



*Complex Adaptive System of Systems  
(CASoS) Engineering Initiative  
<http://www.sandia.gov/CasosEngineering/>*

# Public Health Care as a Complex Adaptive System of Systems

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Eighth International Conference on Complex Systems  
Quincy, MA  
June 26 – July 1, 2011

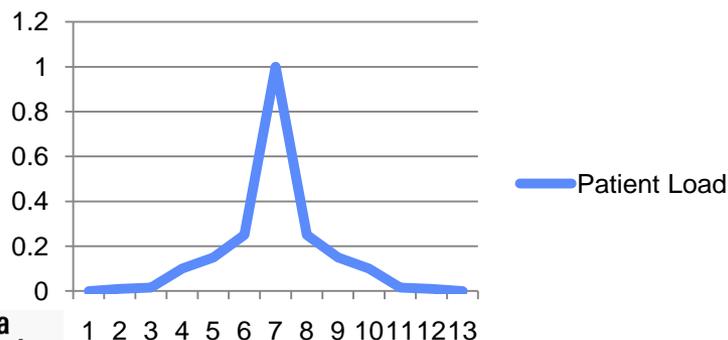
Public health systems are

- **Complex** due to the large number of interdependencies and non-linear interactions among heterogeneous agents, such as individuals, health care organizations, and governmental agencies
- **Adaptive** in that the behaviors of individuals, organizations, and diseases are highly responsive to the behaviors of other such agents, as well as to hazards and natural disasters
- **System-of-systems** nature arises from each system existing in an environment with individual variations in selective pressure

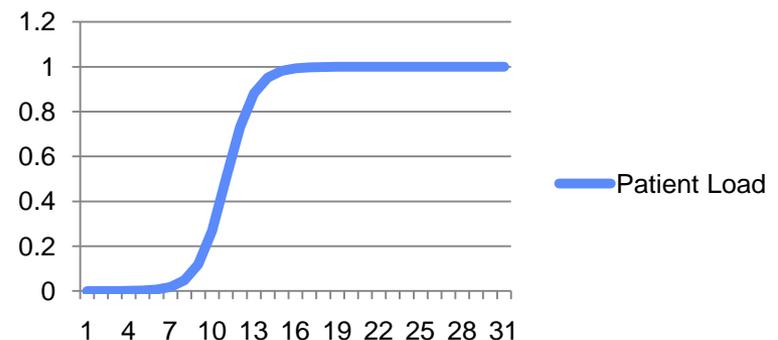
Ultimately, designed solutions (public health care actions) must be shown to be robust to the uncertainties inherent within the CASoS.

- Evolved and engineered systems are adapted against perturbations
- Robust across a range of magnitudes, fragile against excessive forces, or against forces coming from another direction
- Robustness of strategies/policies should also be measured against functional form of perturbation

