Abstract Submitted
for the MAR17 Meeting of
The American Physical Society

Novel physical constraints on implementation of computational processes DAVID WOLPERT, ARTEMY KOLCHINSKY, Santa Fe Institute — Non-equilibrium statistical physics permits us to analyze computational processes, i.e., ways to drive a physical system such that its coarse-grained dynamics implements some desired map. It is now known how to implement any such desired computation without dissipating work, and what the minimal (dissipationless) work is that such a computation will require (the so-called generalized Landauer bound). We consider how these analyses change if we impose realistic constraints on the computational process. First, we analyze how many degrees of freedom of the system must be controlled, in addition to the ones specifying the information-bearing degrees of freedom, in order to avoid dissipating work during a given computation, when local detailed balance holds. We analyze this issue for deterministic computations, deriving a state-space vs. speed trade-off, and use our results to motivate a measure of the complexity of a computation. Second, we consider computations that are implemented with logic circuits, in which only a small numbers of degrees of freedom are coupled at a time. We show that the way a computation is implemented using circuits affects its minimal work requirements, and relate these minimal work requirements to information-theoretic measures of complexity.

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Date submitted: 11 Nov 2016 Electronic form version 1.4