# Brief Glimpse of Agent-Based Modeling

Nathaniel Osgood

Using Modeling to Prepare for Changing Healthcare Need

January 9, 2014

# Agent-Based Models

- Agent-based model characteristics
  - One or more populations composed of individual agents
    - Each agent is associated with some of the following
      - State (continuous or discrete e.g. age, health, smoking status, networks, beliefs)
      - Parameters (e.g. Gender, genetic composition, preference fn.)
      - Rules for interaction (traditionally specified in general purpose programming language)
    - Embedded in an environment (typically with localized perception)
    - Communicate via messaging and/or flows
  - Environment
- Emergent aggregate behavior

# Model Specification

## Stock & Flow Models

- Small modeling vocabulary
- Power lies in combination of a few elements (stocks & flows)
- Analysis conducted predominantly in terms of elements of model vocabulary (values of stocks & flows)
- Directly maps onto crisp mathematical description (Ordinary Differential Equations)

## Agent-Based Modeling

- Large modeling vocabulary
- Different subsets of vocabulary used for different models
- Power in flexibility & combination of elements & algorithmic specification
- Variety in analysis focus
- Mathematical underpinnings differ
- In most cases, lacks transparent mapping to mathematical formulation

# ABMs: Larger Model Vocabulary & Needs

- Events
- Multiple mechanisms for describing dynamics
  - State transition diagrams
    - Multiple types of transitions
  - Stock and flow
  - Custom update code
- Inter-Agent communication (sending & receiving)
- Diverse types of agents
- Data output mechanisms
- Statistics
- Subtyping
- Mobility & movement
- Graphical interfaces
- Stochastics complicated
  - Scenario result interpretation
  - Calibration
  - Sensitivity analysis
- Synchronous & asynchronous distinction, concurrency
- Spatial & topological connectivity & patterning

# Organization in ABM

- ABM adopts the organizational style of object-oriented software engineering by clustering together the elements of state & behavior for entities
- This facilitates convenient representation of
  - Nested relationships (individuals in neighborhoods in municipalities, etc.)
  - Networked relationships (e.g. network of individuals, towns, farms, firms, etc.)

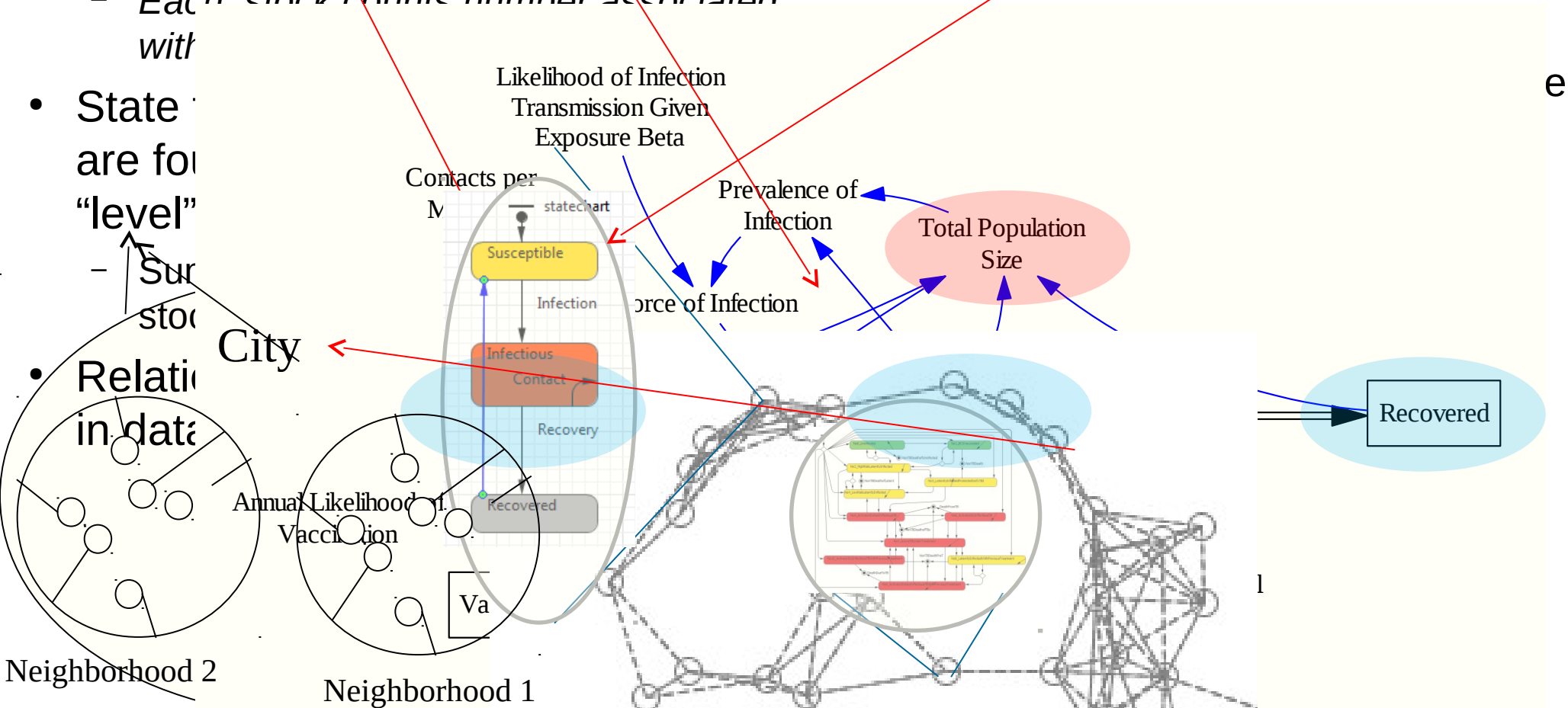
# Contrasting Organization in Aggregate Stock-Flow & ABM

## Aggregate Stock & flow models *Agent-based modeling*

- Within unit (e.g. city)
  - Subdivided according to *state (eg # susceptible, # infective)*
  - *Each stock counts number associated with*
- State
  are fo
  "level"
  - Su
    sto
- Relati
  in data

- Within unit (e.g. city)
  - Subdivided according to constitutive smaller units (e.g.

