As we bring robots out of the laboratory and into the world at large, one of the most important lessons we can learn from nature is how not only to tolerate but to exploit physical interactions with the environment. Examples of robots that need to take advantage of surface interactions include multimodal flying/climbing robots, adhesive microrobots that can pull loads, and robots that grasp and manipulate objects or surfaces using arrays of insect-inspired microspines or gecko-inspired adhesives. In each case, these robots have prompted collaborations with biologists and materials scientists to develop new materials and structures that exploit interactions in the environment. Nature offers many examples of structures and functional materials that help to manage these interactions. Investigations of them also allow us to discover new opportunities for synergy when combining multiple locomotion modes (e.g., flying and climbing).

As the new nature-inspired robots are developed and tested, dynamic models lead to computed “envelopes” of conditions for which the robot is expected to perform reliably – for example, to latch onto a surface without slipping or bouncing off. As contact takes place, the dynamics are typically fast, so that passive properties of mechanisms are more effective than closed-loop control to dissipate energy, distribute forces and stabilize the robot. The results of these models and experiments can provide insight for biologists as well as engineers. They allow both communities to test hypotheses about which effects or principles are most important for successful operation.