Carmichael's Concise Review

Stick Tight!

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The rocky intertidal zone is an extreme environment with high, variable forces from crashing waves and strong ocean currents. A family of fishes, including the northern clingfish (*Gobiesox maeandricus*), has evolved an adhesive disc that allows them to adhere to rocks in the intertidal zone and even launch predatory attacks on molluscs that are attached to the rocks (Figure 1). Dylan Wainwright, Thomas Kleinteich, Anja Kleinteich, Stanislav Gorb, and Adam Summers studied the morphology of this fish disc to understand the properties of a reversibly adhesive disc that has a strong tenacity to stick to irregular, slippery, and wet surfaces [1].

Functional studies by Wainwright et al. compared the adhesive forces of the clingfish disc to manufactured suction cups of different sizes. The force of clingfish adhesion varied between 80 and 230 times the body weight of the fish. Manufactured suction cups had a higher peak stress (maximum force per area) than the clingfish discs on very smooth surfaces. However, the manufactured discs failed to adhere to surfaces that had a grit size more than 22 microns, which would correspond with fine sandpaper. The clingfish disc was able to adhere to surfaces with a grit size of over 250 microns, corresponding to very rough sandpaper that would be used for removing the finish from flooring!

Scanning electron microscopy (SEM) was employed to study the epithelial microstructure of the adhesive disc. The SEM revealed that papillae on the ventral face of the suction disc are arranged as a tiled surface with narrow channels between them. These papillae were identified as a hierarchically structured material with numerous microvilli. The microvilli of clingfish were of similar size (0.2 µm) to the adhesive setae of certain spiders and geckos. This morphology

Figure 1: Photograph of a northern clingfish adhering to a rock, courtesy of Thomas Kleinteich.

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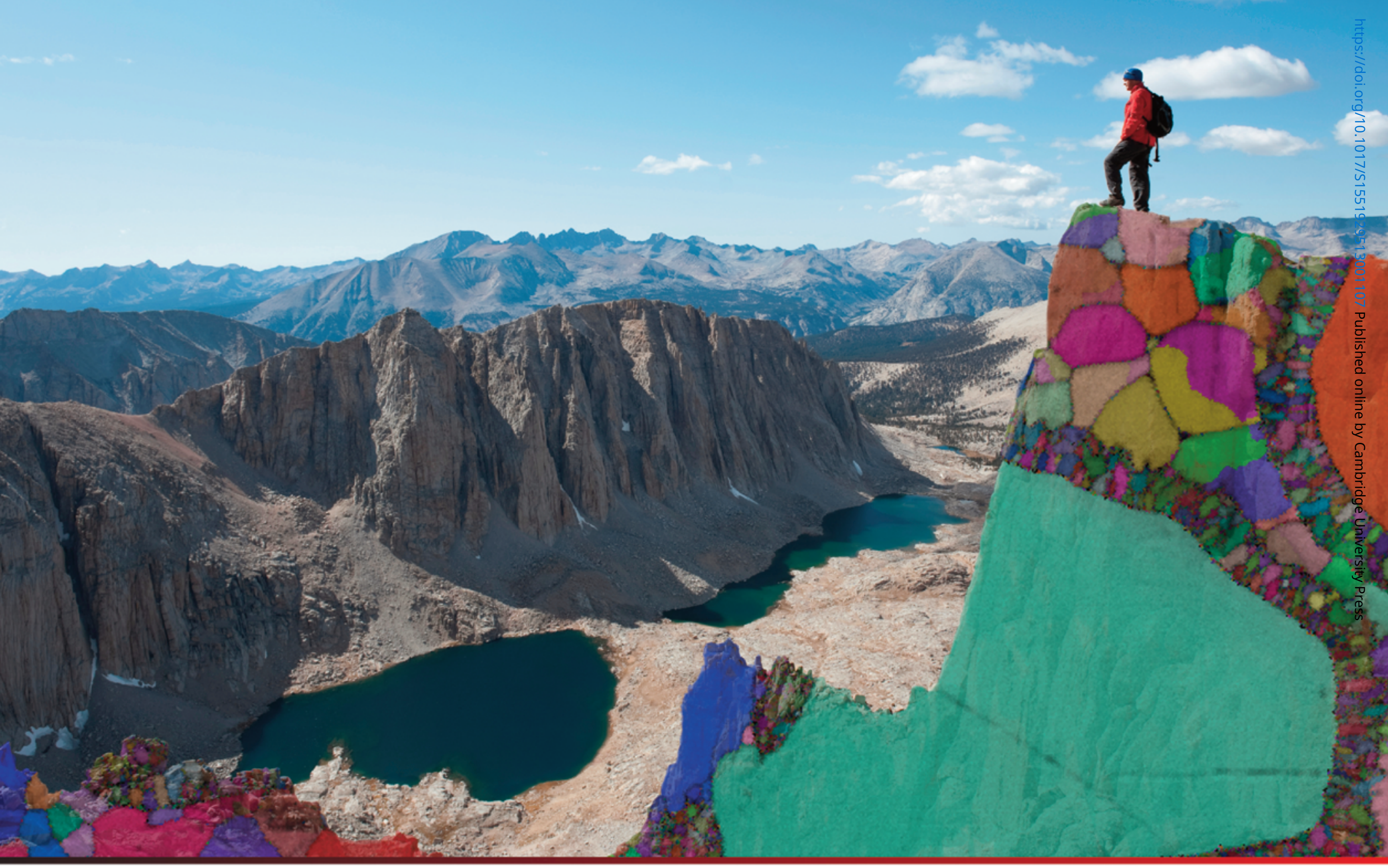

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that allows diverse animals to cling to surfaces provides a striking case of convergent evolution.

Wainwright et al. suggested that the hierarchical structure of the clingfish disc allows the edges of the disc to interdigitate with rough features of a furrowed surface. This interdigitation increases friction at the edge of the disc over surface irregularities, allowing exceptional adhesive performance of rough surfaces. This view is supported by the surprising finding that the clingfish disc adhered poorly on a very smooth surface. This is probably due to a loss of friction that allows the edges of the disc to slide toward the center and fail to stick.

In conclusion, Wainwright et al. suggest that the morphology of the clingfish disc presents a potential biomimetic model for improving adhesion to rough surfaces. If engineers could design a compliant, hierarchical surface at the edges of an attachment device, a much-improved suction cup could be manufactured.

References

[1] DK Wainwright, T Kleinteich, A Kleinteich, SN Gorb, and AP Summers, *Biol Lett* 9 (2013) 20130234.
[2] The author gratefully acknowledges Dr. Adam Summers for reviewing this article.

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