Introduction to Agent-Based Modeling

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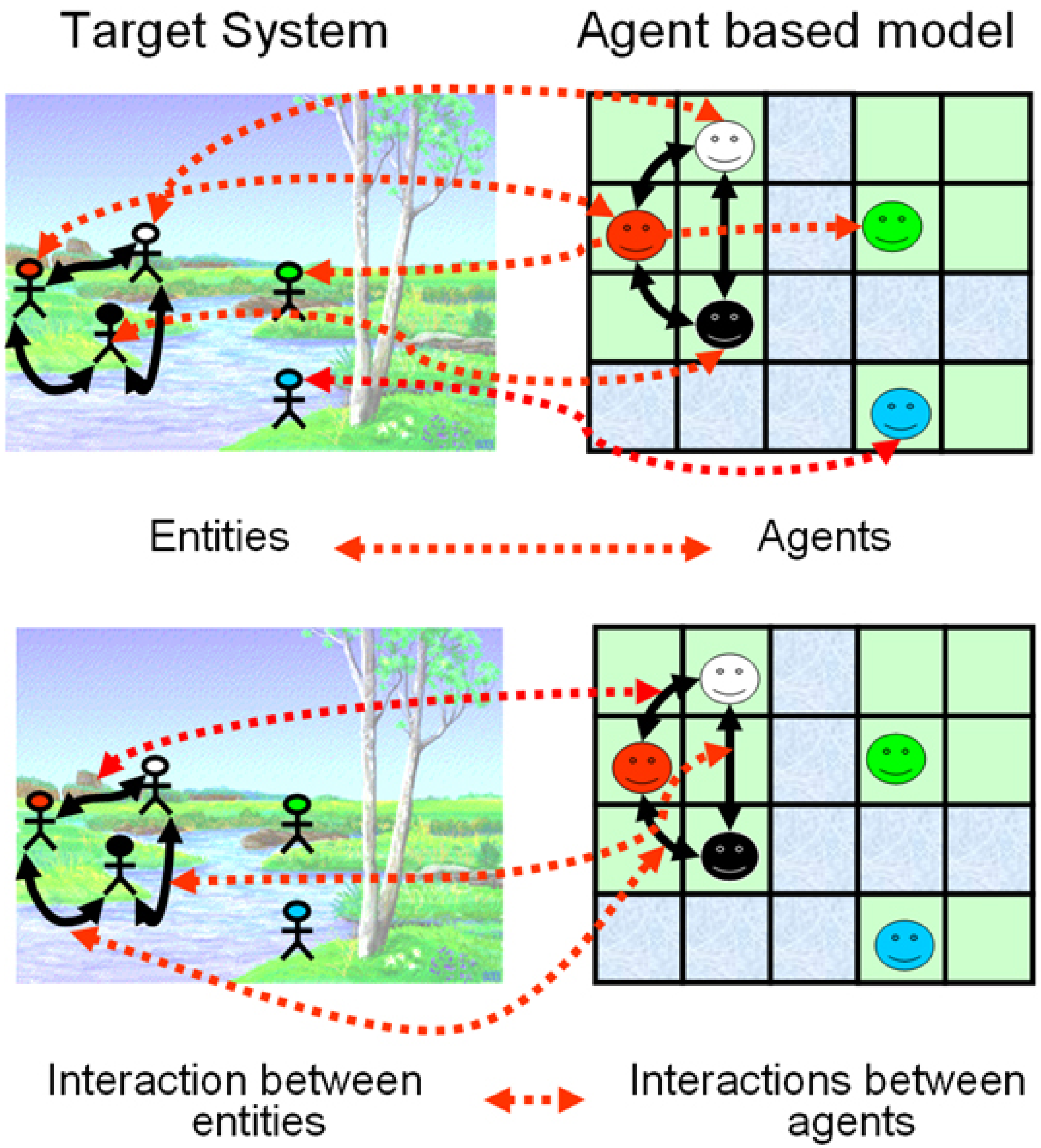
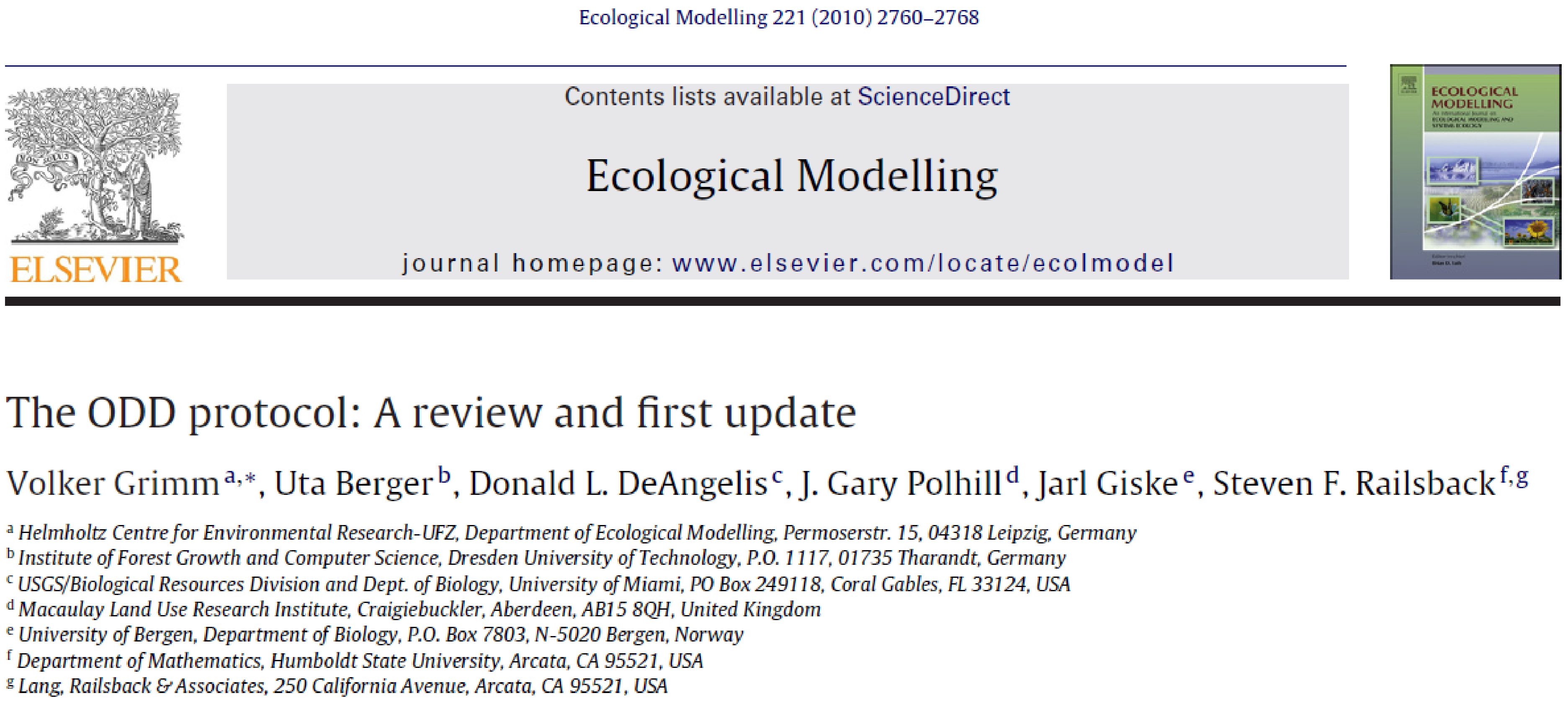
Agent-Based Models

