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Scaling Principles for Understanding and Exploiting Adhesion

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A grand challenge in the science of adhesion is the development of a general design paradigm for adhesive materials that can sustain large forces across an interface yet be detached with minimal force upon command. Essential to this challenge is the generality of achieving this performance under a wide set of external conditions and across an extensive range of forces. Nature has provided some guidance through various examples, e.g. geckos, for how to meet this challenge; however, a single solution is not evident upon initial investigation. To help provide insight into nature's ability to scale reversible adhesion and adapt to different external constraints, we have developed a general scaling theory that describes the force capacity of an adhesive interface in the context of biological locomotion. We have demonstrated that this scaling theory can be used to understand the relative performance of a wide range of organisms, including numerous gecko species and insects, as well as an extensive library of synthetic adhesive materials. We will present the development and testing of this scaling theory, and how this understanding has helped guide the development of new composite materials for high capacity adhesives. We will also demonstrate how this scaling theory has led to the development of new strategies for transfer printing and adhesive applications in manufacturing processes. Overall, the developed scaling principles provide a framework for guiding the design of adhesives.