

Pursuing Biology's Responses to Friction, Lubrication, and Wear

Biological Micro- and Nanotribology: Nature's Solutions

▶ Matthias Scherge and Stanislav N. Gorb
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Reviewed by Howard A. Stone

The Greek word *tribos*, meaning "to rub," is the root of tribology, the scientific and engineering studies of friction, wear, and lubrication. Although the subject can be traced to Leonardo da Vinci in the 15th century, the first quantitative investigations were those of Guillaume Amontons in the 17th century and Charles August Coulomb in the 18th century. Indeed, the law of static friction—that the frictional force is proportional to the normal force with a proportionality (friction) coefficient independent of the (macroscopic) area of contact between the surfaces—is known as the Amontons–Coulomb law, although it was apparently known to da Vinci.

Of course, we now know much more about the origin of the frictional force, the importance of asperities at points of contact, the role of a lubricating film, and the increase in frictional resistance as a lubricating film becomes so thin that molecular ordering becomes possible. Thus, modern tribological investigations focus on the mechanical properties of very thin films, the effect of chemical modification of the surfaces, and other features for reducing friction or controlling adhesion. The same principles act in the joints of animals and in the mechanisms that animals of all kinds use for adhesion and the reduction of friction. Consequently, because of the obvious success of biology in solving these problems, and the recent advances in the fabrication of mechanical parts at micro- and nanometer

length scales, considerable interest has developed among tribologists in using biological structures as a guide to mechanical design.

Matthias Scherge is a researcher in microtribology at the Technical University of Ilmenau in Germany; Stanislav N. Gorb is a researcher in biomechanics, with special emphasis on friction, at the Max Planck Institute for Developmental Biology. In *Biological Micro- and Nanotribology* they have provided a marvelous introduction to and survey of the distinct disciplines of tribology from the standpoints of the mechanics of thin films and the structure and function of biological mechanisms for controlling frictional characteristics, as well as the potential interrelation of the two subjects. Although there are many books about tribology, I am not aware of any book that discusses the tribological aspects of animal mechanics, nor am I aware of another book that discusses the mechanical and biological aspects of tribology in a manner that will help one discipline learn from the other.

Their book is a valuable addition to the literature on the micromechanics of very thin films with emphasis on friction, adhesion, and lubrication. The discussion is exceedingly well organized and well illustrated; many examples are provided from biological systems; and the extensive reference list—more than 700 entries—is up-to-date. Overall, the authors have succeeded admirably in providing an informative and thorough text, the publisher has produced an attractive book, and readers will find much material of interest, especially because recent advances in micro- and nanodesign are stimulating scientific and technological interest in the mechanics of thin lubricating films.

There are six major sections to the presentation. After a short introduction, the first two sections cover mechanical concepts and discuss roughness, stress relaxation, contact mechanics, adhesion, friction, and lubrication. (I was not aware of the use of local vibration to reduce friction.) The third main theme focuses on friction and adhesion in plants and fish, while the fourth is focused on

insects. The last two main sections cover experimental techniques for measurements of thin films and nanoscale characterization. The book concludes with recent results obtained by the authors for adhesion and friction of the attachment pads of both living and dead insects.

Many sections end with short summaries of the major points covered, though, in a few cases, the summaries are less than representative of the discussion given. This is a minor gripe; my only other complaint was the less than adequate, and somewhat out of place, discussion of laminar and turbulent flow over the sculpted, compliant skins of some swimming organisms. Many examples are given of friction and adhesion in biological systems (the origin of Velcro™ based on observations of the use of hooks by plants is one interesting sidebar). Plants, fish, birds, insects, and lizards are all mentioned and discussed.

The fine illustrations make it possible to understand similarities and differences among species and to grasp the techniques Nature has developed to control adhesion and friction. There does seem to be an underlying assumption that the biological systems are optimized, though it seems to me that this may be a good approximation but is unlikely to be an accurate characterization of all systems.

As an added benefit, the authors provide perspective on partly resolved or poorly understood problems and even on those that are as yet unstudied. I was glad to have the opportunity to study this unique book, and I recommend it to anyone who works in the area of micromechanics of friction and lubrication. It offers a useful survey and provides many interesting discussions of biological systems.

The Coming of Materials Science

▶ Robert W. Cahn
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If one takes the broadest view, a significant fraction of modern-day physicists

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