- Involve individuals or “agents”
- Assign rules to describe interactions with other agents and how each behaves with some probability in different scenarios
- Can involve spatial variations
- Can capture behaviors that emerge from many individuals interacting dynamically


Target System
Agent based model
Entities
Agents
Interaction between entities
Interactions between agents

Outlining an Agent-Based Model



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The ODD protocol: A review and first update

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Outlining an Agent-Based Model

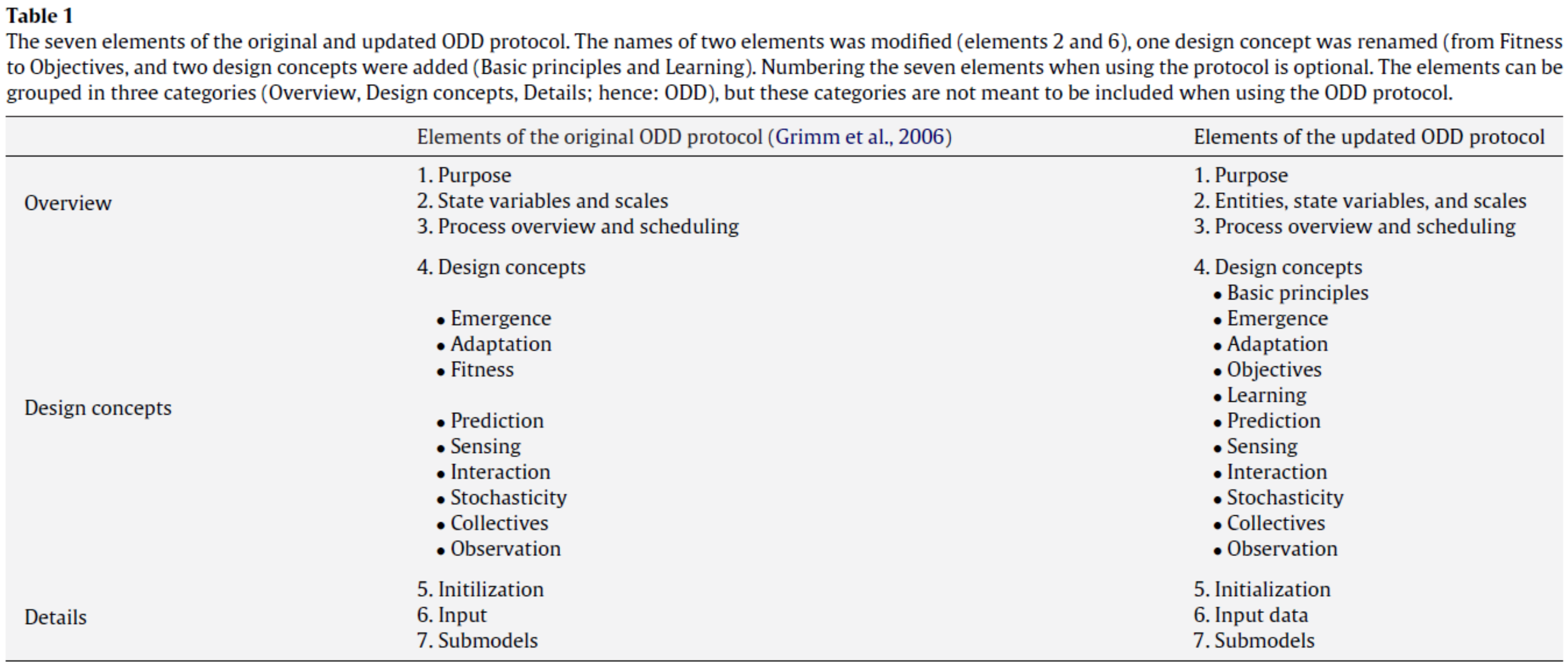
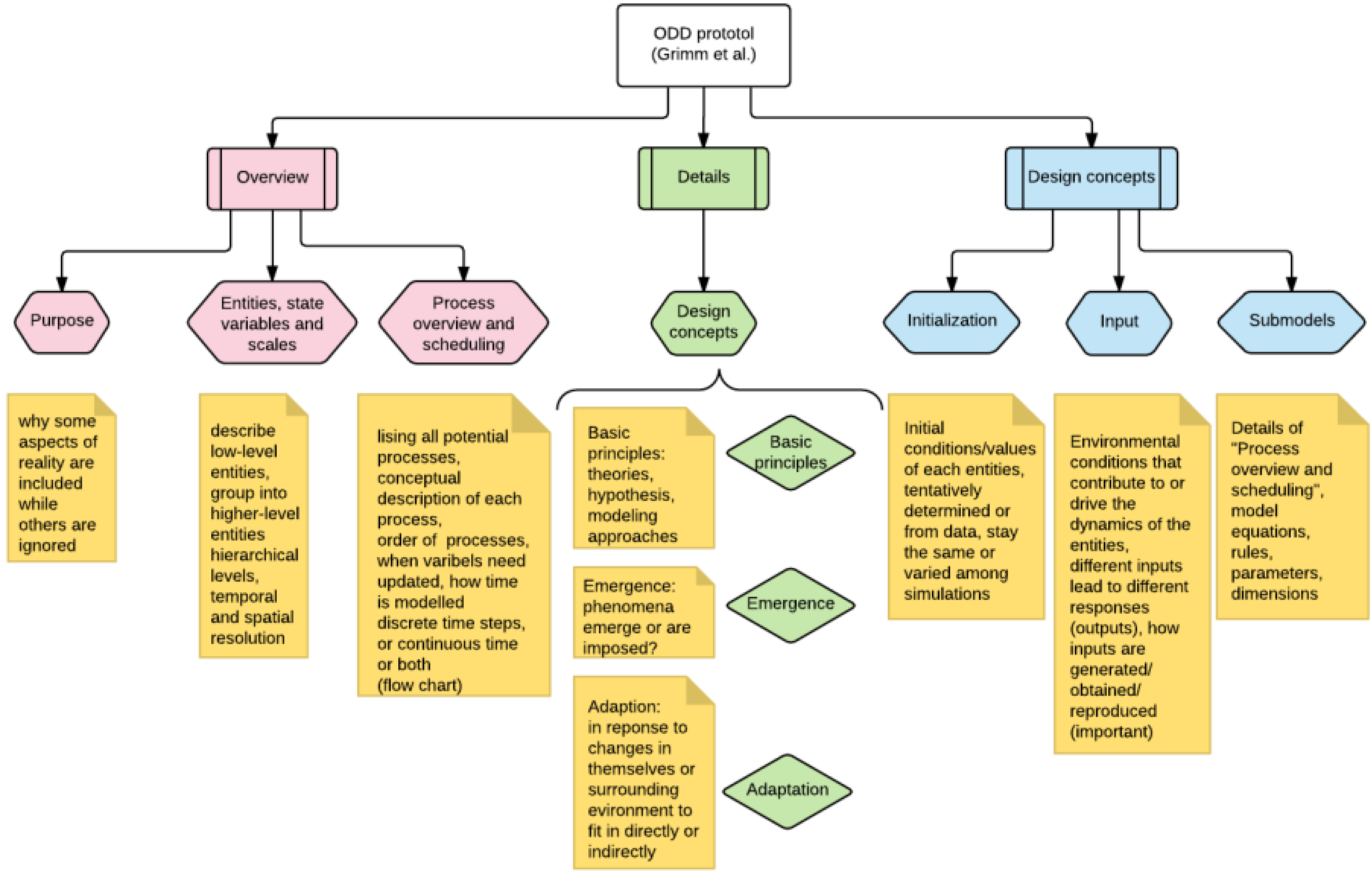
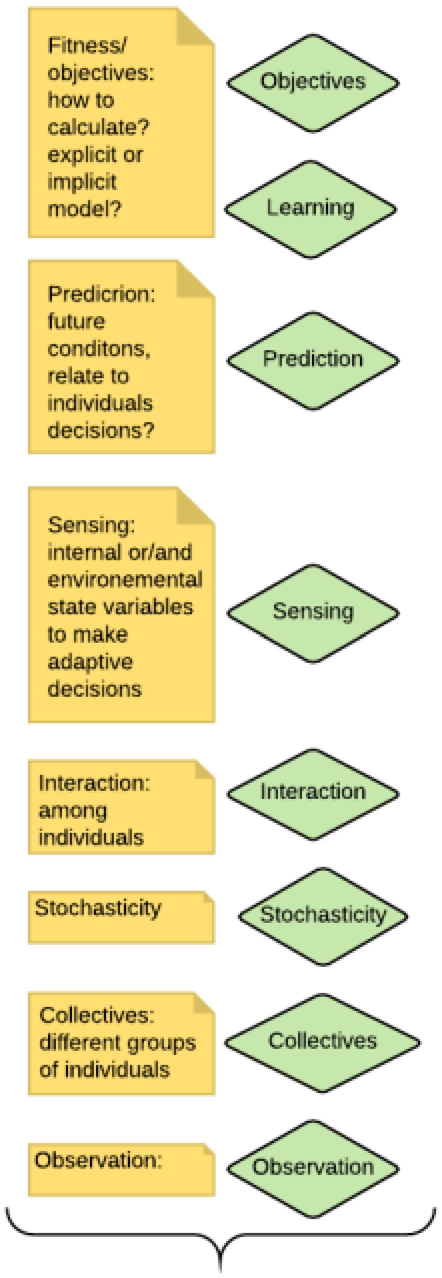