### Spike (Earthquake)



### Sustained surge (Hep C)

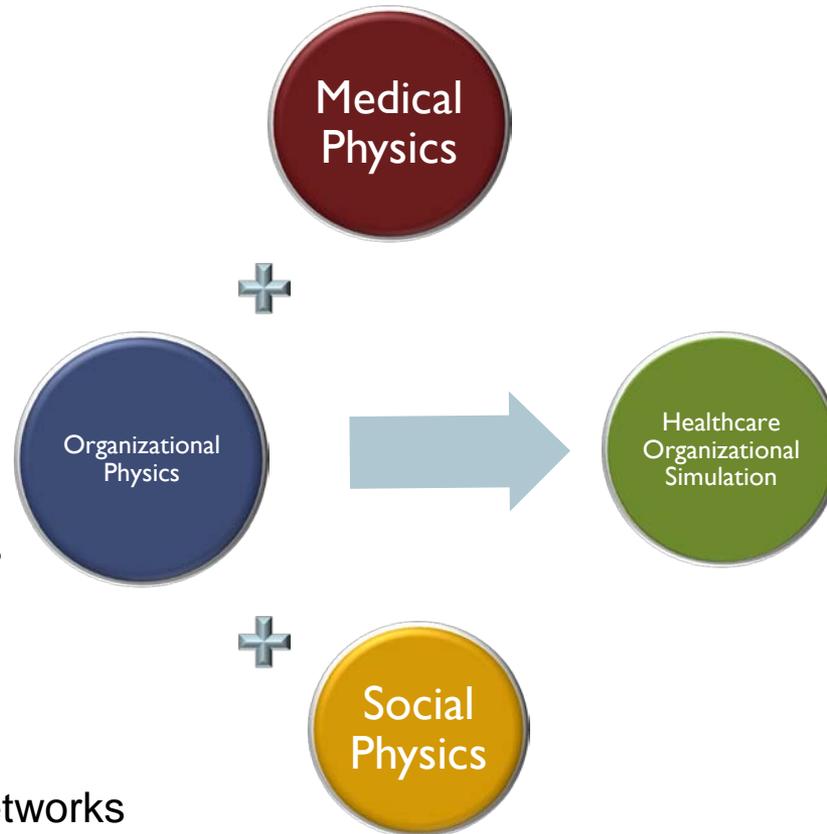


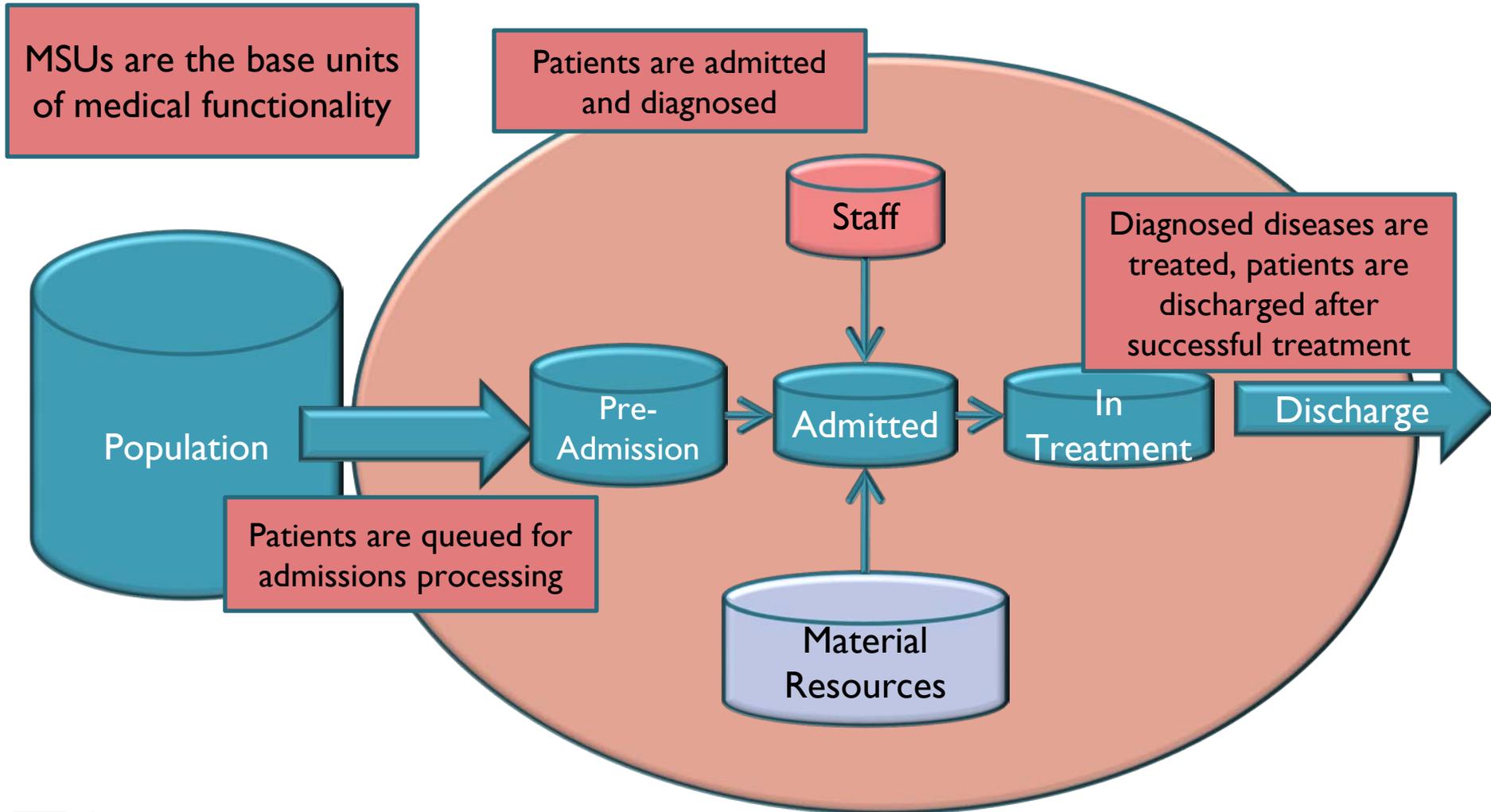
# Multilevel Selection In