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The thermodynamics of prediction SUSANNE STILL, University of Hawaii at Manoa, DAVID SIVAK, UCSF, ANTHONY BELL, RCTN, UC Berkeley, GAVIN CROOKS, LBL, Berkeley — We expose the fundamental equivalence between model inefficiency and thermodynamic inefficiency, measured by dissipation. The dynamics of any system responding to a stochastic environmental signal can be interpreted as computing an implicit model of the driving signal. The system's state retains information about past environmental fluctuations, and a fraction of this information is predictive of future fluctuations. The remaining nonpredictive information reflects model complexity that does not improve predictive power, and thus represents the inefficiency of the model. We find that instantaneous nonpredictive information: 1) is proportional to the work dissipated due to environmental change; 2) provides a lower bound on the total average dissipated work when summed over the length of a driving protocol; 3) augments the lower bound on heat generated due to information erasure (Landauer's principle). Our results hold far from thermodynamic equilibrium and are thus applicable to a wide range of systems, including biomolecular machines. They highlight a profound connection between the effective use of information and efficient thermodynamic operation: any system constructed to keep memory about its environment and to operate with maximal energetic efficiency has to be predictive.

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