Table 1
The seven elements of the original and updated ODD protocol. The names of two elements was modified (elements 2 and 6), one design concept was renamed (from Fitness to Objectives, and two design concepts were added (Basic principles and Learning). Numbering the seven elements when using the protocol is optional. The elements can be grouped in three categories (Overview, Design concepts, Details; hence: ODD), but these categories are not meant to be included when using the ODD protocol.

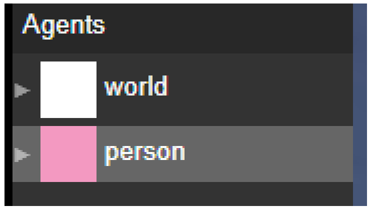
	Elements of the original ODD protocol (Grimm et al., 2006)	Elements of the updated ODD protocol
Overview	1. Purpose	1. Purpose
	2. State variables and scales	2. Entities, state variables, and scales
	3. Process overview and scheduling	3. Process overview and scheduling
Design concepts	4. Design concepts	4. Design concepts
		• Basic principles
	• Emergence	• Emergence
	• Adaptation	• Adaptation
	• Fitness	• Objectives
		• Learning
	• Prediction	• Prediction
	• Sensing	• Sensing
	• Interaction	• Interaction
	• Stochasticity	• Stochasticity
	• Collectives	• Collectives
	• Observation	• Observation
Details	5. Initilization	5. Initialization
	6. Input	6. Input data
	7. Submodels	7. Submodels

