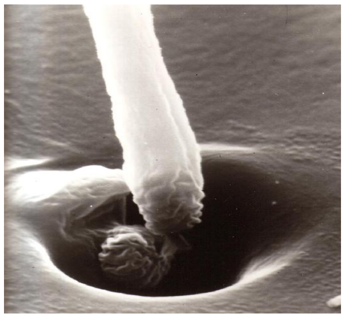
How do sharks and crabs sense depth?
Crabs in space and out of their depth

The Crabs in Space team used a very simple mathematical calculation to prove a fundamental part of their research. Applying a branch of mathematics known as **hydrostatics** enabled them to understand how a change in water pressure can stimulate the crab's balancing system. Hydrostatics describes and predicts what happens to fluids (this includes gases and liquids) at rest – **hydrodynamics** is the equivalent study for fluids in motion.

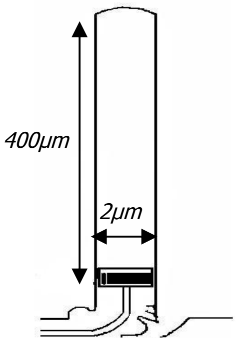
The crab's balancing system is made up of a liquid-filled 'vestibular' cavity with sensory hairs inside. These tiny thread hairs are linked to mechanoreceptors, telling the crab that it needs to re-balance. The team had discovered that a movement of just 17 nanometres (17 billionths of a metre) was enough to stimulate the hair mechanoreceptor.



The crab's thin sensory hair is linked to a mechanoreceptor

But nobody had yet understood how this system could work under water, since most similar work had been done on animals with gas-filled organs linked to their vestibular systems.

Hydrostatics shows that gases compress considerably under pressure, but liquids only compress by tiny amounts – for example, seawater has a **compressibility** of 44 x 10^{-6} per bar (a bar is a unit of pressure which is approximately equal to atmospheric air pressure at sea level). This means that for each increase in pressure by 1 bar, the volume of the water reduces by 44 millionths.



The link to the hair acts as a piston

The team realised that as a crab travelled into deeper water and the water pressure increased, the minute change in the volume of the liquid in the hair was enough to move the link to the mechanoreceptor. The link to the hair worked as a piston - as the volume of the liquid inside the hair reduced under increasing pressure, it disturbed the mechanoreceptor and sent a sensory signal to the crab's brain.

They considered the hair as a cylinder filled with water-like liquid but with incompressible walls. The hair is 2 micrometres (2 millionths of a metre or 2 μm) in diameter and 400 μm long. The volume of the liquid is given by π x $(\text{radius})^2$ x length.

If the crab is exposed to an extra 1 bar of pressure, the volume of the liquid reduces. Because the walls of the hair are incompressible, the diameter of the liquid remains constant - so only the length of the liquid cylinder changes. So, using the compressibility of seawater given above, the length of the cylinder of liquid reduces by 44 x 10^{-6} x 400 = 17600 x 10^{-6} μm (or 17.6 nanometres) – exactly the displacement needed to stimulate the mechanoreceptor of the crab's balancing system.

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