Book review

Attachment devices of insect cuticle

Gorb, S. 2001: Attachment Devices of Insect Cuticle. Kluwer Academic Publishers, Dordrecht/Boston/London. 305 pages. ISBN 0-7923-7153-4.

How does a fly manage to walk on the ceiling or on a glass-window surface? These are questions that Dr. Stanislav Gorb deals with in his book "Attachment Devices of Insect Cuticle".

The structure of the book is logical and systematic, starting with the basal physics of attachment (friction, adhesion, surface texture, and liquid films), followed by various aspects of interactions between bodies in contact, and ending with ecological implications of changing surface textures and constructions.

In the first chapters, Gorb recollects our basic knowledge of the insect cuticle: its design and mechanical properties, and continues by classifying cuticular protuberances like acanthae and microtrichia. He gives examples of their universal functions: in body coloration pattern, oxygen retention, thermoregulation, aerodynamic-active surfaces, sound generation, defence, grooming and food grinding.

After that, attention is directed to the principles of cuticular attachment in Arthropoda, which the author divides into the eight fundamental classes: hooks, locks/snaps, clamps, spacers, suckers, expansion anchors, adhesive secretions and friction. They are exemplified with scanning electron micrographs and line drawings.

He then discusses the frictional systems that are found in Arthropoda. Frictional systems are parasite-host or predator-prey associations, attachments during copulation or attachment to the substratum. In the latter part, comparisions with vertebrates are drawn, exemplified by the ability of lizards to hang on the ceiling or to climb on vertical glass surfaces. Interlocking of body parts, e.g. coiling of the proboscis in Lepidoptera, is explained by high friction between processes that act like pressing the hairs of two stiff brushes together. Protuberances are often directed in the way that ensures an optimal function. In the ovipositor valvulae, comb-like structures angled posteriorly prevent eggs from moving in the wrong direction, on the body surface, angled outgrowths provide an ability for directional motion within a substratum with high viscosity (dung, mud, or living tissues).

The head-arresting system in dragonflies and damselflies is described in detail in a chapter with explanations of the skeleton-muscle organization and functional significance of the arrester.

Frictional surfaces adapted to affix parts of the body, such as tarsi or antenna, and the design of the insect unguitractor apparatus on the pretarsus is the theme of another chapter. Here are also described the self-folding armored membranes in Diptera. These are found in six families and exist in joints between basal segments of legs, and in transitional areas between segments. The author found at least six types of microstructures of these membranes and the construction makes the membrane possible to fold in only certain ways. Locking devices are also found e.g. in syrphid flies that position the legs in certain ways during flight.

Wing-locking devices are dealt with in a special chapter. Such microstructures, microtrichia fields, are described from hind wings, elytrae, thorax, and abdomen in Coleoptera; tegmina and metanotum in Dermaptera; thorax and alulae in Diptera; scutellum in Hymenoptera; and forewings of Heteroptera.

Attachment pads, the devices used by the insect for walking on smooth surfaces, are either hairy or smooth. Dr. Gorb gives an overview of the external tarsal morphology from all orders and describes the surface characteristics of the cuticle protuberances. We learn that flies use four different movements of the foot to detach it during walking, namely shifting, twisting, rotation and pulling. High-speed recordings show these findings. Did you know that flies have three feet in contact with the surface when they walk on vertical or horizontal surfaces, while they have four while walking upside down on the ceiling? Different types of setae on the pulvilli have evolved, depending of the size of the animal. The heavier the insect, the larger the setal tip.

The dependence of secretion in frictional systems is also of great interest. Spirally oriented pore canals seem to assist in the distribution of these substances onto the substratum. Dr. Gorb shows that flies can make footprints on glass surfaces. The secretions seem to make the setae act as suckers on smooth surfaces.

After discussing the sensory organs that register the position of the different body parts, the evolution of the frictional systems is clarified, especially that of the odonate head arrester, the ovipositor coverage, and the wing-locking devices. Using a cladogram, the author also tries to fit the evolution of pad structures into hexapod phylogeny.

Ecological implications are also discussed, and comparisons made with host-plant surfaces. There certainly has been coevolution between plants and insects also in this matter, which for instance has caused the plants to evolve "dusty" surfaces to prevent insects from walking on them. Different examples of plant surface waxes are shown, patterns that apparently function in the mechanical interaction between plants and insects.

The last chapter is titled "Nature's design as a basis for biomimetics". Parallels between natural surface systems and man-made inventions of fasteners are discussed, for instance Velcro fasteners of different types and car tires.

Despite its minor inconsistencies, the book gives a good overview of where we stand today in the questions of arthropod attachments. After reading this book, you will understand much more of the flies' problems of walking on the ceiling. It is not just to do it; you must also know exactly how to lift your feet and how to detach them.

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