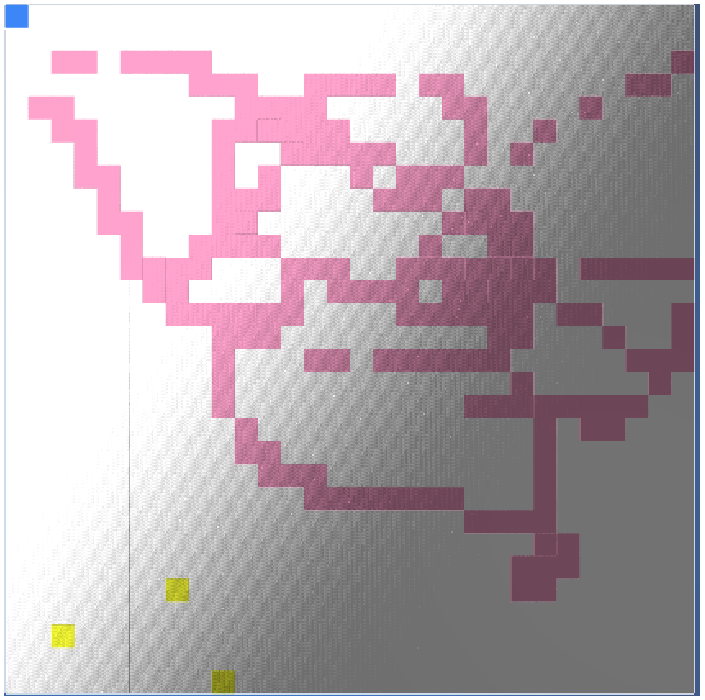

ODD prototol (Grimm et al.)
Overview
Details
Design concepts
Purpose
Entities, state variables and scales
Process overview and scheduling
Design concepts
Initialization
Input
Submodels
why some aspects of reality are included while others are ignored
describe low-level entities, group into higher-level entities hierarchical levels, temporal and spatial resolution
lising all potential processes, conceptual description of each process, order of processes, when varibels need updated, how time is modelled discrete time steps, or continuous time or both (flow chart)
Basic principles: theories, hypothesis, modeling approaches
Basic principles
Emergence: phenomena emerge or are imposed?
Emergence
Adaption: in reponse to changes in themselves or surrounding evironment to fit in directly or indirectly
Adaptation
Initial conditions/values of each entities, tentatively determined or from data, stay the same or varied among simulations
Environmental conditions that contribute to or drive the dynamics of the entities, different inputs lead to different responses (outputs), how inputs are generated/ obtained/ reproduced (important)
Details of "Process overview and scheduling", model equations, rules, parameters, dimensions


Fitness/ objectives: how to calculate? explicit or implicit model?
Objectives
Learning
Predicrion: future conditons, relate to individuals decisions?
Prediction
Sensing: internal or/and environemental state variables to make adaptive decisions
Sensing
Interaction: among individuals
Interaction
Stochasticity
Stochasticity
Collectives: different groups of individuals
Collectives
Observation:
Observation

Object Oriented Agent Cubes: Infection & Recovery Simulation

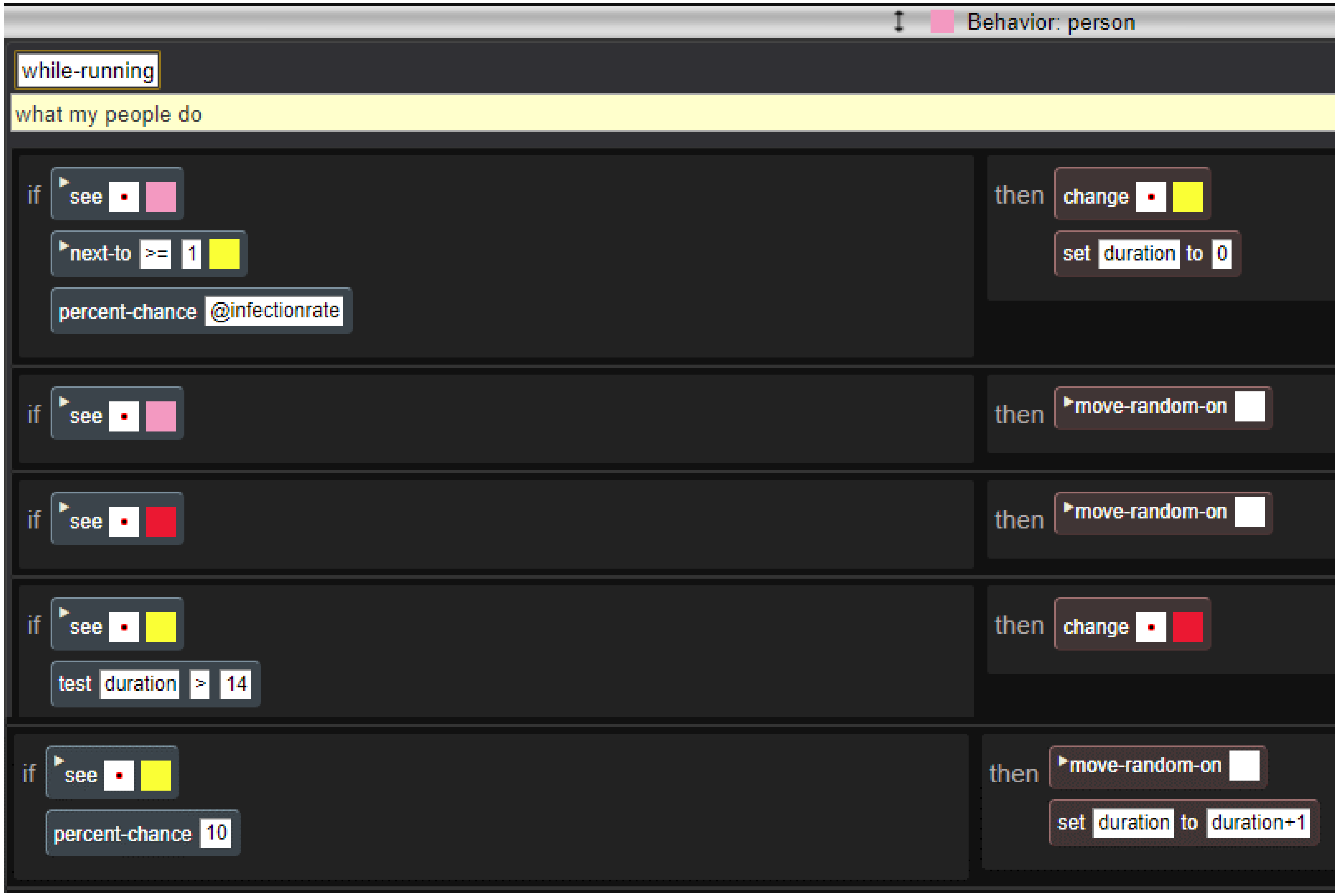
- Purpose: simulate healthy people (pink) getting sick (yellow) and recovering (red)
- Entities: world, person
- States: healthy, sick, recovered
- Initialization:





