Sticky States and the Adhesion Effect: A Novel Model of Directional Evolution Without Darwinian Selection

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Traditional Darwinian models of evolution treat adaptive selection as the primary evolutionary factor for most traits. Although this approach is predictive in many cases, it struggles to explain some observed effects, most notably the persistence of complex yet apparently non-adaptive features. This study introduces adhesion, a novel evolutionary process in which a subset of an organism's state space exhibits statistical stability independent of adaptive fitness. This can be understood as a "sticky" region of the selection landscape, which may not coincide with an adaptive niche. Adhesion results from a recursive self-stabilization, in which the phenotype of a genetic state reduces the likelihood of departing from that state. This is turn stabilizes the phenotype, resulting in directional evolution at the population scale. The adhesion effect is demonstrated mathematically and in an in-silico model population. Adhesion is shown to be independent of natural selection, but capable of producing similar, though statistically distinguishable, population-level effects. A mathematical approach is defined which disentangles the effects of Darwinian selection from those of adhesion. Applying this method to the modelled population demonstrates that adhesive trait distributions are only sporadically predicted by adaptive fitness, with statistically significant deviations from the Darwinian model ($p < 0.001$) occurring in 99% of samples. The adhesion effect is shown to have implications for the early evolution of noncoding RNAs and protein motifs. An understanding of adhesion may also provide insight into a range of biological processes, including the evolution of pathogens and viral immune escape.

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