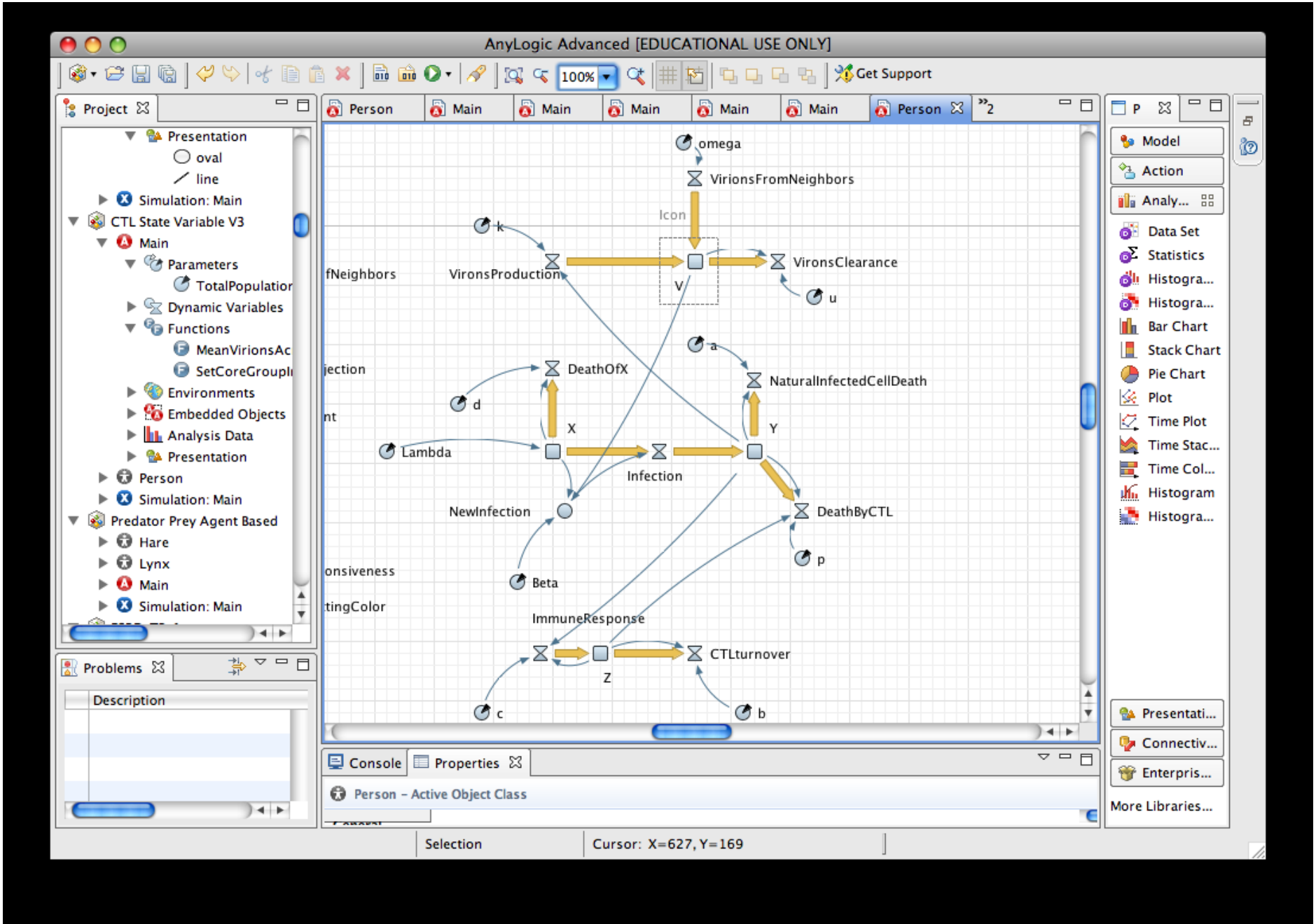
e



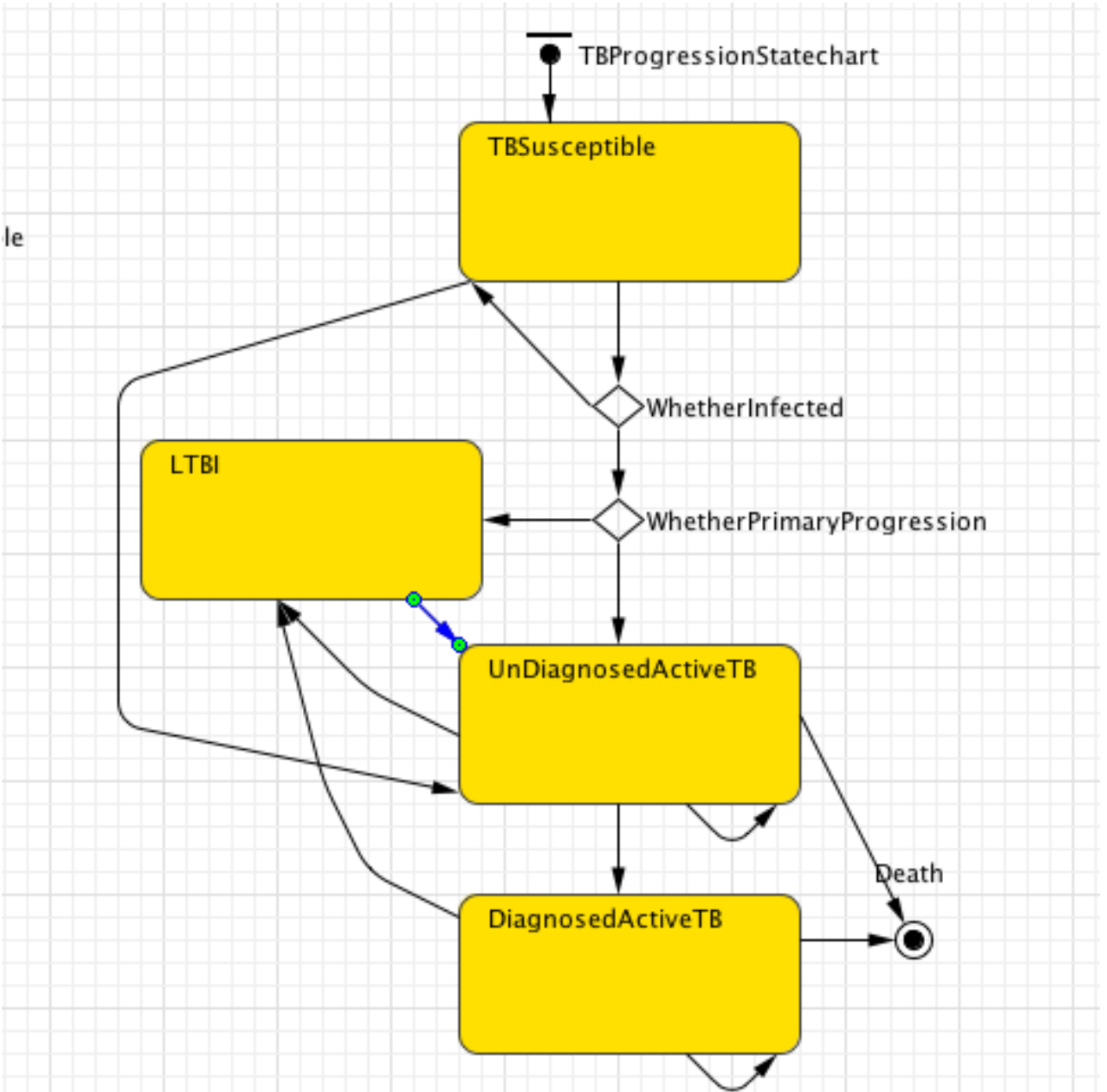
# Example Elements of Individual State

- Discrete
  - Ethnicity
  - Gender
  - Categorical infection status
- Continuous
  - Age
  - Elements of body composition
  - Metabolic rate
  - Past exposure to environmental factors
  - Glycemic Level

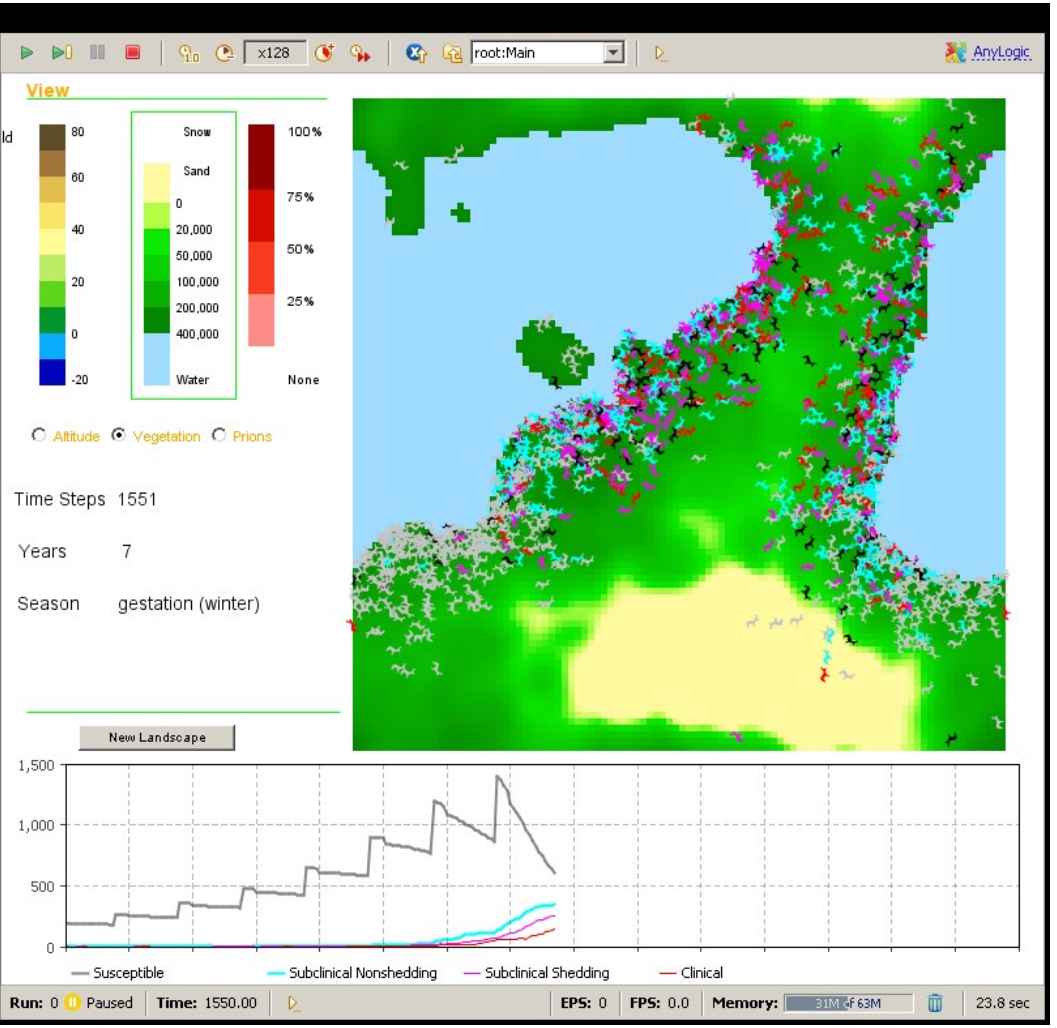
# Example of Continuous Individual State