Infection & Recovery Simulation

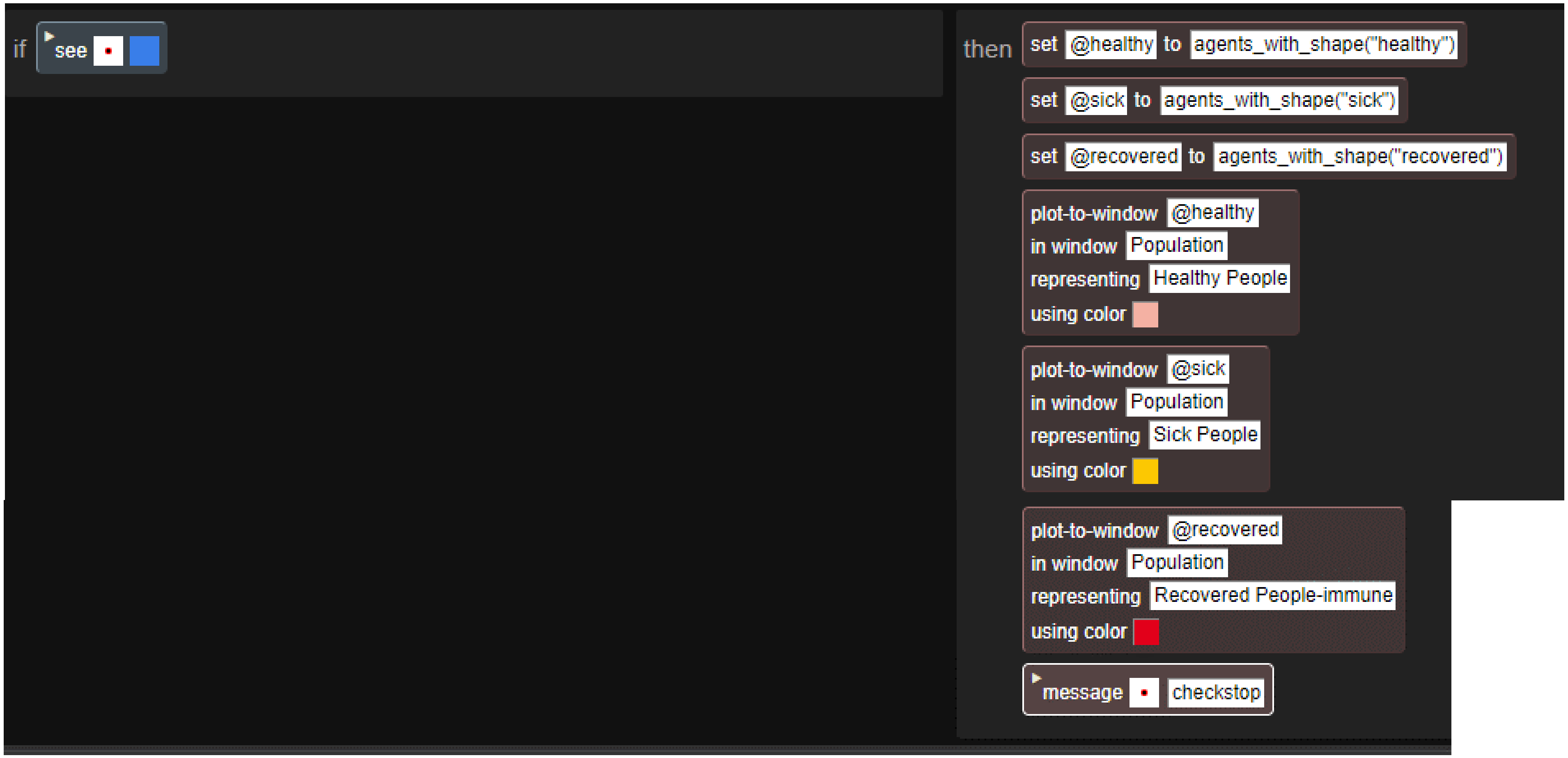
- Rules Part 1:



```
                                              Behavior: person
while-running
what my people do

if  see • 🟪                                  then  change • 🟨
    next-to >= 1 🟨                                 set duration to 0
    percent-chance @infectionrate

if  see • 🟪                                  then  move-random-on ⬜

if  see • 🟥                                  then  move-random-on ⬜

if  see • 🟨                                  then  change • 🟥
    test duration > 14

if  see • 🟨                                  then  move-random-on ⬜
    percent-chance 10                               set duration to duration+1
```