Organizations

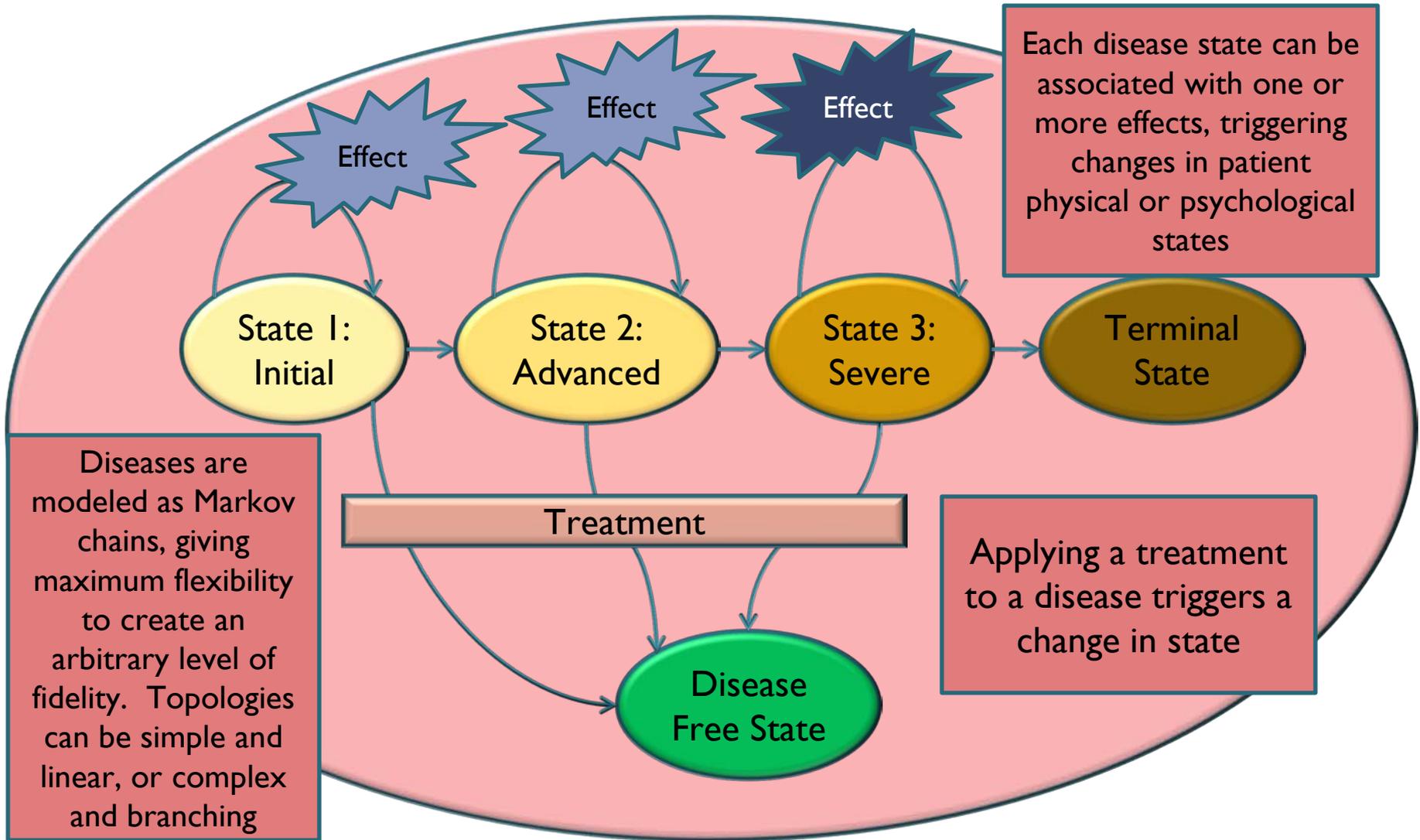
- MLS in biological organisms applies analogously to other adaptive systems with existential hierarchies
- Conflicts between levels of selection
- What are you selecting for?
- Selection at the level of the individual hospital can have negative consequences for the system as a whole

