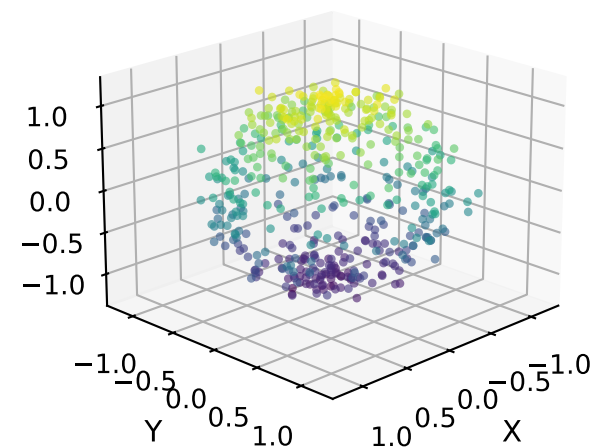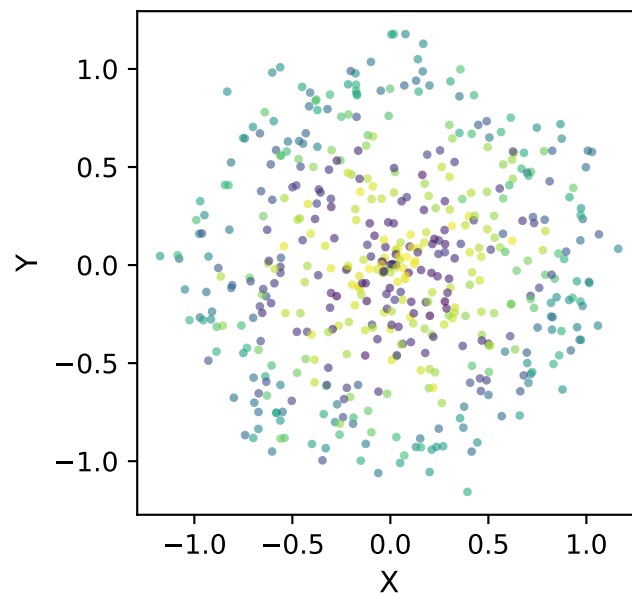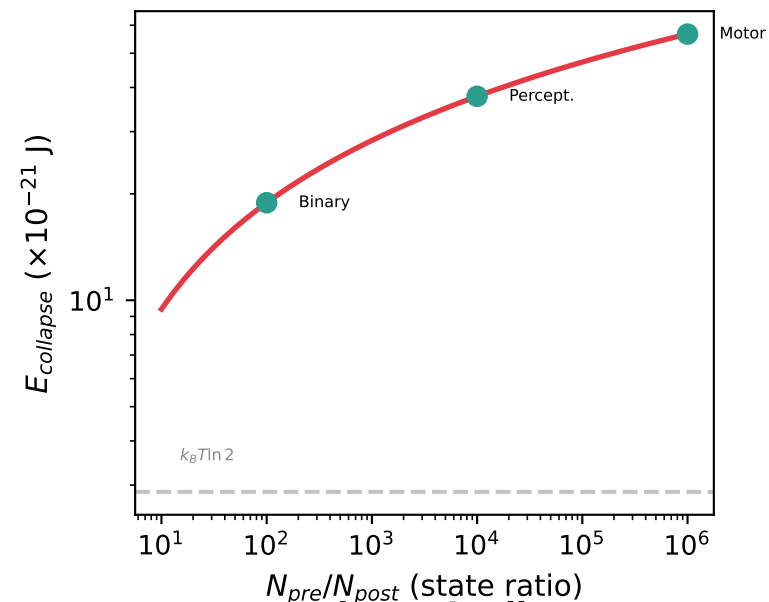# A. High-D State Space
($N_{\varepsilon,pre}$ **states**)

B. Collapsed to Low-D
($N_{\varepsilon,post}$ **states**)

C. Projection Bound
$E \geq k_B T_{eff} \ln(N_{pre}/N_{post})$

Motor

Percept.

Binary

$k_B T \ln 2$

N_{pre}/N_{post} (state ratio)

F. Linear Scaling
$E \sim (D_{eff} - D')\ln(L/\varepsilon)$

Neural range

D_{eff} (pre-collapse dimension)

FULL PROJECTION BOUND

$E \geq k_B T_{eff}[\ln(N_{pre}/N_{post}) - KL_{pre} + KL_{post}]$

$\ln(N_{pre}/N_{post})$: geometric compression

$-KL_{pre}$: pre-constraint lowers bound

$+KL_{post}$: output specificity raises bound

TYPICAL-SET APPROXIMATION

Near-uniform distributions
(high-D, many modes):

KL terms ≈ 0

↓

$E \geq k_B T_{eff} \ln(N_{pre}/N_{post})$

Pure geometric bound