Infection & Recovery Simulation

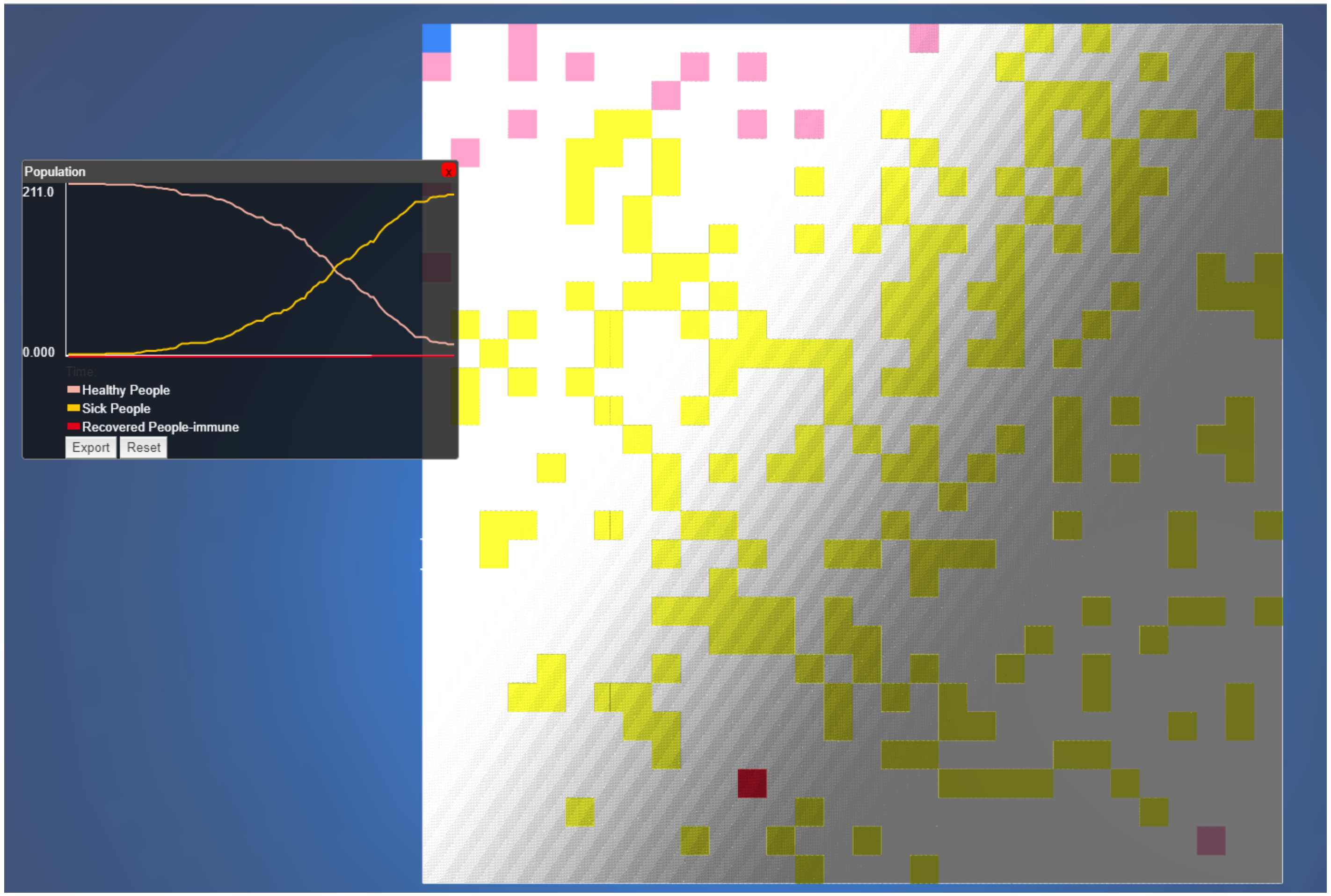
- Rules Part 2:



```
if  see ● ■
then
  set @healthy to agents_with_shape("healthy")
  set @sick to agents_with_shape("sick")
  set @recovered to agents_with_shape("recovered")
  plot-to-window @healthy
  in window Population
  representing Healthy People
  using color ■
  plot-to-window @sick
  in window Population
  representing Sick People
  using color ■
  plot-to-window @recovered
  in window Population
  representing Recovered People-immune
  using color ■
  message ● checkstop
```