# Est omnis divisa in partes tres...

- Medical Physics
  - Diseases and treatments
  - Labor, resources
- Organizational Physics
  - Distinction between MSUs
    - Capacity
    - Capabilities
    - Resources
  - Resource allocation policies
    - Initial
    - Dynamic
- Social Physics
  - Mood contagion in social networks
  - Social components of lifestyle associated diseases
  - Dissemination of practice





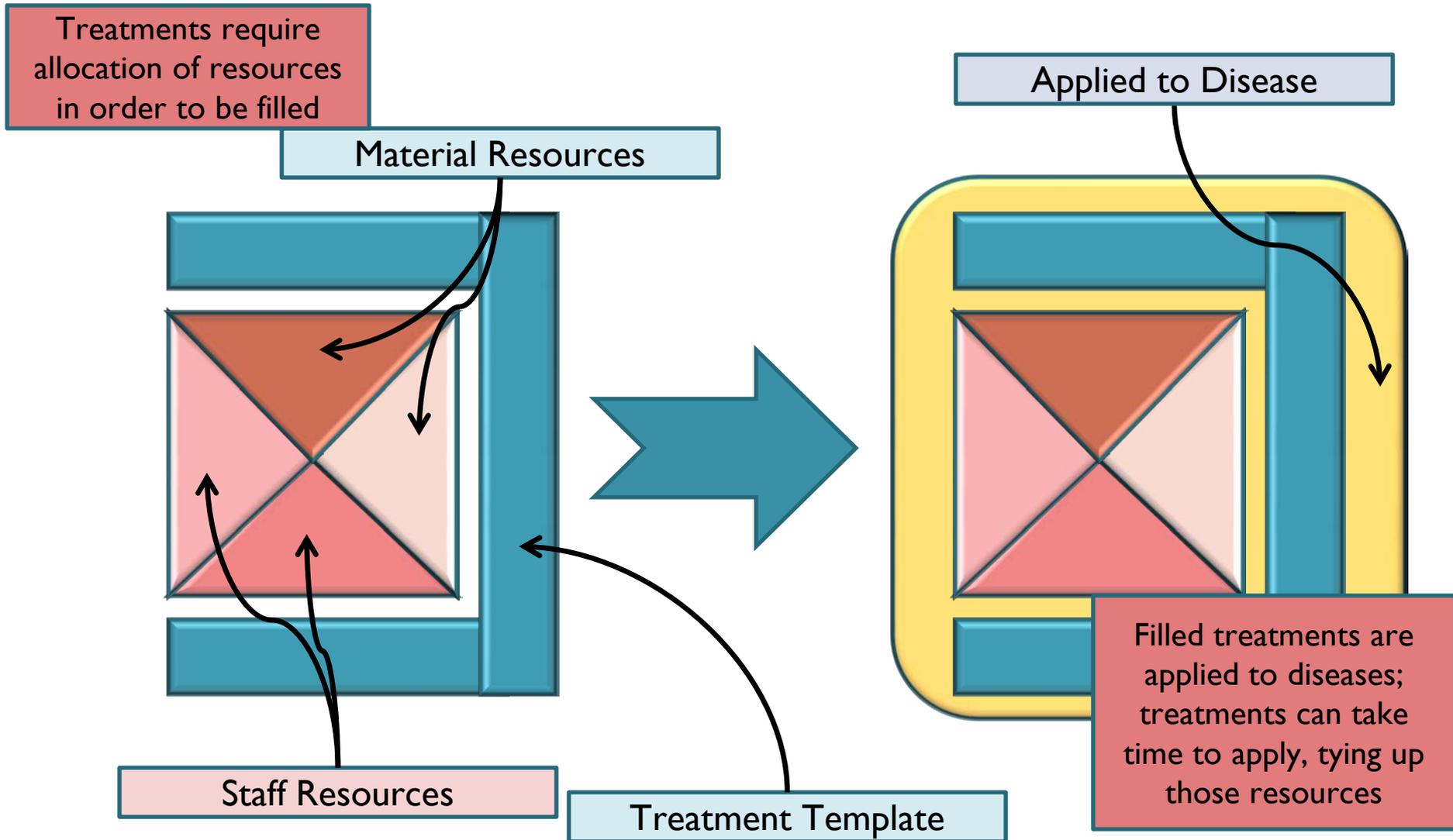


Diseases are modeled as Markov chains, giving maximum flexibility to create an arbitrary level of fidelity. Topologies can be simple and linear, or complex and branching

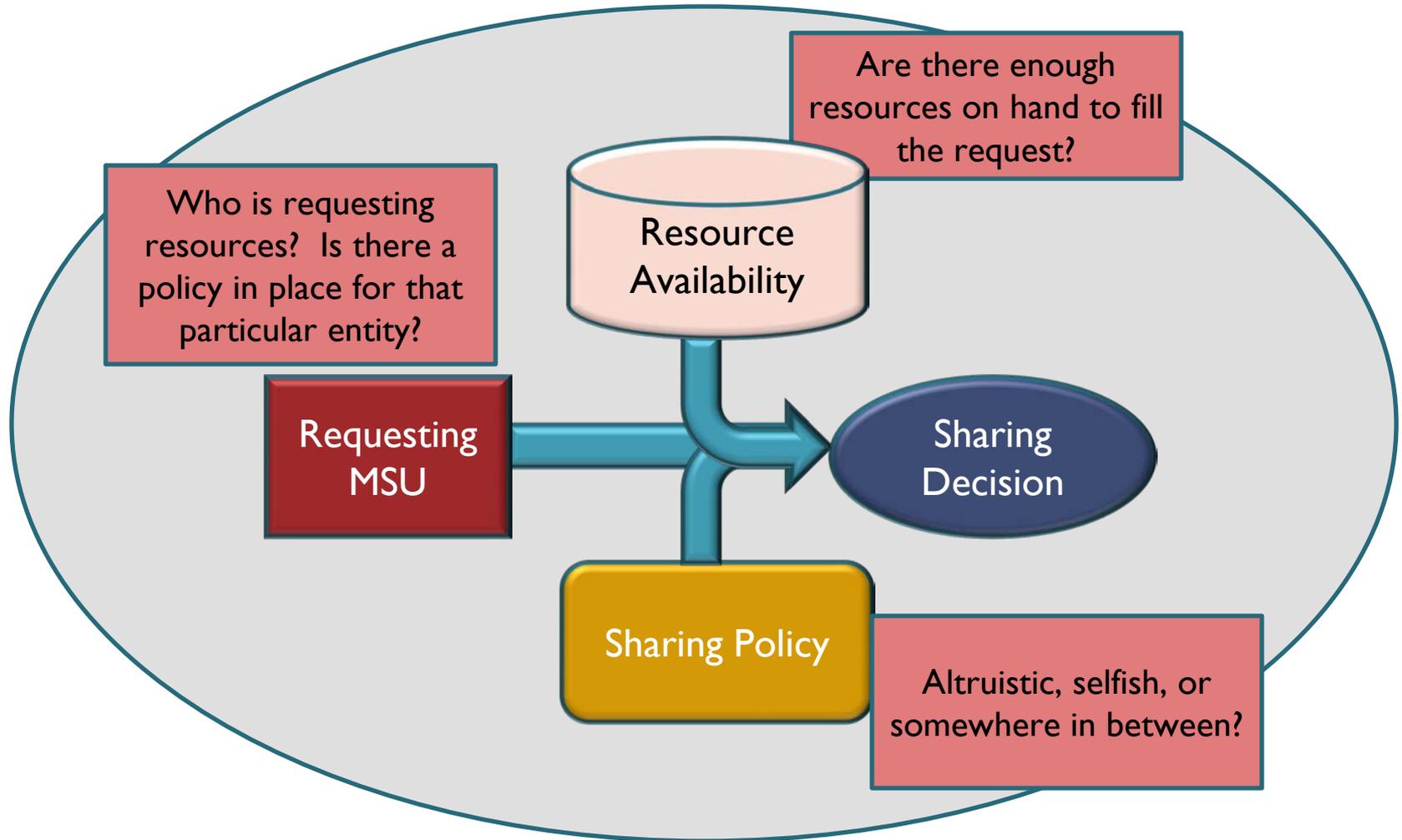
Each disease state can be associated with one or more effects, triggering changes in patient physical or psychological states

