows out over the gills.
PARALLEL FLOW (Cartilaginous)
Blood flows between gill plates under pressure in opposite direction of water (countercurrent flow). Blood always meets water with higher O₂ content it removes 80% of O₂ from water.

3xs the rate of humans
COUNTER-CURRENT FLOW (Bony)
How it works!

We are going to represent water flow over the gill plate/lamellae

Volunteers –
You are water or red blood cells....

- 4 water molecules with slowly walks across lamellae
- At the end of the lamellae go back to the start and pick up more oxygen

- 4 RBCs in capillary take O2 from water as it goes past you through lamellae
- At end of lamellae, go back to start and give up all oxygen
Draw two lines – a blue line starting from 100% oxygen saturation (on the left) and a red line started from 0% (on the right).
Which is which?

% saturation of oxygen

Distance along the gill plate

Water 90 70 50
Blood 10 30 50

Water
Blood

% saturation of oxygen

Distance along the gill plate

Water 90 70 50
Blood 10 30 50

Water
Blood
(a) Concurrent flow

% Saturation  Gill lamellae

Blood flow  20% 20% 20%

Water flow  100% 50 50 50 50 50 50 50 50 50

(b) Countercurrent flow

% Saturation

Blood flow  20% 25 30 35 40 45 50 50 55 60 65 70 75 100

Water flow  25% 30 35 40 45 50 55 60 65 70 75 80 100

Blood flow  20% 25 30 35 40 45 50 55 60 65 70 75 100

Blood gets max 50% saturation!
COMPARISONS

CARTILAGINOUS

• Just behind head - 5 gill clefts open at gill slits
• Water in the mouth is forced over the slits when floor of the mouth is raised.

BONY

• 4 pairs of gills and each gill is supported by a gill arch.
• Along each arch there are thin plates called lamellae + on these there are gill plates where gaseous exchange happens
• The gills are covered by a flap called the OPERCULUM
Additional Diagrams
GETTING OXYGEN FROM WATER: FISH GILLS

- Each gill made of four bony 
  *gill arches*.

- Gill arches lined with hundreds of
  *gill filaments* that are very
  *thin* and *flat*. 
GETTING OXYGEN FROM WATER: FISH GILLS

- Gill filaments are have folds called **lamellae** that contain a network of **capillaries**.
- Blood flows through the blood capillaries in the **opposite direction** to the flow of water.
Each gill arch has many filaments
Each filament has many lamellae