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How Does Fur Keep Animals Warm in Cold Water?

MIT researchers have studied the entrainment of air in hairy surfaces and the water-repellant properties of fur and feathers, which may inspire the design of novel textiles -- like hairy wet suits

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WASHINGTON, D.C., November 23, 2015 -- Rather than relying on a thick layer of body fat for insulation as many aquatic mammals do, some seabirds and semiaquatic mammals such as fur seals and otters trap a layer of air in their feathers and furs for thermal insulation against the ice cold drink. While scientists have extensively studied the influence of chemistry and surface roughness on water-repellency of textured surfaces such as skin, little is known about the role of larger flexible objects such as hair, a common feature of the skin of semiaquatic insects, spiders and aquatic mammals.

Now a team of researchers from the Massachusetts Institute of Technology has experimentally studied the trapping of air in hairy surfaces and the water-repellent properties of undeformable hairy textures, which is key for animals' thermal regulation. The results may also inspire the design of novel textiles with advanced water-repellant features. The researchers will present the study at the 68th Annual Meeting of the American Physical Society's Division of Fluid Dynamics, being held Nov. 22-24, 2015 in Boston.

"We found that the geometric properties (such as hair length and hair spacing) of hairy surfaces play a significant role in the surface's water-repellent properties," said Alice Nasto, the primary researcher and a doctoral student of Mechanical Engineering at MIT. "The denser and the longer the hairs are, the dryer or the more water-repellent the hairy surface is. Since the thermal conductivity of air is much smaller than that of water, trapping a layer of air in hairy surfaces reduces thermal conduction, which keeps animals warm in cold water," Nasto said.

Most earlier research work on water-repellant surfaces has been focused on nano- and micro-scale materials. Now for the first time, the team has demonstrated that larger-scale materials (at the scale of millimeters or centimeters), such as fur, can produce similar water-repellant properties. Such materials are likely to be less challenging to fabricate in large quantities than their smaller-scale counterparts.

"We hope that our research could inform technological advances and inspire the design of new textiles with advanced water-repellant features, such as novel wet suits, in which staying warm and dry is paramount," Nasto noted.

Using a combination of model experiments and theory, Nasto's team explored and explained the dynamics of hairy surface air entrainment. In the model experiment, the researchers fabricated hairy surfaces using laser cut molds to cast samples with a soft silicone rubber called Polydimethylsiloxane (PDMS). To study how water interacts with the hairy surfaces under flow, the researchers submerged samples into a bath of liquid using a motorized stage, an apparatus capable of plunging the samples into liquids at a precise speed.

According to Nasto, when the hairy surface is submerged into the liquid, the liquid penetrates between hairs due to the hydrostatic pressure that arises from the weight of the fluid above the hairy surface. This penetration is resisted by the viscous resistance to flow, which delays the depletion of the air layer.

To examine how the hair properties (such as hair length and hair spacing) affect the wettability of the surface, the researchers experimented with various parameters including hair length, hair spacing, fluid viscosity and plunging speeds, finding that the geometry of the hairy surface plays a significant role. In particular, the denser the hair array, the more water repellant the surface is.

The team also found the hairy texture entrains a much larger quantity of air than that of the classical dip coating called the Landau-Levich coating, thereby creating an "augmented version" of dip coating. However, unlike classic Landau-Levich, the dominant balance at orders of length relevant to aquatic animal hair is between viscous stresses and hydrostatic pressure. "We hope these findings could also potentially inform advances in coating technology," said Nasto.

The team's model successfully predicted the dynamic properties of the undeformable hairy textures. However, since the fur or feathers of many animals in real world are relatively long and deformable, the researchers' next step is to study flexible hair-like features.

"Might flexibility of the hairs allow for air to be trapped beyond a critical depth? How does this 'sealing depth' depend on the density, geometry and flexibility of the hairs? These are all remaining questions for the next steps of our research," Nasto said.

Presentation #L28.2, "Keeping warm with fur in cold water: entrainment of air in hairy surfaces," is authored by Alice Nasto, Marianne Regli, Pierre-Thomas Brun, Christophe Clanet and Anette Hosoi. It will be at 4:18 p.m. on Monday, Nov. 23, 2015 in Room 309 of the Hynes Convention Center in Boston.
ABSTRACT: http://meetings.aps.org/Meeting/DFD15/Session/L28.2

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MEETING INFORMATION

The 68th Annual Division of Fluid Dynamics Meeting will be held at Hynes Convention Center in Boston, Mass. from Nov. 22-24, 2015. More meeting information: https://apsdfd2015.mit.edu/

REGISTERING AS PRESS

Any journalist, full-time or freelance, may attend the conference free of charge. Please email: <jbardi@aip.org> and <dfdmedia@aps.org> and include "DFD Press Registration" in the subject line.

ON-SITE AND ONLINE PRESS ROOMS

Workspace will be provided on-site during the meeting. The week before the meeting, news, videos and graphics will be made available on the Virtual Press Room: http://www.aps.org/units/dfd/pressroom

LIVE MEDIA EVENT

A press briefing featuring a selection of newsworthy research talks will be streamed live from the conference at 1:00 p.m. ET on Monday, Nov. 23. For more information, email jbardi@aip.org

ABOUT THE APS DIVISION OF FLUID DYNAMICS

The Division of Fluid Dynamics (DFD) of the American Physical Society (APS) exists for the advancement and diffusion of knowledge of the physics of fluids with special emphasis on the dynamical theories of the liquid, plastic and gaseous states of matter under all conditions of temperature and pressure. DFD Website: http://www.aps.org/units/dfd/index.cfm

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Photo Caption: Idealized model of furs, used in experiments emulating the water-repellant nature of semi-aquatic mammal fur (i.e fur seals and otters).

Photo Credit: Felice Frankel

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