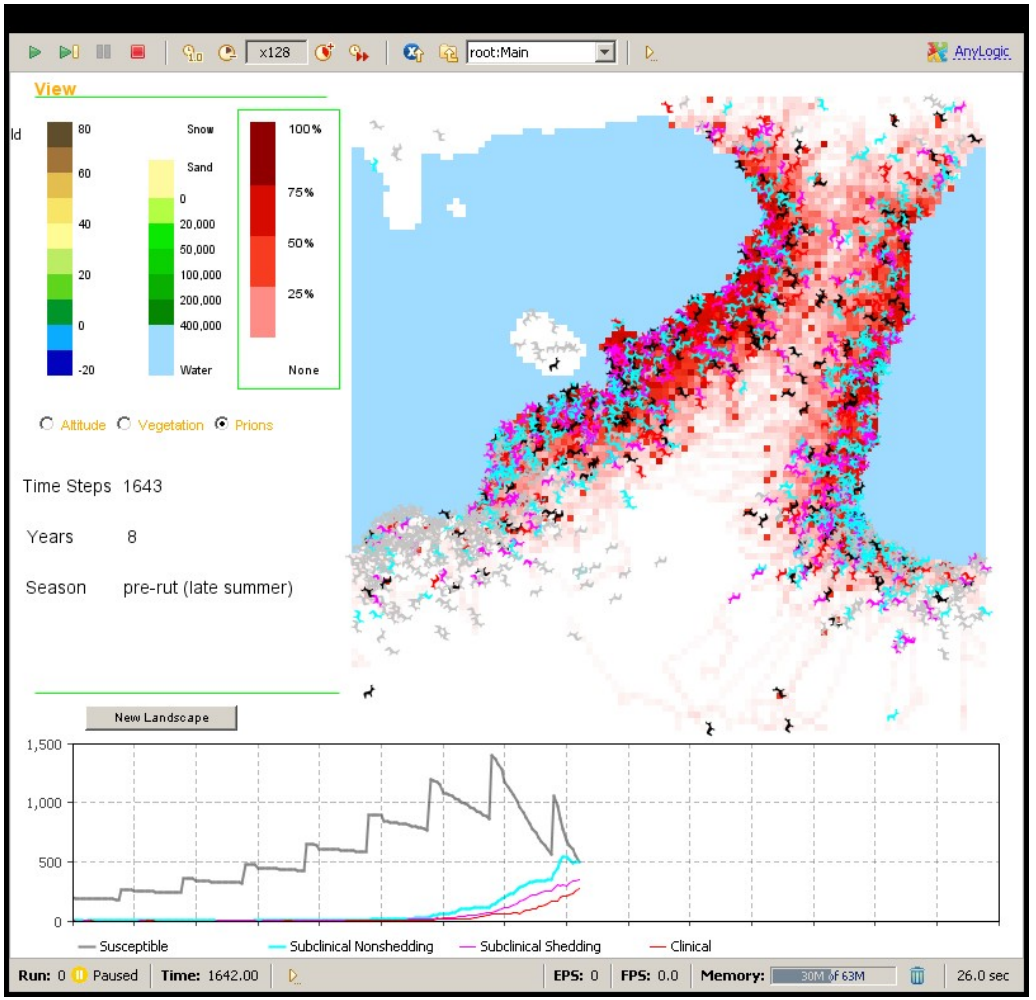


# Example of Discrete States
# Binary Presence in Discrete State



# Chronic Wasting Disease



# Tuberculosis Spread, Prevention & Control
## (Earlier Version)

ABM_858_1 : Simulation - AnyLogic Advanced [EDUCATIONAL USE ONLY]

x1 | experiment: ABM... | AnyLogic

**Contact Tracing Simulation**

*We can make it better!*

Run Model

run_multiple

**Network type**

- (•) Random
- ( ) Small world
- ( ) Scale free

**Network Settings**

**Connect Per Agent** 29

Notes: Connects Per Agent is for Random and Small World Networks

**Neighbourhood Link Prob** 0.95

Notes: Link Prob is for Small World Networks

**ScaleFreeM** 3

Note: ScaleFreeM is for Scale Free Networks

**Contact Tracing Policy Selection**

- (•) No Contact Tracing Program
- ( ) Contact Tracing With Priority

**Contact Tracing Priority Settings (Weight)**

AgeWeight | EthnicityWeight

GenderWeight | ContactsWithTB

**Contact Tracing Targets**

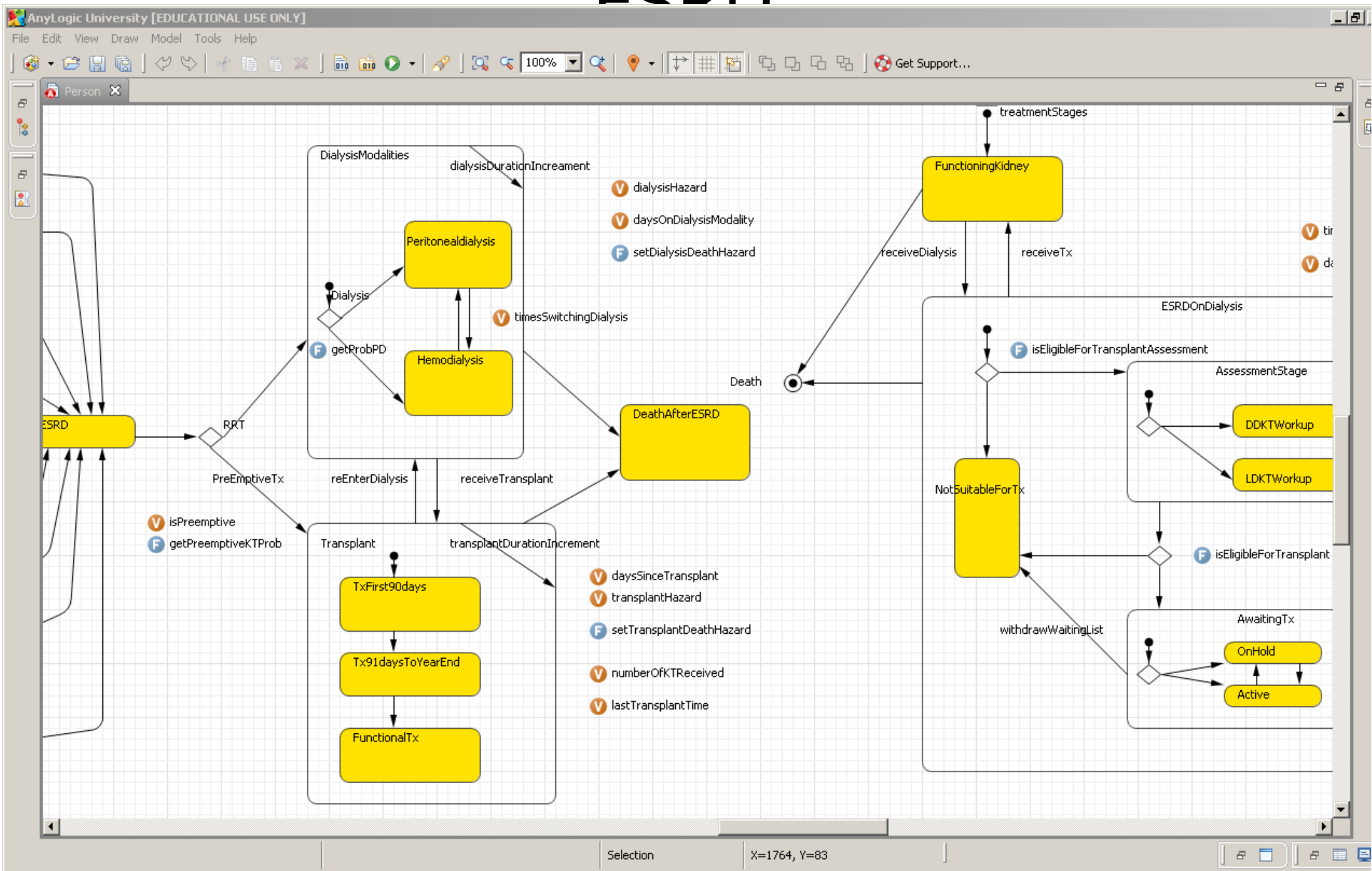
- (•) Tracing Infectious Active TB Cases ONLY
- ( ) Tracing All Active TB Cases

