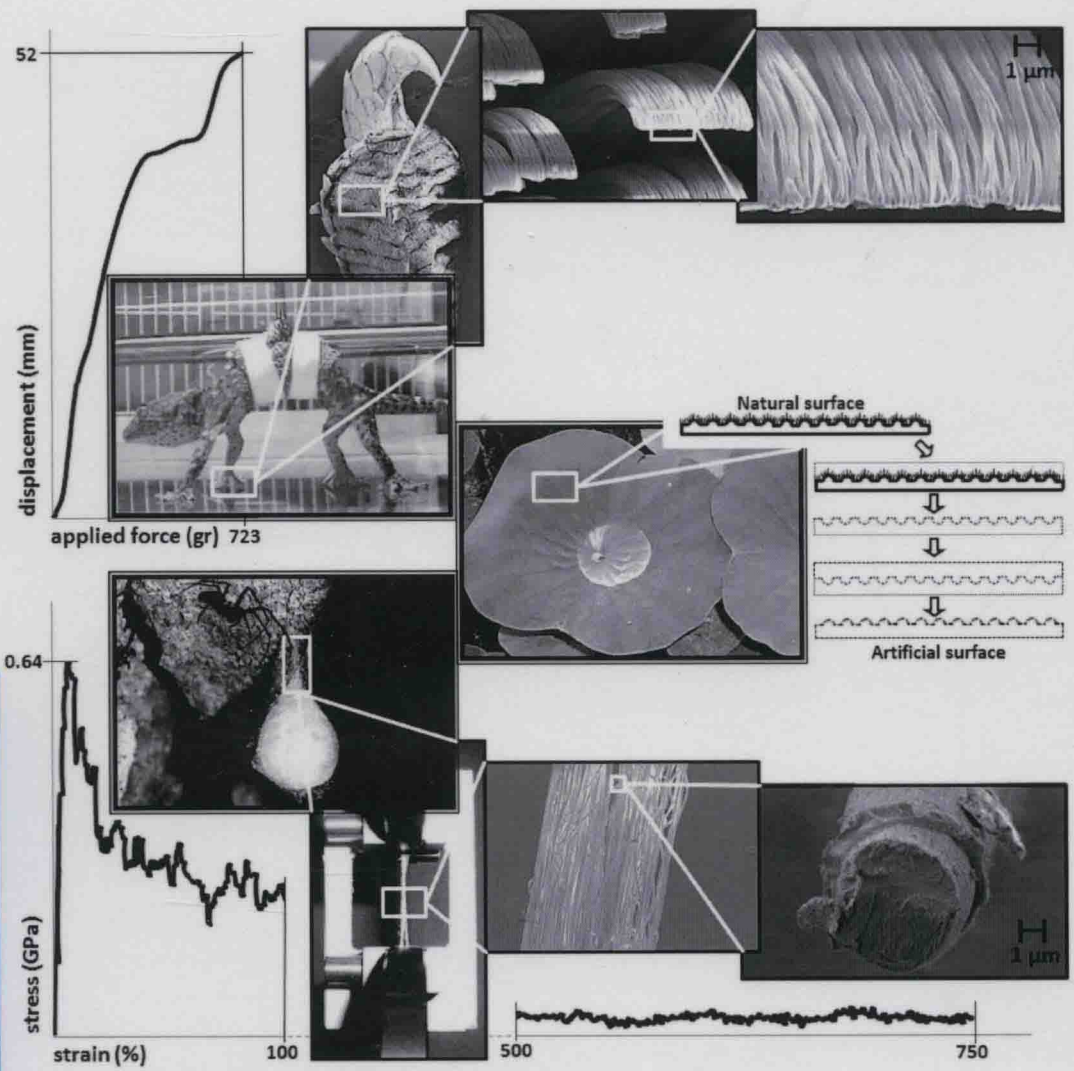
An Experimental Study on Adhesive or Anti-adhesive, Bio-inspired Experimental Nanomaterials

Emiliano Lepore, Nicola Pugno



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Emiliano **Lepore**
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Dedicated to
small things which become great

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I am very thankful to my mother Marilena and my father Vittorino who, when I was a child, taught me how only honesty and respect for the others are the two milestones in human relationships, thus also in work. Unfortunately, these are not common human values.

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Figure 1.10 Interpretation of experimental results for adhesion tests on various roughness of PMMA surfaces. (A) Setae (represented in blue) and sub-hierarchical structures (spatulae) can adapt well on virgin PMMA; (B) The adhesion on PMMA2400 is better because of the higher number of spatulae-substrate interactions; (C) On PMMA800, only partial contact interactions are achieved.

Figure 2.1 Spider and gecko feet showed by SEM (Zeiss EVO 50). The Tokay gecko (Fig.2.1F) attachment system is characterized by hierarchical hairy structures, which start with macroscopic lamellae (soft ridges ~1 mm in length, Fig.2.1H) and branches into setae (30-130 μm in length and 5-10 μm in diameter, Fig.2.1I, 2.1L (Hiller, 1968; Ruibal, 1965; Russell, 1975; Williams, 1982)). Each seta consists of 100-1000 substructures called spatulae, the contact tips (0.1-0.2 μm wide and 15-20 nm thick, Fig.2.1M (Hiller, 1968; Ruibal, 1965)) responsible for the gecko's adhesion. Terminal claws are located at the top of each singular toe (Fig.2.1G). Van der Waals and capillary forces are responsible for the resultant adhesive forces (Autumn, 2002a; Sun, 2005a), whereas the claws guarantee an efficient attachment system on surfaces with very large roughness. Similarly, an analogous ultrastructure is found in spiders (*e.g. Evarcha arcuata* (Kesel, 2003)). Thus, in addition to the tarsal claws, which are present on the tarsus of all spiders (Fig.2.1C), adhesive hairs can be distinguished in many species (Fig.2.1D, 2.1E). Like for insects, these adhesive hairs are specialised structures that are not restricted only to one particular area of the leg, but may be found either distributed over the entire tarsus - as for lycosid spiders - or concentrated on the pretarsus as a tuft (scopula) situated ventral to the claws (Fig.2.1A, 2.1B) - as in the jumping spider *Evarcha arcuata* (Kesel, 2003).

Figure 2.2 Weibull statistics (F is the cumulative probability of detachment/failure and *ti* is the measured adhesion time) applied to the measured adhesion times on PMMA surfaces. PMMA 1 (red lines, for which we made 4 sets of measurements on four different days with gecko G1), PMMA 2 (dotted lines, for which we made 2 sets of measurements on two different days, one with gecko G1 (red) and one with gecko G2 (blue)), and PMMA 3 (blue double-line, for which we made the measurements in a single day with gecko G2).

Figure 2.3 A simple interpretation of our experimental results on the adhesion tests for living geckos on PMMA surfaces with different roughness. (A) Setae cannot adapt well on PMMA 1; (B) On PMMA 2, the adhesion is enhanced because of the higher compatibility in size between setae and roughness; (C) On PMMA 3 only partial contact is achieved. On the right, we report the analysed three-dimensional roughness profiles for all three investigated surfaces (from the top: PMMA 1, 2 and 3).