

# Surprises from the Inside: Navigating the interplay of fast and slow change in system dynamics

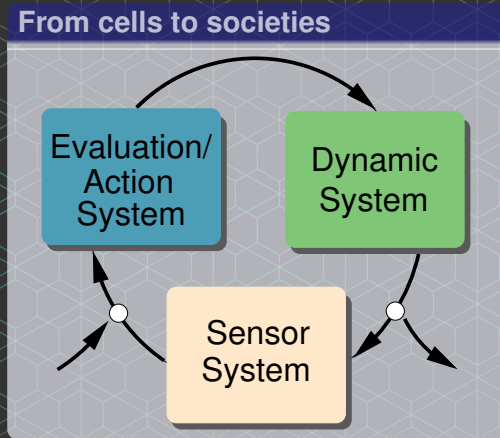
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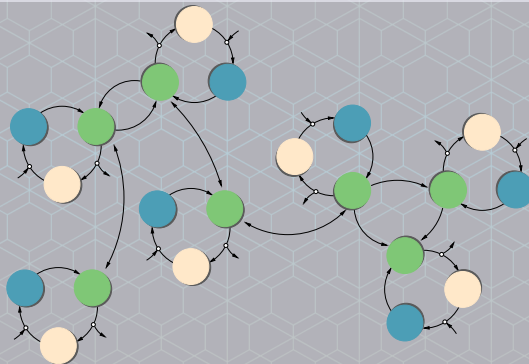
NAS Panel III: Adapting to Shocks and Surprise  
December 1, 2020

# Fundamental Building Blocks of Complex Systems



# Networked Building Blocks of Complex Systems

## Regulatory Feedback Networks Create Persistent Patterns/Structures



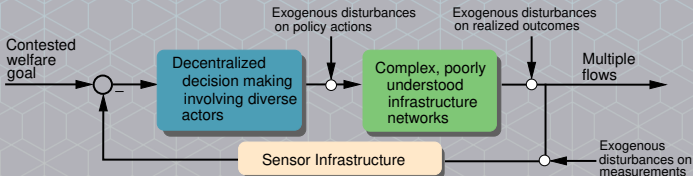
# Shocks from Without - Building Robustness for Sustainability

## Social-Ecological Systems Feedback Loops

### A: Idealized feedback control loop

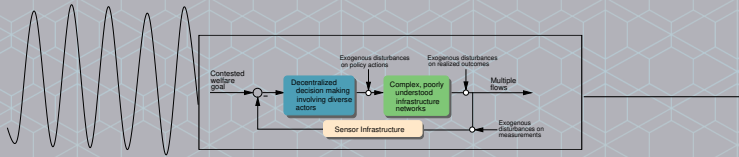


### B: Real-world feedback control loop



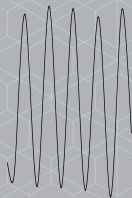
# Shocks from Without - Building Robustness for Sustainability

## Social-Ecological Systems Feedback Loops

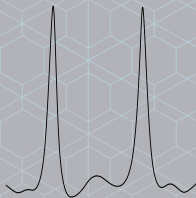


# Surprises from Within: Tensions Between the Fast and the Slow

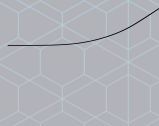
## Fundamental Robustness-Fragility 'Fast-Slow' Tradeoffs



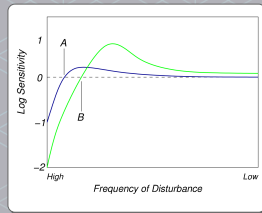
high frequency



low frequency



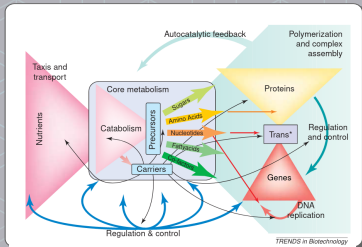
very low frequency



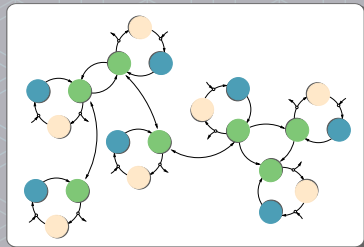
conservation of fragility

# Surprises from Within: Tensions Between the Fast and the Slow

## System Architectures



Bow Tie Architectures  
Csete & Doyle, TRENDS in Biotechnology  
Vol.22 No.9 September 2004



Spiraling complexity and cascading failures

# Concluding Thoughts

## Governance structures to address variability across scales

- Fundamental robustness-fragility tradeoffs suggest it will be very difficult to manage across very 'fast' and very 'slow' variables. Awareness of these trade-offs may improve governance:
  - Live with variability (equitably/justly)
  - Carefully manage layers of complexity aimed at managing variability
- Focus on simpler solutions (fewer hidden internal fragilities), i.e. justice and equity.
- Challenging conversation about how societies will bear the costs reducing fragilities - what are the performance tradeoffs?