**Scenario Information**

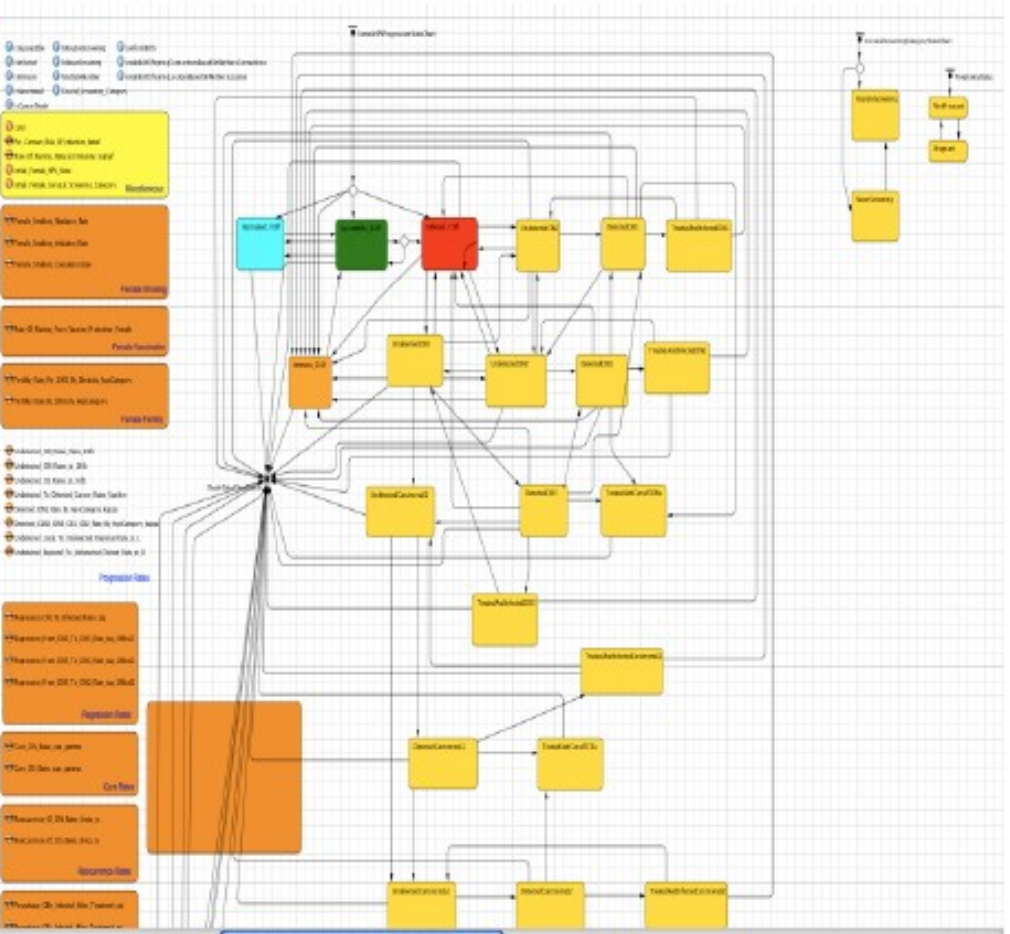
**Scenario Comments** simulation test[enter comment]

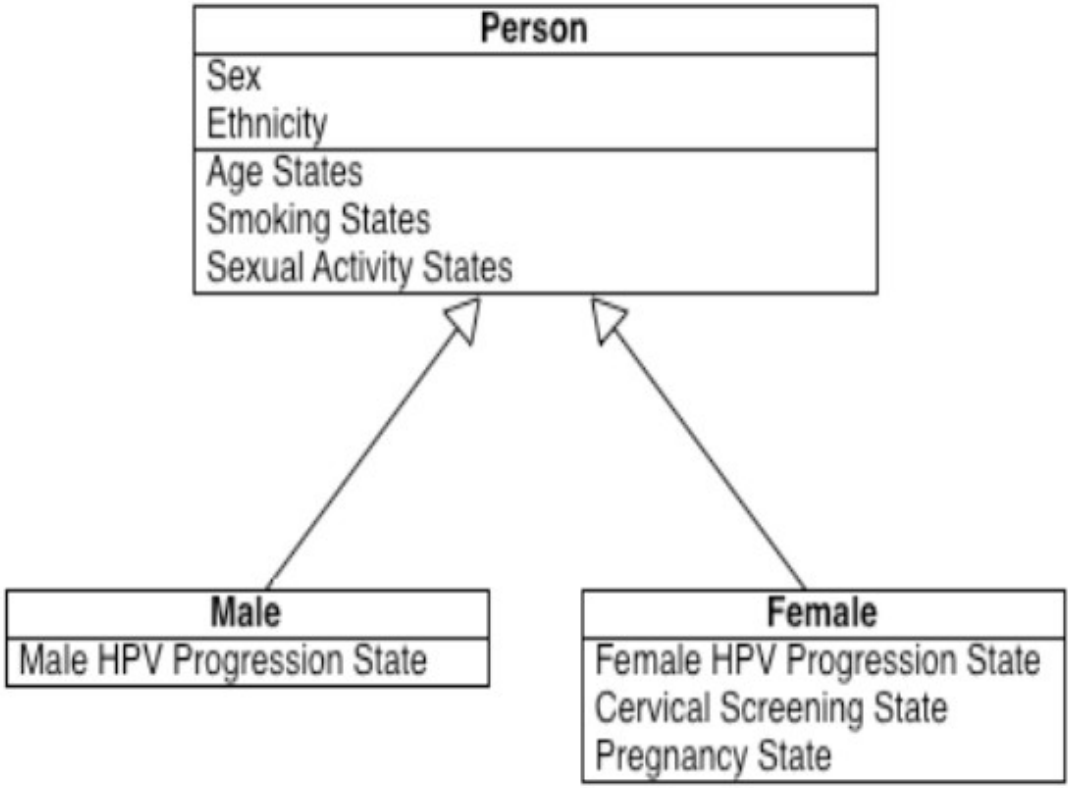
Run: 0 Idle | Time: 0.00 | Simulation: Stop time not set | Memory: 11M of 254M | 0.0 sec

