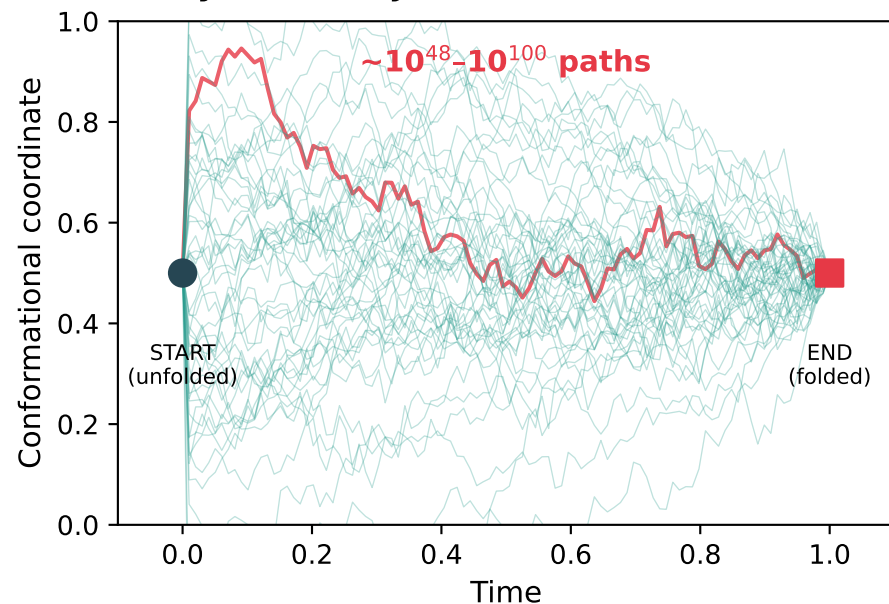
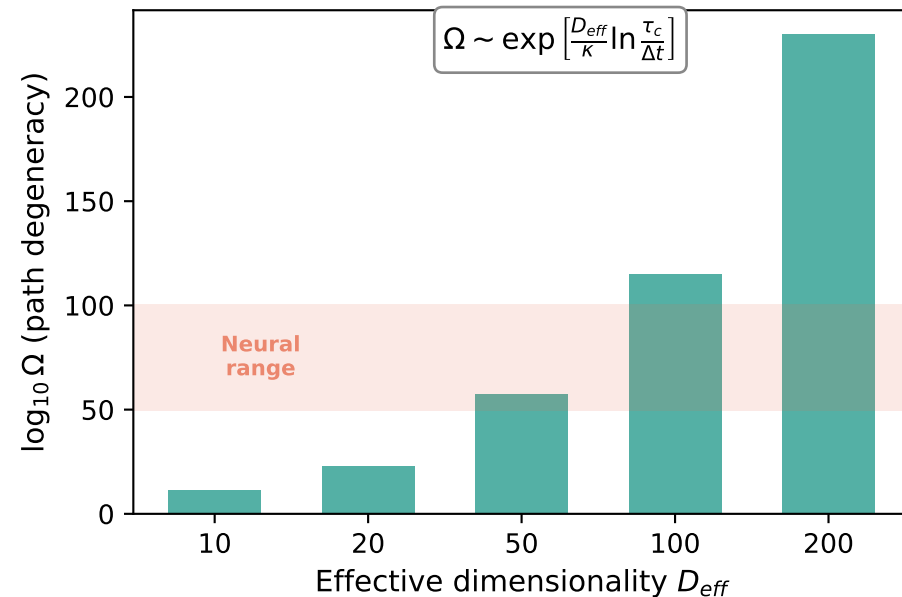


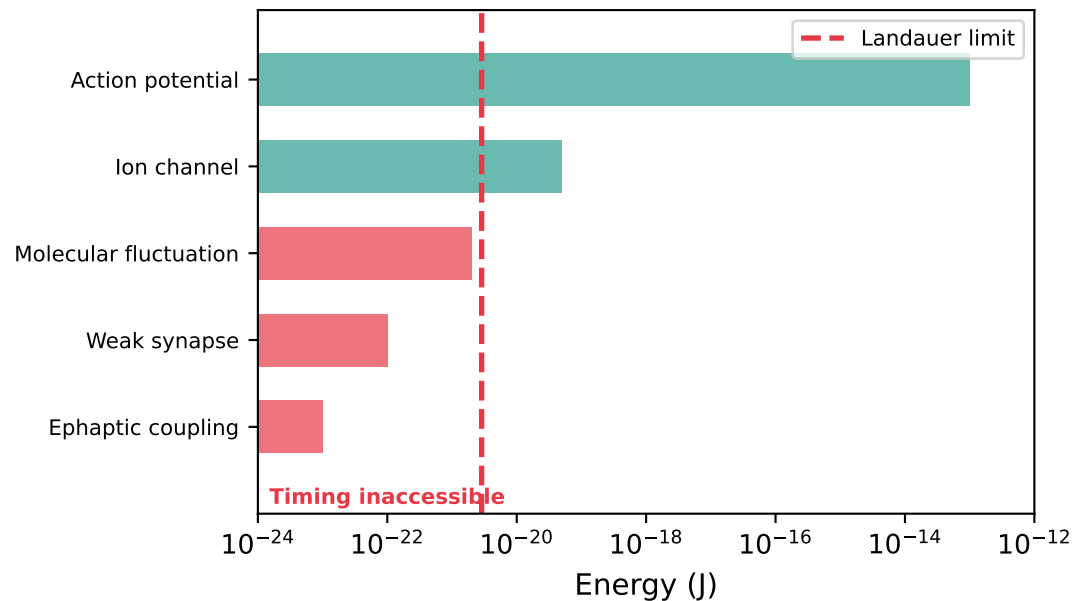
### A. Many Micro-Trajectories, One Macro-Outcome



### B. Degeneracy Scales Exponentially with Dimension



### C. Sub-Landauer Domain



## PATH DEGENERACY

Below Landauer: stabilizing a reusable record requires  $\geq k_B T \ln 2$  per order bit

Exponentially many micro-trajectories map to same macro-outcome

Digital: pay per bit | Continuous: pay at projection

$$E_{\min}^{time} \geq k_B T \ln 2 \cdot \log_2 (M!)$$

Temporal Registration Bound