Skoltech

Press release

Skoltech,

Moscow, August 29, 2025

Unusual microbug anatomy shown to optimize wing weight

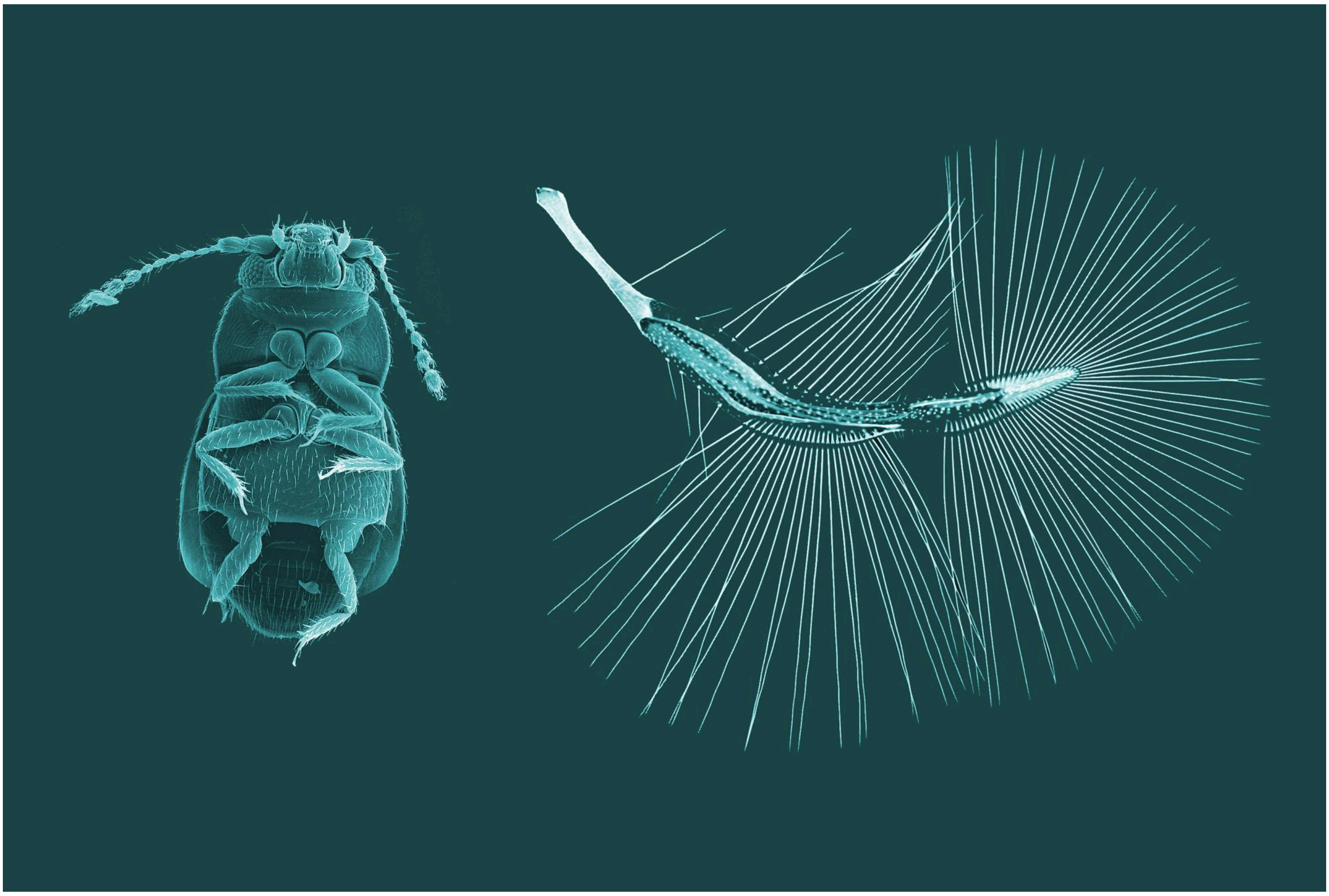

Image. Colored photo of a Nephanes titan bug and its bristled wing. Credit: Dmitry Kolomenskiy et al./PNAS

Skoltech and MSU scientists have uncovered the advantage gained by microscopic bugs from their featherlike wings that are unlike those of dragonflies, bees, mosquitoes and other familiar insects. A wing largely made up of bristles that stand somewhat apart from each other is lighter than the conventional membranous wing that comes in one piece. This advantage is crucial for microinsects, which are strongly affected by air resistance. They overcome it with wing motions reminiscent of those made by oars in rowing. The findings could come in handy when the miniaturization of insect-sized unmanned aerial vehicles reaches these truly tiny, submillimeter dimensions. Backed by a Russian Science Foundation grant, the study came out in the journal *PNAS* and appeared on the cover of the issue.