# Health & Cost Implications of Diabetic ESRD

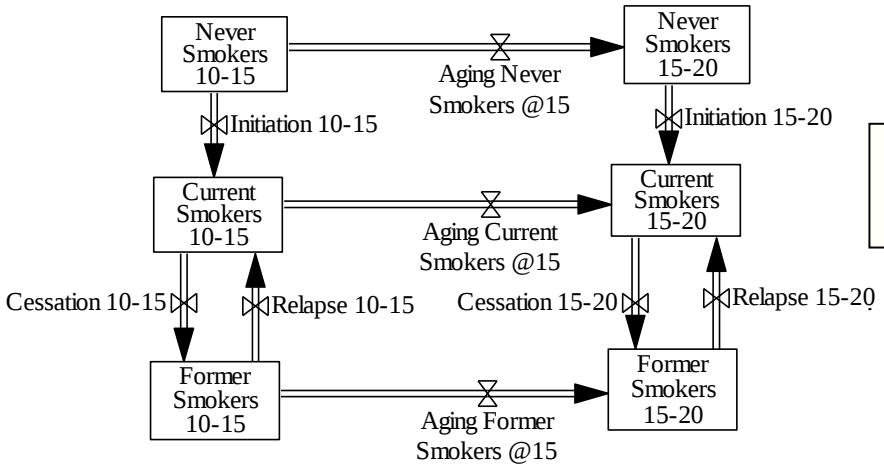


# HPV & Smoking




Person
Sex
Ethnicity
Age States
Smoking States
Sexual Activity States
Male
Male HPV Progression State
Female
Female HPV Progression State
Cervical Screening State
Pregnancy State

