From the fly foot to the snake skin: adhesive and frictional phenomena on animal surfaces

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Our research includes approaches of several disciplines: zoology, botany, structural biology, biomechanics, physics, and materials science. Using a wide variety of methods, we study mechanical systems and materials evolved in biological evolution. The research is mainly focused on biological surfaces specialised for enhancement or reduction of frictional or/and adhesive forces. Such surfaces are composed of highly-specialised materials and bear surface structures optimised for a particular function. Some of these systems employ secretory substances, modulating forces in the contact area [1-5]. The first example in the lecture is biological attachment systems that demonstrate interesting adhesion and friction properties and high reliability of contact. Experimental studies show that the effective elastic moduli of fiber arrays and spatula-like terminal elements in these systems are low, and this is of fundamental importance for enhancement of contact forces on rough substrata and for an increased tolerance to defects at the level of individual contacts. Based on the broad structural and experimental studies of biological attachment devices, the bioinspired reversible attachment devices were developed, which adhesive and frictional properties were characterised using variety of measurement techniques and compared with the flat surface made of the same polymer. The second example of tribologically interesting biological surface is the snake belly surface, which owing to the lack of extremities in snakes, is in almost continuous contact with the substrate. From a tribology point of view, their ventral skin surface has to fulfill two opposite functions: (1) to support body propulsion during locomotion by generating high friction in contact with the substrate, and (2) to save energy and reduce skin material abrasion by generating low friction in forward-sliding along the substrate. The second part of the lecture summarizes recent activities in studying anisotropic frictional properties of the snake skin and mechanisms of friction and wear reduction. Furthermore, possible ways to biomimetics of tribologically-optimized surfaces inspired by the snake skin are discussed.

Books for further reading: [1] Gorb, S. N. (2001) *Attachment Devices of Insect Cuticle*. Dordrecht, Boston, London: Kluwer Academic Publishers. 305 pp.; [2] Scherge, M. and Gorb, S.N. (2001) *Biological Micro- and Nanotribology*. Berlin et al.: Springer. 300 pp.; [3] Gorb, S.N. (Ed.) (2009) *Functional Surfaces in Biology II: Adhesion Related Phenomena.* Berlin et al.: Springer. 270 pp.; [4] Wolf, J.O. and Gorb, S.N. (Eds.) (2016) *Attachment Structures and Adhesive Secretions in Arachnids.* Berlin et al.: Springer. 184 pp.; [5] Gorb, S. N. and Gorb, E. V. (Eds.) (2017) *Functional Surfaces in Biology III: Diversity of the Physical Phenomena.* Springer. 250 pp.

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Stanislav Gorb is a group leader at the Zoological Institute of the University of Kiel, Germany. He received his PhD degree in zoology and entomology at the Schmalhausen Institute of Zoology of the Ukrainian Academy of Sciences in Kiev, Ukraine. Gorb was a postdoctoral researcher at the University of Vienna, Austria, a research assistant at University of Jena, a group leader at the Max Planck Institutes for Developmental Biology in Tübingen and for Metals Research in Stuttgart, Germany.

Gorb's research focuses on morphology, structure, biomechanics, and evolution of surface-related functional systems in animals and plants, as well as the development of biologically inspired technological surfaces and systems. He received the Schlossmann Award (1995), Science Award of the Donors' Association for the Promotion of Science in Germany (2005), International Forum Design Gold Award (2011); Materialica "Best of" Award (2011), Transfer-Price of Schleswig-Holstein (2011) and was the BioFuture Competition winner for his works on biological attachment devices (1998). Gorb has authored three books; more than 300 papers in peer-reviewed journals; and four patents. He is corresponding member of Academy of the Science and Literature Mainz (since 2010), Germany and member of the National Academy of Sciences Leopoldina, Germany (since 2011).

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VIDEOS:

TED talk:

https://www.youtube.com/watch?v=VCKNEoJpXUU

Attachment systems (BBC):

https://www.bbc.com/news/av/science-environment-20220708/sticky-tape-inspired-by-beetles

Snake skin (Beilstein):

http://www.beilstein.tv/video/snake-skin-as-functional-biological-material-abrasion-properties/