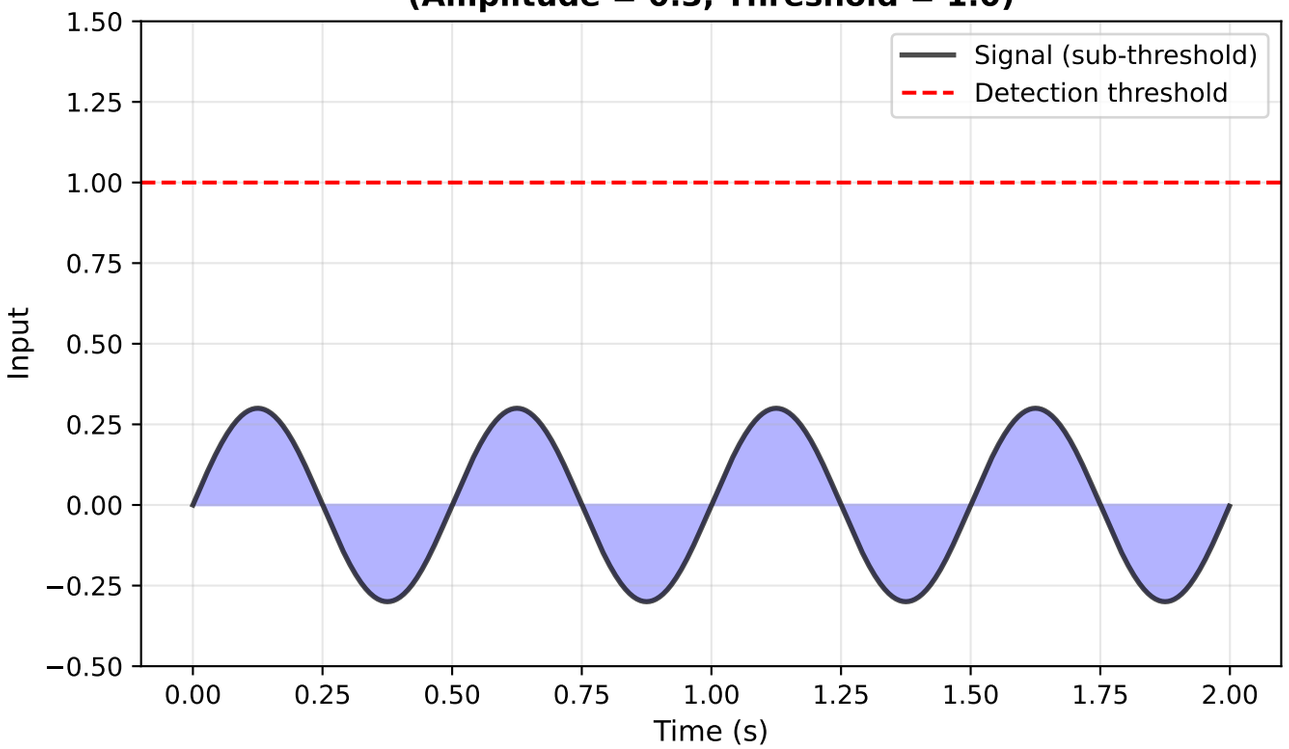

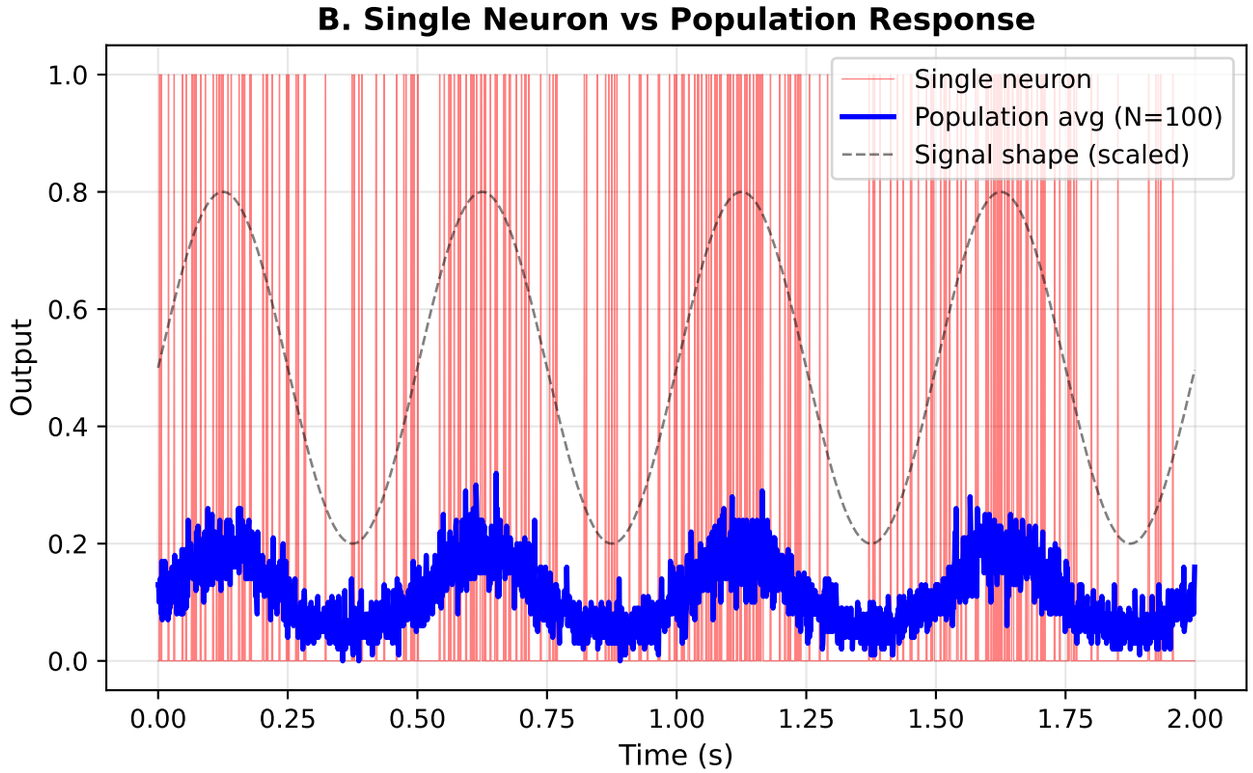

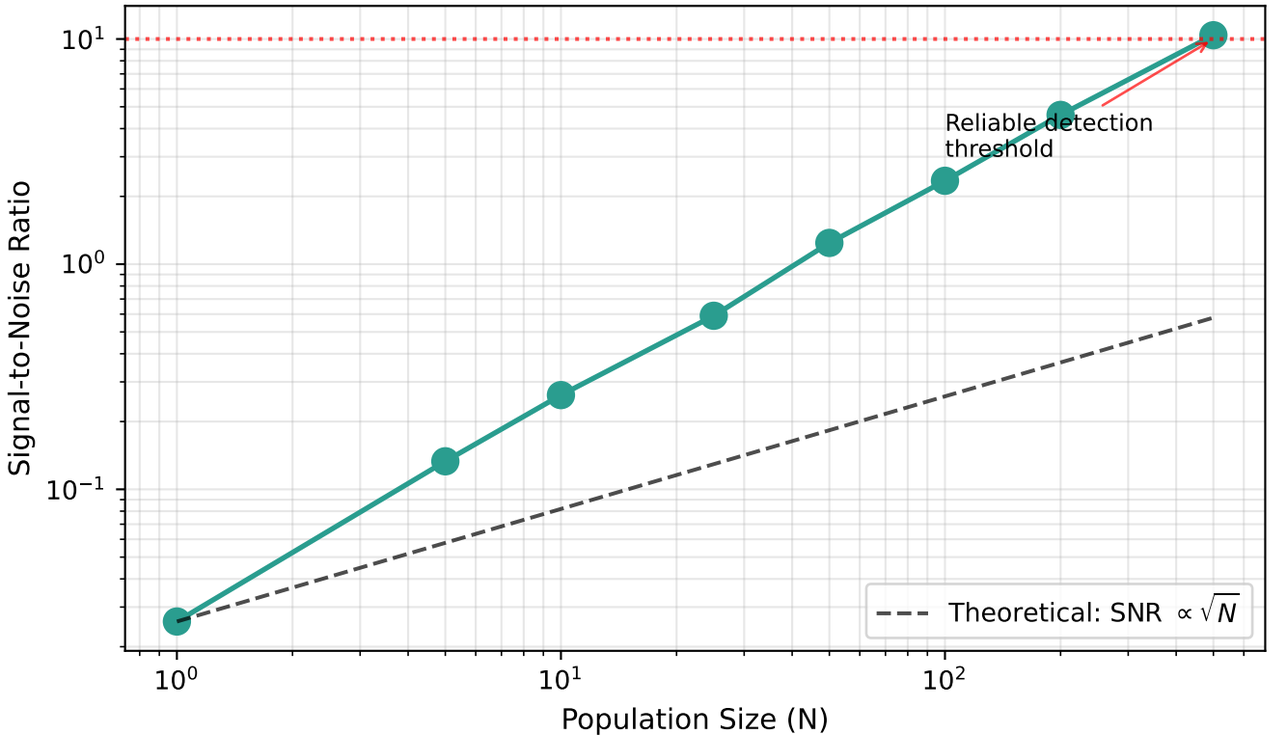

D. The Sub-Landauer Domain

THE SUB-LANDAUER DOMAIN

Individual Level:
- Signal energy < $k_B T \ln 2$
- Cannot be recorded as a discrete bit
- Binary measurement destroys the pattern

Population Level:
- SNR ∝ √N (Eq. 9)
- "Ensemble fingerprints" become detectable
- Information preserved through correlation

BIOLOGICAL IMPLICATION:

Many causally-relevant patterns in neural systems exist in this regime:

- Ephaptic coupling (~1 mV/mm)
- Weak synaptic inputs
- Metabolic oscillations

These patterns shape behavior but resist Popperian falsification at the single-unit level. Only ensemble statistics can access them without destruction.