# Interacting Individuals




Age: 12.23
Smoker:Never

Age: 87
Smoker:Never

Doctor

Age: 53
Smoker:Curre

Friends

Age: 13.3
Smoker:Current

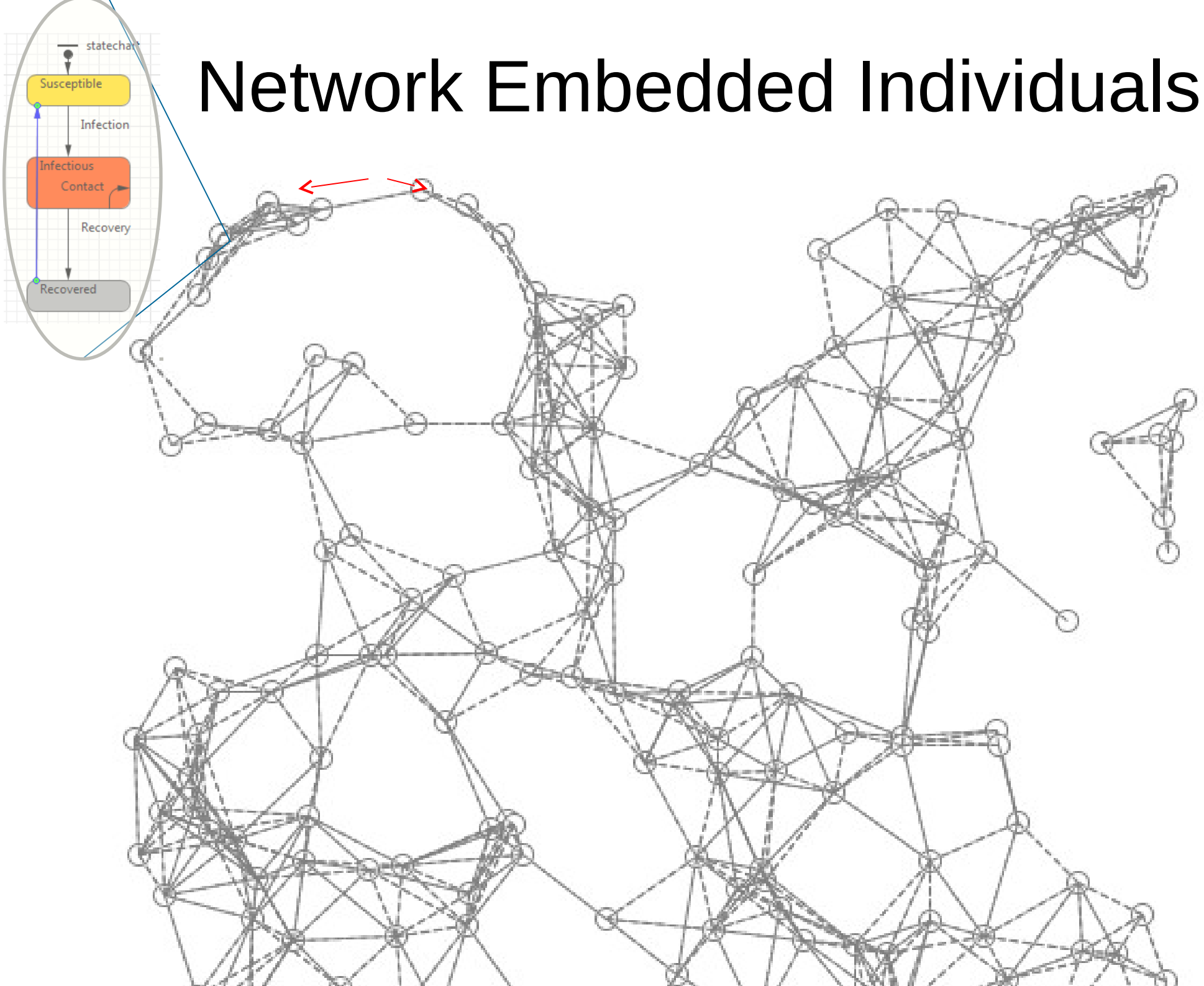
Friends

Parent

Age: 14.01
Smoker:Current

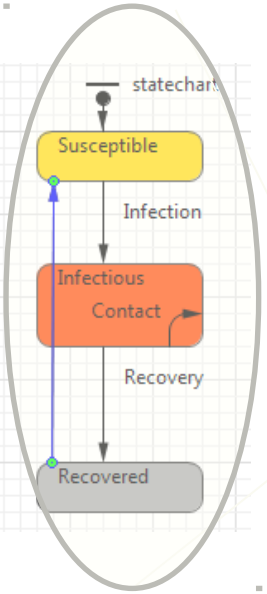
Age: 35.72
Smoker:Former

# Network Embedded Individuals

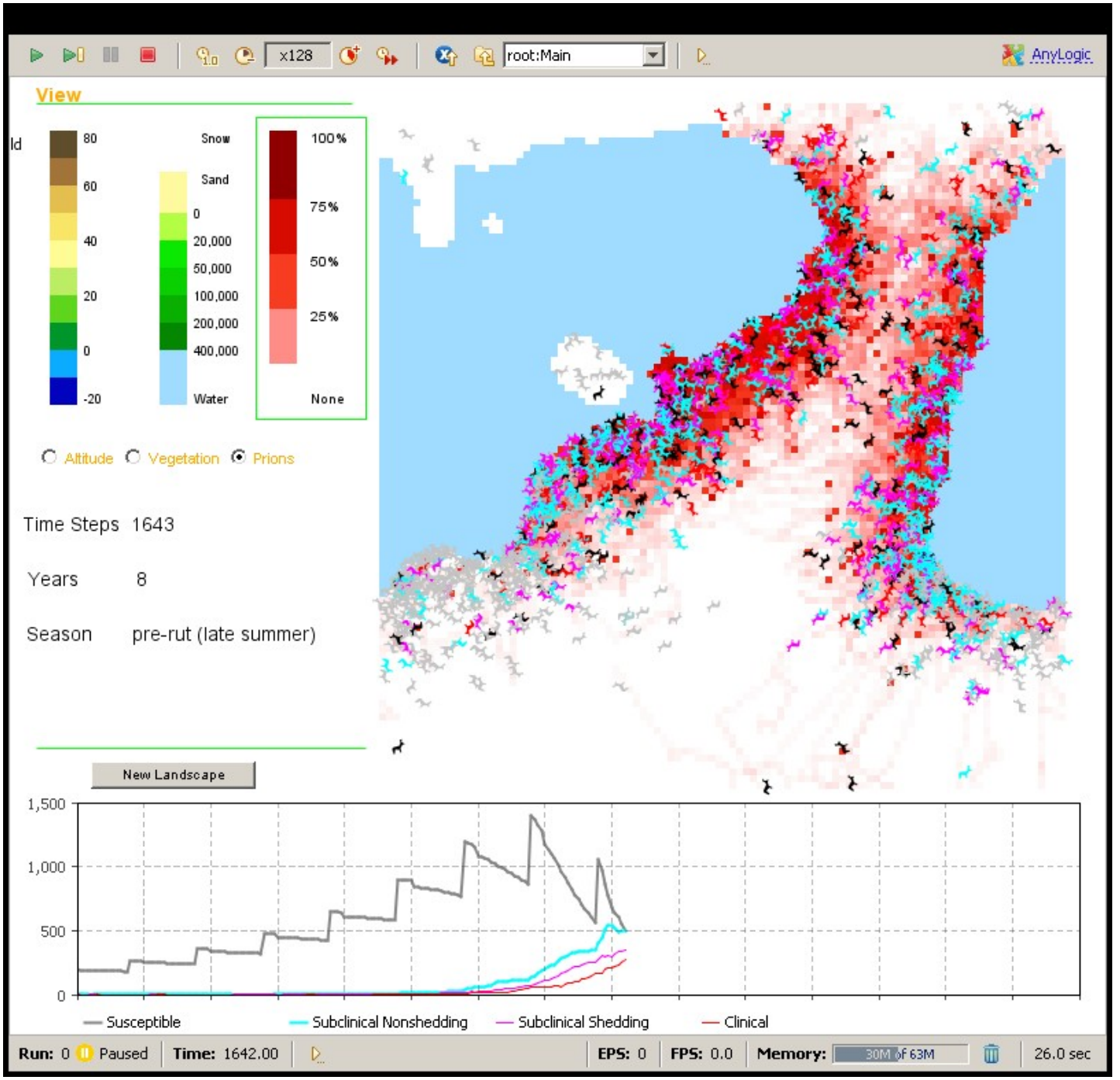


# Irregular Spatial Embedding

# Emergent Behavior in Regular Spatial Embedding




# Aggregate & Spatial Emergence



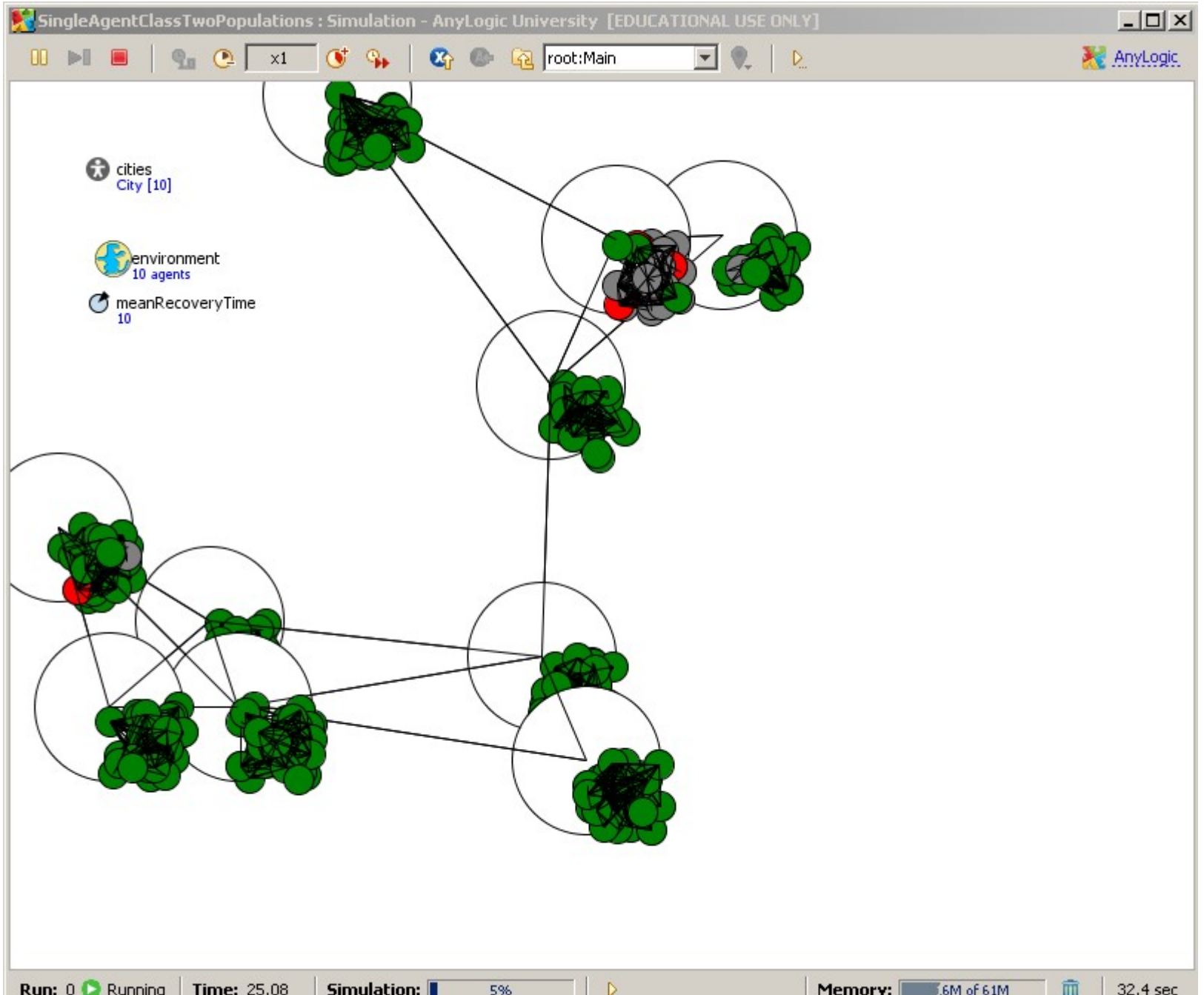
# Emergent Behavior

- “Whole is greater than the sum of the parts”, “Surprise behavior”
- Frequently observed in stock and flow models as interaction between stocks & flows
