Bio Focus

Miniature shock waves in water droplets keep birds, butterflies, leaves dry

There are many materials in nature with more impressive properties than scientists are currently capable of engineering, such as superhydrophobicity, the ability to repel water. Superhydrophobic materials are useful for keeping roads dry when it rains or for making containers from which all the liquid contents can be extracted. Superhydrophobic materials in nature include the wings of birds and insects, both of which can fly in rain without becoming waterlogged, as well as the surfaces of certain leaves. Recently, a group of bioengineers led by Sunghwan Jung at Cornell University studied the mechanisms by which bird feathers, butterfly wings, and leaves repel water. They found that raindrops are not just being repelled by these surfaces, but rather they are being shattered.

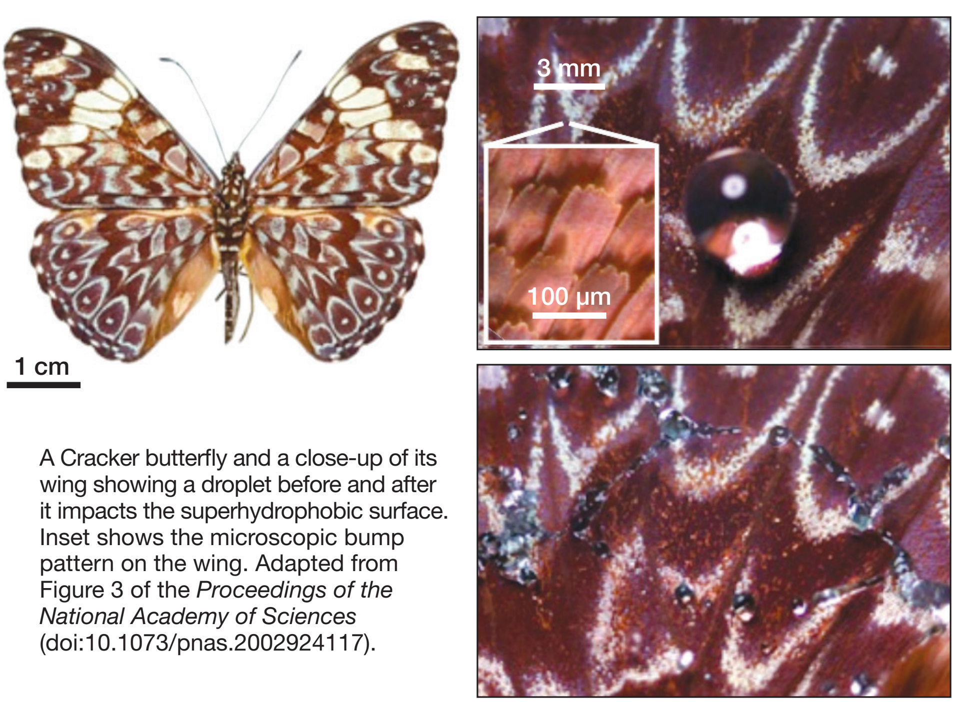
As reported in a recent issue of the *Proceedings of the National Academy of Sciences* (doi:10.1073/pnas.2002924117), their experiments involved releasing droplets of varying speeds and diameters onto the feather of a Northern Gannet (a white seabird), the wing of a Cracker butterfly (see Figure), and the leaf of a Katsura plant (a broad-leafed tree found in Japan and China), and filming the droplet impact with a high-speed camera. Normally when a droplet hits a surface, it flattens temporarily and bounces back up, depositing some water in the process. In the case of the superhydrophobic materials, the researchers observed that waves form in the flattened droplet, propagating outward from the center of the impact with similar behavior to a shock wave. The flattened, wavy droplet eventually forms holes, which expand until the droplet loses cohesion, breaking up into many smaller droplets that are expelled from the surface. Because the droplets after breakup leave the surface after much less time than they would on a regular surface, significantly less water is retained on the surface, leaving it dry.

The researchers hypothesized that the sources of the wave-induced droplet breakup are microscopic bumps found on each surface. Although bird feathers, insect wings, and leaves all have very different properties, they are covered in bumps that are tens to hundreds of micrometers wide, and these bumps can cause ripples to form as droplets spread over them, inducing the observed surface waves. To test this hypothesis, the researchers created artificial surfaces with similarly sized periodic bumps and repeated the droplet breakup experiment. Their observations were similar to those seen in the initial experiments. They concluded that the microscopic bumps on the surfaces of superhydrophobic biological surfaces led to the physical phenomenon of shock wave-induced drop breakup, allowing organisms to stay both dry and warm in the rain. Because heat transfers faster through water than air, getting wet can increase the risk of hypothermia, and reducing the contact time of water droplets allows these organisms to stay warm as well as dry.

"In the last 20 years, many superhydrophobic coatings have been developed by mimicking natural water-repellent surfaces, such as the well-known lotus leaves," says Philippe Bourrianne, a researcher at the Massachusetts Institute of Technology who studies fluid dynamics and superhydrophobic surfaces. "Kim et al. confirm and amplify such observation by adding complexity in the defects pattern leading to dramatic drop fragmentation during the impact. The elegance of their study relies on the fine comparison between synthetic solids and their natural counterpart, in another convincing demonstration of the ability of nature to inspire scientists."

This research has provided insight about how flying organisms reduce their risk of hypothermia and maintain flight stability when wet, and in the future, the lessons learned from studying droplets on biological surfaces may be used to engineer better moisture-proof materials.

Alex Klotz



A Cracker butterfly and a close-up of its wing showing a droplet before and after it impacts the superhydrophobic surface. Inset shows the microscopic bump pattern on the wing. Adapted from Figure 3 of the *Proceedings of the National Academy of Sciences* (doi:10.1073/pnas.2002924117).

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