Applying a treatment to a disease triggers a change in state

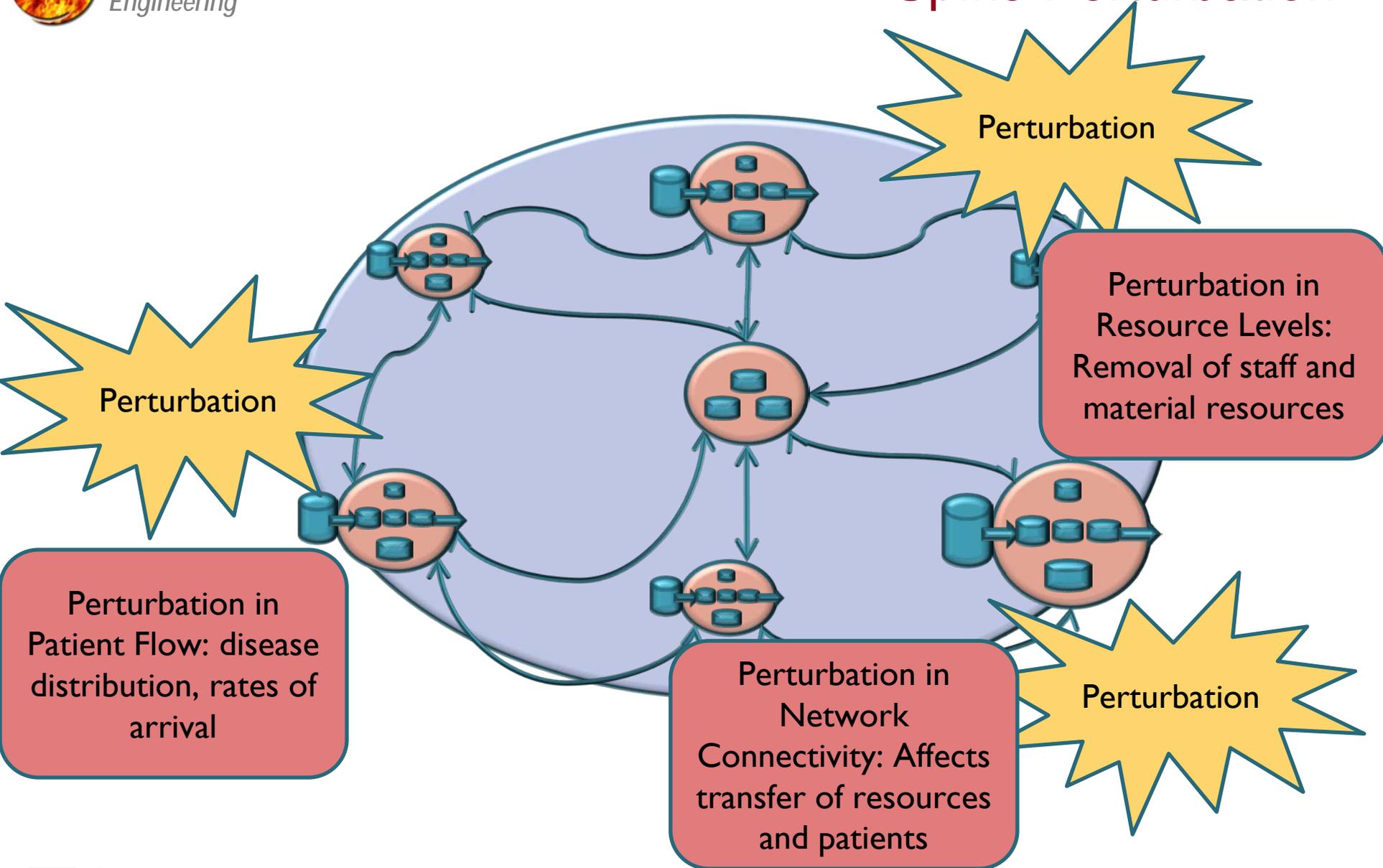
# Treatment Representation



# Policies for Resource Dynamics



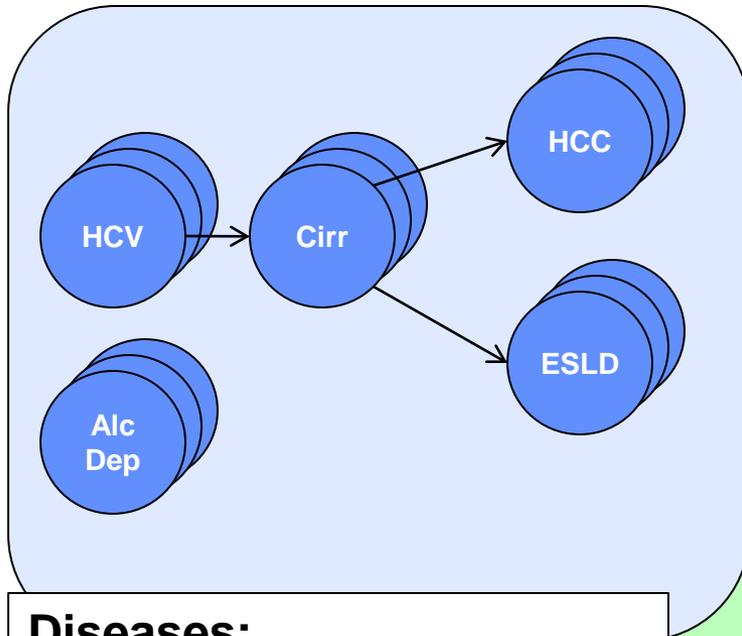
# Spike Perturbation



# Spike Perturbation

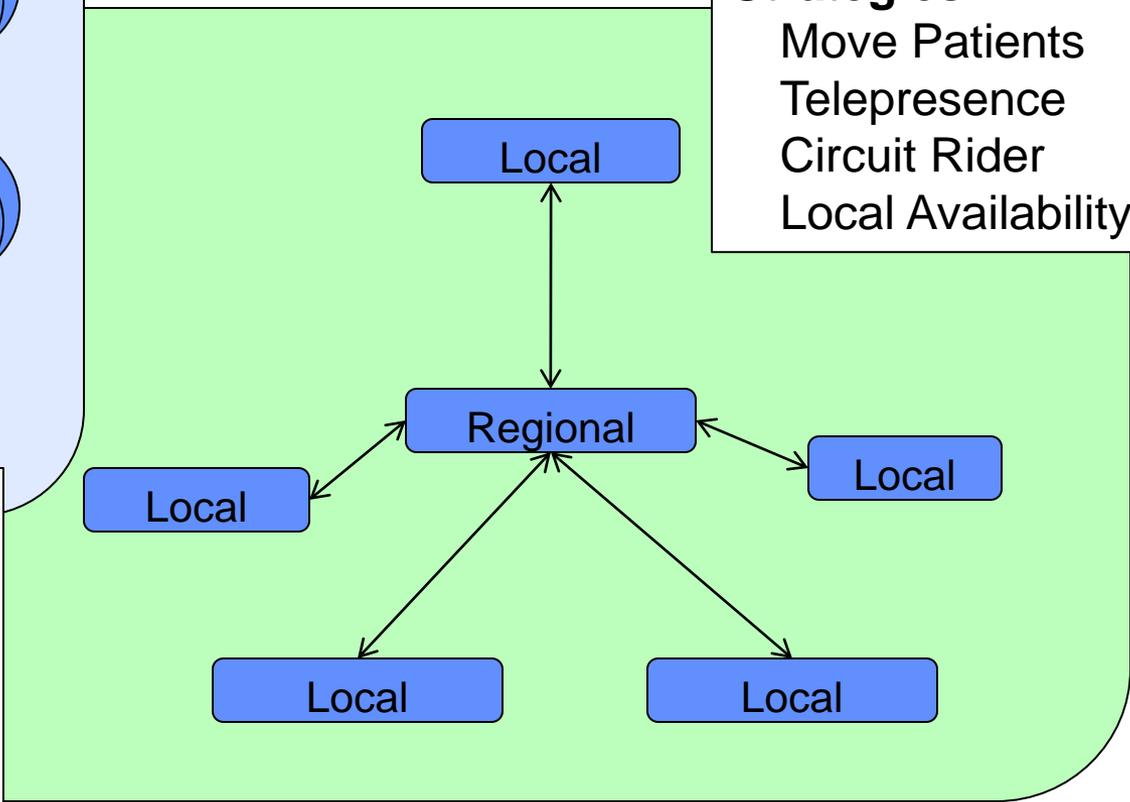
- How does cost-based optimization at the level of individual hospitals affect the ability of the system as a whole to respond to emergency driven surges in demand?
- What levels of network-motivated (pro-social) behaviors are necessary to maintain systemic flexibility? What levels of individual-motivated behaviors compromise system functionality?
- The hypothesis is drawn from multi-level selection theory: A conflict can exist between levels of a hierarchical entity, such that optimization at one level yields sub-optimal results at another level
- In this case, operating MSUs at or above capacity leads to sub-optimal performance at the network level when a perturbation (such as a pandemic, earthquake, or flood) occurs
- Availability and coordination of resources necessary to minimize negative consequences of large perturbations
- “Double spike” can continue to occupy resources at a high level even after first order effects have passed

# Hepatitis C Problem Configuration



**Diseases:**  
 Hepatitis C  
 Cirrhosis  
 Hepatocellular Carcinoma  
 End Stage Liver Disease  
 Alcohol Dependency

**Strategies:**  
 Move Patients  
 Telepresence  
 Circuit Rider  
 Local Availability



- Moving patients is a reasonable strategy with limited population size
- Telepresence extends capabilities and can multiply effectiveness of key personnel, constrained by disease severity
- Circuit riders play a key role, constrained by local resource availability, patient load (population size)
- Local presence becomes required for high load, advanced disease population
- Dynamic population profiles require dynamic policies

- We created a flexible simulation environment with composable medical facilities capable of modeling at multiple scales
- Different policies and strategies are necessary for different driving functions in perturbations
- Application of selective pressure must be done at the level of the phenomenon to be optimized
- Transparent integration of facilities helps with resource sharing, facilitates better patient care
- Individual strategy selection must be based in the situation on the ground