- In ABMs, we see this phenomena not only at level of aggregate stocks & flows, but – most notably – *between agents*

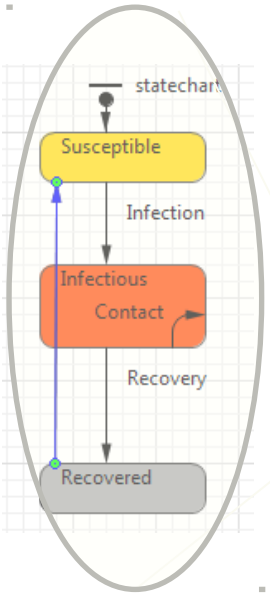
# Matters of Scale

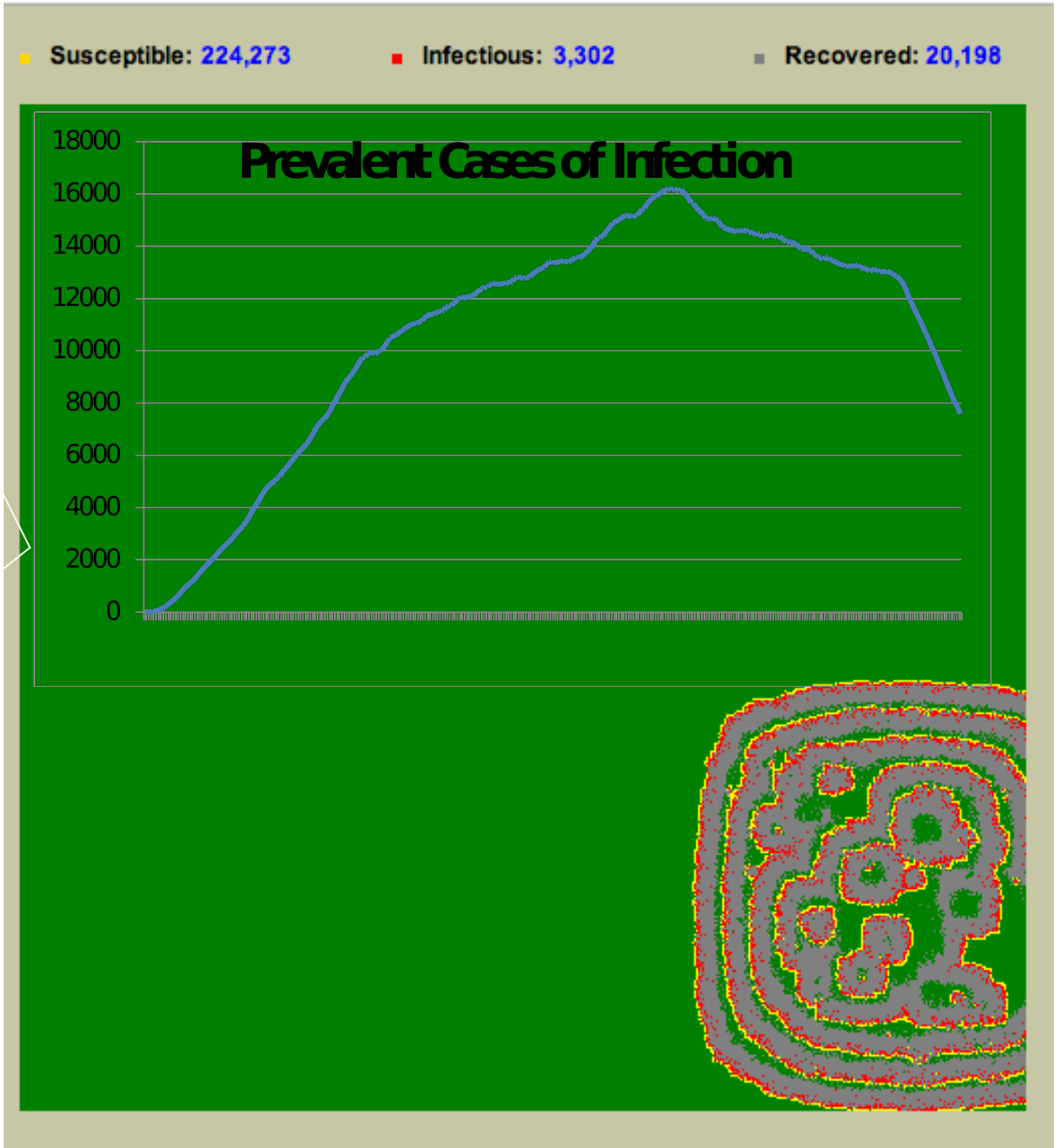
- It is straightforward to set up ABMs so that we have multiple (and possibly nested) levels of context present
  - Individual person / neighborhood / school / municipality / country
  - Individual deer / herd / ecoregion / population
- Emergent behavior frequently differs strikingly by scale
  - By their nature, some concepts (e.g. “Prevalence”) require at least a certain scale of analysis

# A Multi-Level (Dynamic) Model



# Emergent Aggregate & Spatial Dynamics



# Agent-Based Modeling: Key Strengths

- Capacity to represent situated perception, decision making, learning
- Capturing longitudinal progression
  - Lifecourse perspective
  - Ability to calibrate to & validate off of longitudinal data
- Representing spatial/network/multi-level context
- Representing heterogeneity: Scalability & flexibility
  - Multi-comorbidities
  - Examining fine-grained consequences e.g., transfer effects w/i population
- All of above: Support for highly targeted policy planning
- Representing relationship dynamics
- Simpler description of some causal mechanisms
- Familiar perspectives for some stakeholders