# From the insect adhesion to snake slithering: tribology and contact mechanics aspects of biological surfaces

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Different surfaces have been evolved several times independently in animal evolution, in order to attach to or/and move along various substrates. Some of these structures have been structurally studied, but their functional mechanisms, based on the interplay between ultrastructure, material properties and physical interactions, remained unresolved until recently. In my presentation, I will discuss these surfaces and materials, as well as their physical properties and show how they together contribute to their function. Conceptually, it is a trial to make a "dissection" of the biological functional system at different levels of its morphological organization linked to specific tribological properties.

**Keywords (from 3 to 5 max):** biotribology, biomechanics, locomotion, attachment

## 1. Introduction

For attachment and propulsion generation during locomotion, different surface adaptations have been evolved in the course of animal evolution. Some of these structures have been well structurally studied, but their functional mechanisms, based on the interplay between the ultrastructure, material properties and physical interactions remained unresolved until recently. The reason for this is that such research requires approaches of several disciplines: zoology, structural biology, biomechanics, physics, and surface science. In addition to the use of a wide variety of microscopy techniques, we established a set of experimental designs that allows obtaining information about adhesive and frictional properties, as well as local and global mechanical properties of materials of animal attachment devices (part 1) and belly surface of the snake skin (part 2), in order to understand tribological mechanisms behind these biological surfaces. In my presentation, I will discuss these surfaces, as well as their physical properties and show how they together contribute to the function. Conceptually, it is a trial to make a kind of "dissection" of the biological functional system at different levels of its morphological organization linked to specific properties.

## 2. Attachment: flies, spiders, geckos on the ceiling

In order to show different functional principles, we experimentally tested about 600 different locomotory attachment devices on legs of insects (Figure 1), spiders and geckos and tried to outline general rules of the interrelationship between their structure and function. Since these broad comparative studies include a wide variety of organisms, some questions about the evolution of these systems could be resolved [1-3].

## 3. Snake skin tribology

Owing to the lack of extremities, the ventral body side of snakes is in almost continuous contact with the substrate. In spite of this, snakes are one of the most successful animal groups in occupying various ecological niches. 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 reduce skin material abrasion by generating low friction in forward sliding along the substrate. Here I summarize recent activities in studying anisotropic frictional properties of the snake skin and mechanisms of friction and wear reduction [3]. These mechanisms are based on specialized surface microstructure, material properties and surface chemistry of the skin. Furthermore, possible ways to biomimetics of tribologically-optimised surfaces inspired by the snake skin are discussed.

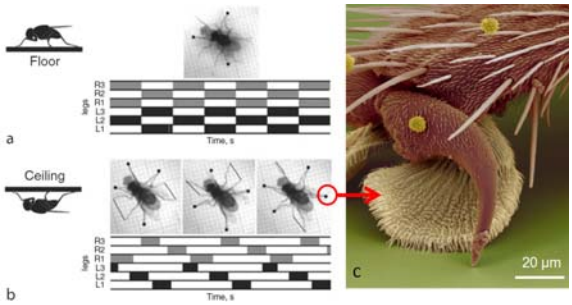


Figure 1: (a, b) Gait pattern of the fly on the floor and on the ceiling. Please, note an additional contact point, when running on the ceiling. (c) SEM image of structures responsible for contact formation and generation of friction and adhesion.

## 4. References

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