The Open University

Biology: uniformity and diversity

Spiders: Boating spiders

Bob Suter, Vassar College, New York State
The features of spiders that let them walk on water are primarily that they can't get wet. And secondarily that they have hairs on them that also can't get wet. That is the surface of both at the molecular level are hydrophobic. And that means that water is repelled by them.

Narrator
Raft spiders are another species that can walk on water. Their weight is supported by two difference forces.

Bob Suter
The surface tension is really the primary one in this case. The other is buoyancy. Because when she makes a dimple by pushing down in the water, that acts just like a hole of a boat is supported some by the density of the water trying to flow in.

Narrator
Each leg makes its own supporting dimple in the water. So a floating spider is like a tiny multi hulled boat.

Bob Suter
Now how about how we're being propelled, propelled toward the shore. Let's try not to go there. As I pull against these oars, what's happening is that I'm pushing water away from me backwards. And the momentum that I give to the water backwards is the same as the momentum that I give to the boat forwards. That's one of Newton's laws. And actually when you look out there, at the end of an oar, you can see that it's moving the water backwards, the boat goes forwards.

Narrator
For fishing spiders it's not quite so simple. They have very little to push against. Because there's almost no friction between the spider and the water. Yet they still manage to row across what is for them a very slippery surface.

Bob Suter
There have been a variety of models of how that might happen. One is that as the spider's leg moves backwards, if it moves backwards fast enough there's a wave that forms on the leading edge of that leg.

Narrator
As with an oar the leading edge is the side that's pushing against the water.

Bob Suter
Another possibility is that the leg and the dimple that moves with it could themselves act like an oar and really behave the way an oar does.

Narrator
To test the wave theory, Bob uses a leg from a dead spider attached to a sensitive force meter.

Moving water pushing against a fixed leg mimics a moving leg pushing against still water. The end result is the same. As the water speeds up a wave starts to build on the side of the leg that's pushing against the water.

Bob Suter
It turns out a really interesting thing about waves on water, is that there are no waves on the earth on water. If the thing causing the wave is less than 20cm a second. That is waves just don't go less than 20cm a second on the earth. Well, a quick experiment measuring the force on the leg, as the leg moves slowly and then faster and then faster and then faster shows that there's a continuous rise in the force that's generated from zero velocity to say 40cm a second.

Narrator
A slow moving lake still creates a propulsive force. If waves were what mattered, the spider couldn't get under way unless it moved its rowing legs backwards at more than 20cm a second.

Metallised beads and a low par laser reveal that the dimples that support the spider are also the key to rowing. Just like an oar, a moving dimple creates turbulence, and chances the momentum of the water around it.

Bob Suter
Any time you change the velocity of the water you're changing the momentum that the water has. And a change in momentum is the same thing as a force.

Narrator
The momentum the moving leg gives to the water backwards is the same as the momentum that the water gives to the spider forwards. It's the viscous drag of the water tugging at the leg and dimple that provides the resistance the spider needs to propel itself forward.

High-speed video reveals that a rowing spider is like a four-oared boat.

Bob Suter
When a spider wants to start moving by rowing, it picks it legs up, moves them forward, then pushes them into the water surface, making this thing that I keep calling a dimple. And it's that deep dimple then that gets moved across the water surface and constitutes the same thing as the paddle part of an oar. That is the wide part of an oar. There we go. So now watch the dimples change shape. Push down, push down, go off screen. Let's look at that one more time. And watch both sides now. Third set of legs now. Second set of legs next. So each time it takes a stroke like that, it's pushing its legs down into the water just a bit. Now enough to break through the surface tension. Just enough to make this dimple. Which is the equivalent of taking something that's long and skinny and pushing it down into the water surface and making it into something that's oar shaped. Because it goes from being a skinny leg to being this dimple. Pushes the dimple back, makes the spider go forward.

Narrator
But rowing still has its drawbacks.

Bob Suter
When a spider is rowing then it's got serious problems as to how fast it can go. It's partly because it's touching the water on part of the return stroke. And partly because it can't move its legs very fast backwards and still have the dimple intact.

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