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Water walkers' climbing wall

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Scientists at MIT have found the way tiny insects use molecular forces in the surface of water to zip about like speedboats

David Hu and John Bush have reported in *Nature* this week that insects move at thirty body lengths a second when they strike a pose and move up the slope of water at the edges of a puddle, without even moving their legs!

The water surface

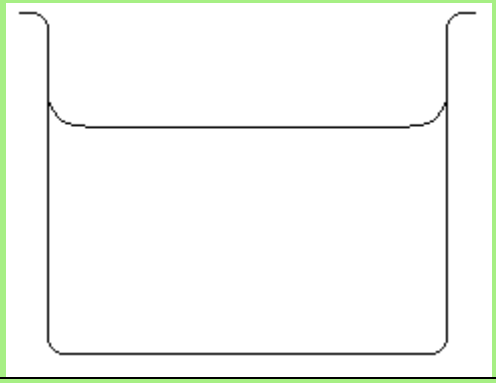
Water molecules consist of two positively charged hydrogen atoms linked to one negatively charged oxygen atom, but the way the atoms are placed is not symmetrical. Thus, at short distances, water molecules show *polarity*, like magnets with North and South poles, and exert powerful electric forces.

When well within a body of water, where other molecules surround a molecule, there is no net effect of these forces. But at the surface, with a mass of water on one side and nothing on the other, the surface molecules feel a strong inward pull. The surface of water is thus like a tight membrane, which resists anything creating a gap in the surface and getting in.

The surface can thus support a reasonable weight and the surface of ponds or puddles supports a whole universe of tiny, millimeter-scale life-forms, which find the water surface as rigid as any other.

Getting their feet wet

This is so long as the insects' feet stay dry. If they got wet and the separation between the feet and the mass of water disappeared, the feet would sink. We may have seen that a drop of water on a glass sheet that is just a little greasy does not spread out, but forms a little bubble, as it tries to pull itself into a ball, its smallest surface. But if the glass is clean, then the forces between the water molecules and the glass are as strong as the force of the water mass and the drop spreads out.



The attraction of glass for water molecules, in fact, is quite strong and we can see that the edge of water in a glass tumbler slopes upwards at the sides of the tumbler. If we dip a thin glass tube into water, the force can raise the water to a considerable height. This *capillary effect* is what helps nutrients flow up the roots of plants and trees.

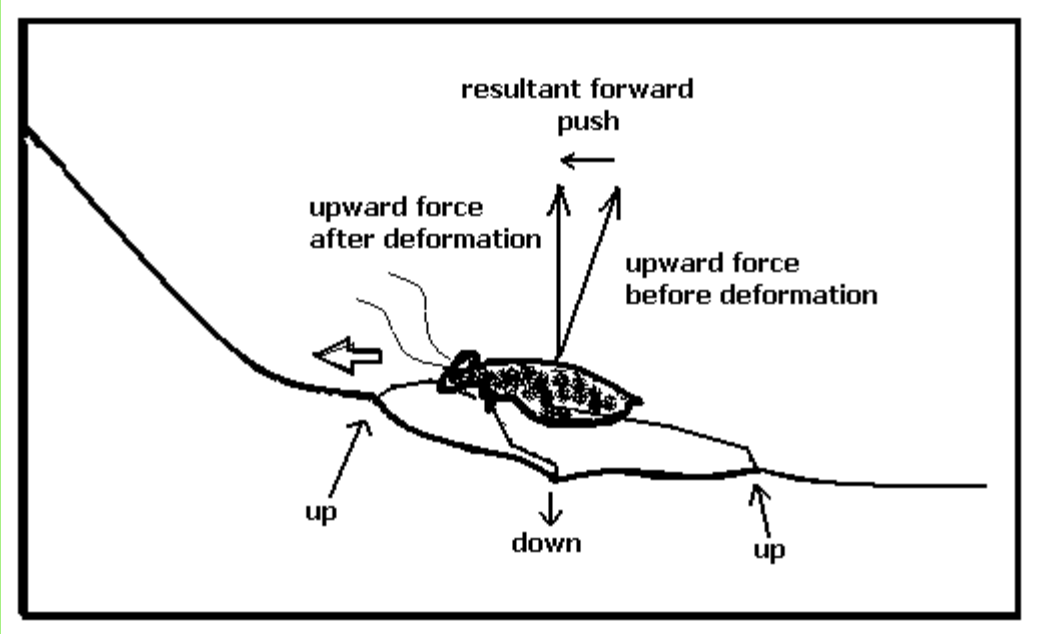
But if the insects' feet are dry, the surface of water does not break and the insects can ride the surface like a sledge over snow, using the fore and rear legs as support and the middle legs as paddles. The insects' secret is that their feet are covered with the fine hair which traps air, to keep the water away from the feet!

The research at MIT

For all the facility of moving over the water surface, tiny insects face a challenge when they come to the edges of the surface. At the edges, the surface slopes upward, like at the side of a glass tumbler. And for a millimeter-scale insect, the slope is high and steep and slippery! Many insects do need to come to dry land. But they may well be trapped on the water by the gradient-barrier at the water edge.

The MIT scientists used high speed video – 500 frames a second – to capture the action. They found that the insects adopt a specific posture along the edges of the pond or puddle and then make capillary forces propel them out of the water! The insect does this by selective wetting of its front and rear feet, while keeping the middle ones dry.

As the insect approaches the sloping edge of the water, it lets down claws that it otherwise keeps drawn in from its front and rear feet. The insect then takes up a stance where the front and rear limbs pull up the surface of water while the middle feet push down. The capillary forces that draw the feet that are wet then add up to a net force that pulls the insect up the slope.



It is a delicate operation, with the limbs to be stretched just so, somewhat like a sailor ‘tacking’ the sails to move against the wind. But the insects manage to reach speeds of around 10 cms a second!

“The normal locomotion of animals is to use muscles to move or raise things”, say Hu and Bush. But with water walking insects, the muscular force is used to deform a surface, to tap molecular forces.