Small-scale drones that mimic some of the features observed in insects so far remain a lab curiosity, but with further advances in technology they could prove useful for collecting information where compact size, unobtrusiveness, or stealth are of the essence. Someday swarms of insect-inspired drones could become viable for search-and-rescue operations, infrastructure monitoring in tight spaces, such as in elevator or ventilation shafts, observing wild animals in nature, or gathering intel.

The smallest controllable drones are the University of Pennsylvania's Piccolissimo (2016), which measures 2.5 centimeters and weighs 2.5 grams, Harvard's 3-centimeter RoboBee (2012), and the recently unveiled 1.5-centimeter, 0.3-gram mosquito drone (2025) created at China's National University of Defense Technology. The latter two rely on winged flight. Propellers, notably, tend to create more noise and cause greater damage in the event of a collision.

What hampers further miniaturization apart from the obvious challenges with battery size is the mechanics of flight itself. Taking microbugs as an example, on such a small scale, the forces of viscous air friction turn out to be comparable to the forces of inertia of a flying insect. It therefore becomes more difficult for these flyers to "wade" through the air than for larger creatures. Accordingly, the wings of the smallest insects are arranged in an unexpected way.

"It has long been known that the size of about a millimeter presents something of a division line, where larger insects have familiar membranous wings and many of the smaller-sized species employ wings consisting of separate bristles with intervals between them. It was unclear why," said the lead author of the study, Assistant Professor **Dmitry Kolomenskiy** of Skoltech Materials.

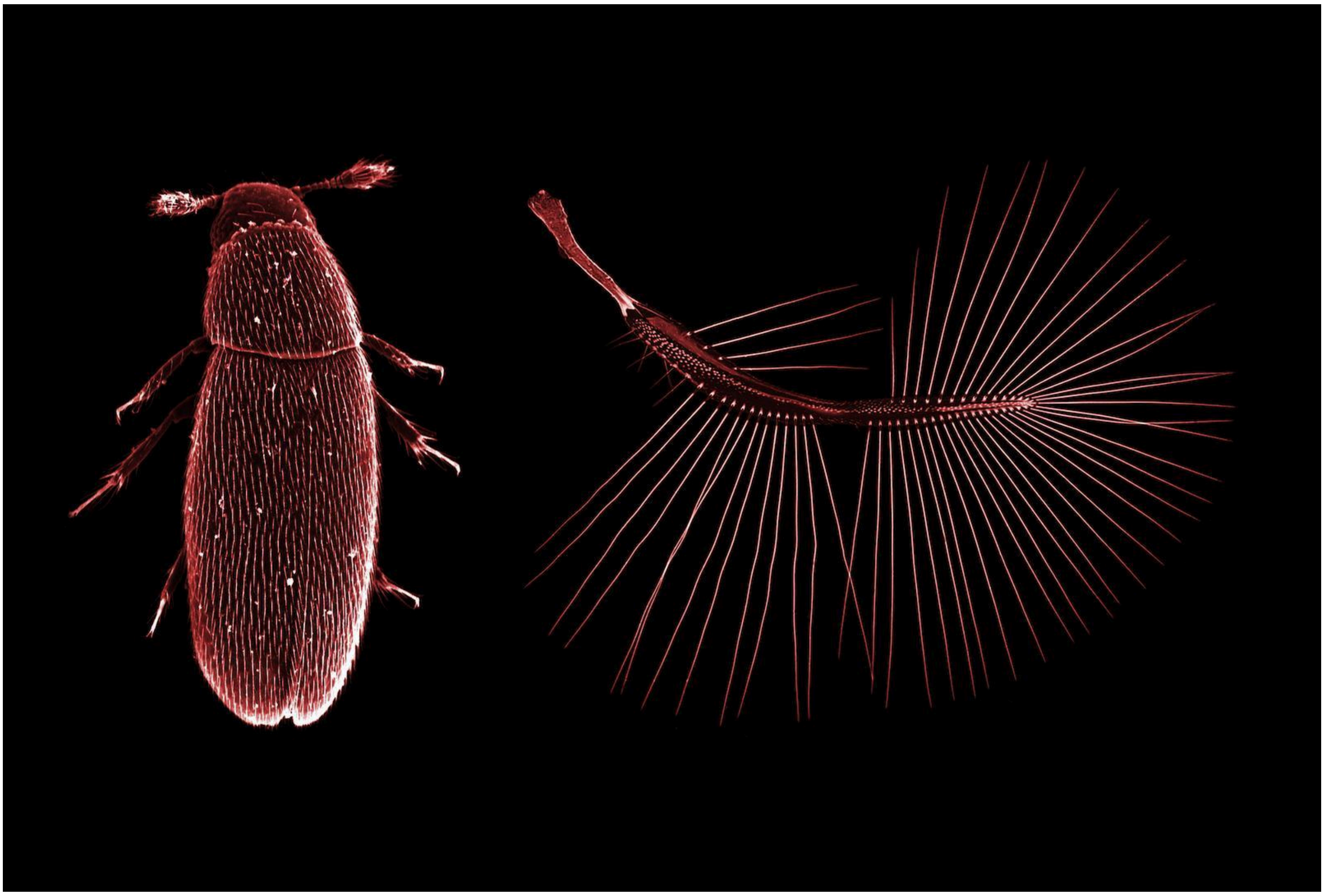

Image. Colored photo of a Primorskiella bug and its bristled wing. Credit: Alexey Polilov and Sergey Farisenkov/Lomonosov Moscow State University

The matter of why microinsects use featherlike wings is of more than theoretical importance. The way natural selection works, not any solution developed by flyers in nature is worth borrowing for drone design. Until wing shape has been tied to flight advantages, there always remains the possibility that this particular piece of anatomy evolved for attracting other insects, propagating odors, or for any number of other benefits useless to a drone.

The authors of the Skoltech-MSU study collected data on a dozen related species of beetles of various sizes, analyzed the structure of their wings, and confirmed that the presence of featherlike wings is well explained by mechanical considerations. Not surprisingly, this structure minimizes wing mass: If you took a plastic ruler and eliminated most of the material from it, leaving only the first millimeter in each centimeter untouched, such a comb-shaped structure would clearly reduce weight. It would also be useless for flying in the large-scale world of birds or even mosquitoes, of course, but the design does work for microinsects.

“We think the lengths and the diameters of the bristles in the wing are such as to prevent excessive bending. And the intervals between the bristles are maximized, while ensuring that they remain close enough together to prevent the flow of air through the wing during flight. Specifically, the intervals are about 10 times the diameter of the bristles. A further expansion of the intervals would not be feasible for flying, and positioning the bristles closer together would make the wing unnecessarily heavier,” study co-author Senior Research Scientist **Petr Petrov** from Lomonosov Moscow State University explained.

According to the researchers, as engineers grapple with the issue of battery size and other technical obstacles preventing the further miniaturization of insectlike drones, structures imitating bristled wings could find applications in pumping fluids through ultrathin tubes and filtering microscopic particles. Also, certain advanced materials could theoretically make the bristled wing architecture feasible on a somewhat larger scale than in nature.

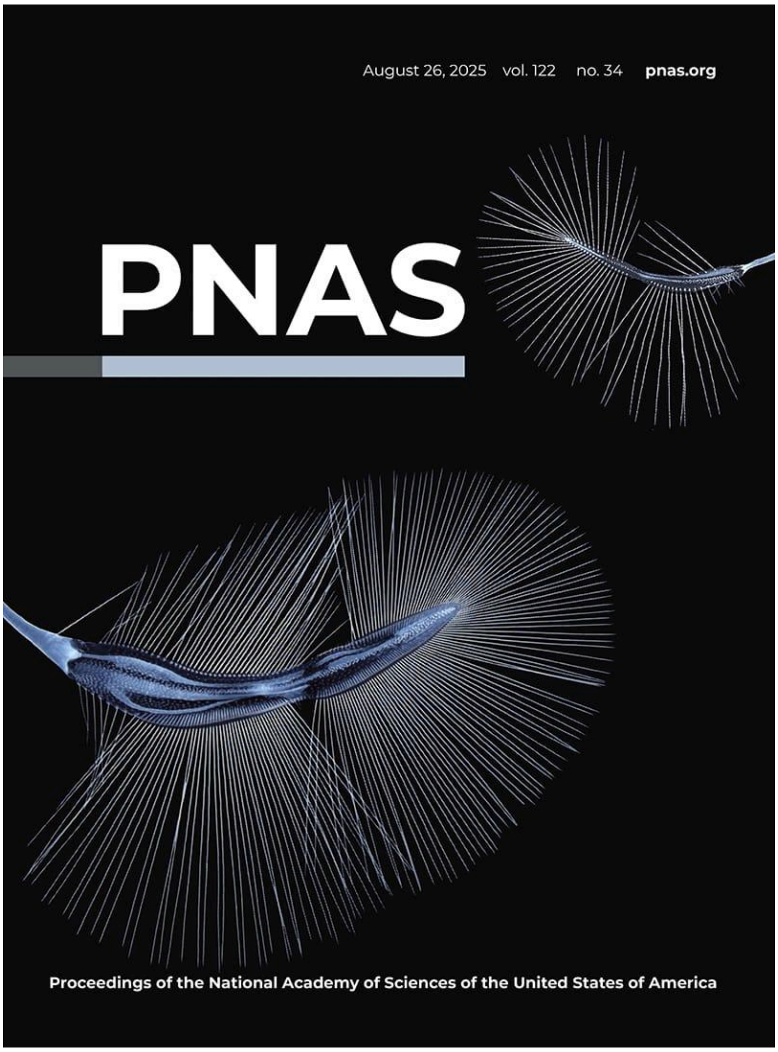

Image. Microinsect wing photos from the Skoltech-MSU study appearing on the cover of the Proceedings of the National Academy of Sciences issue that featured the study

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