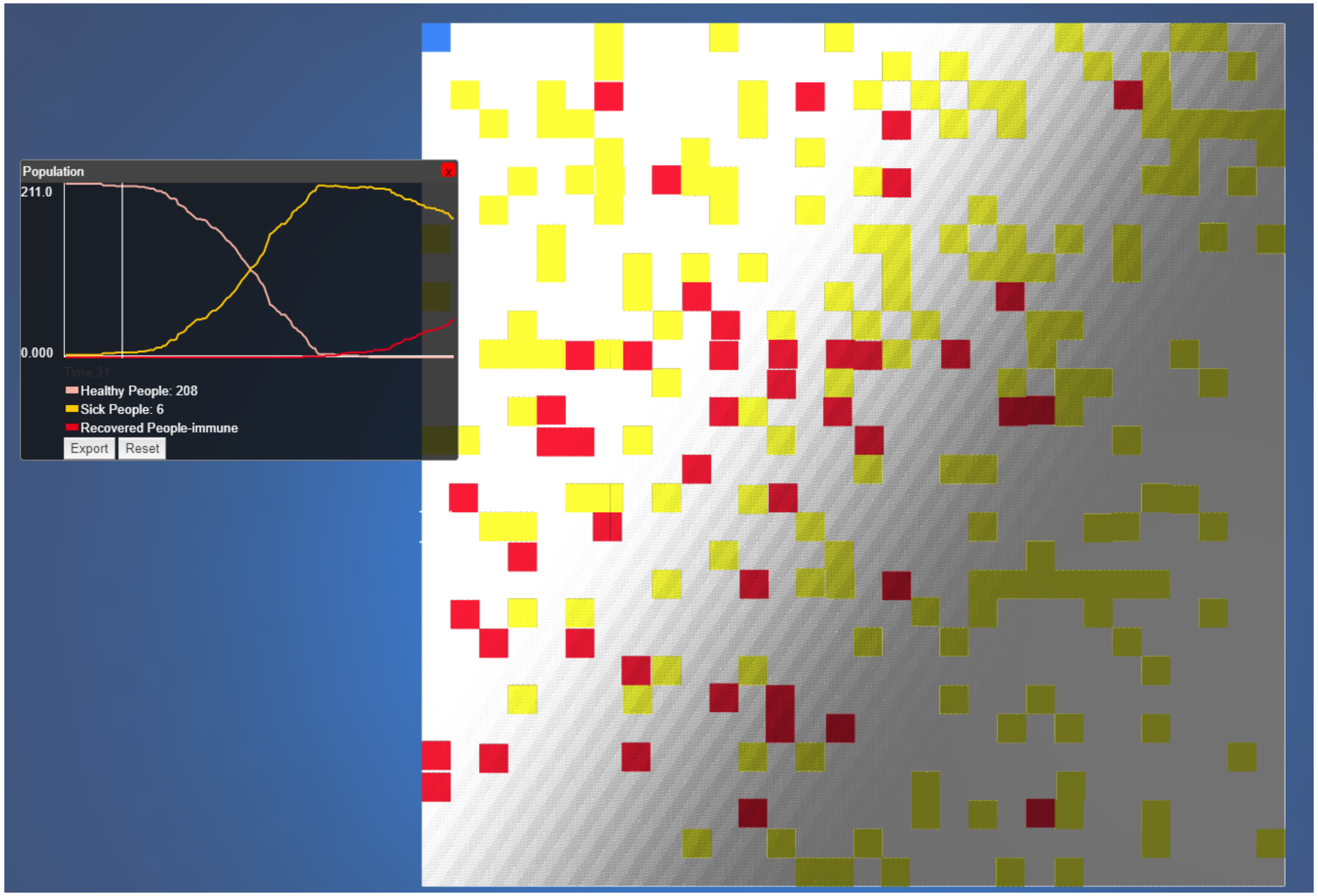
Infection & Recovery Simulation

- Results:



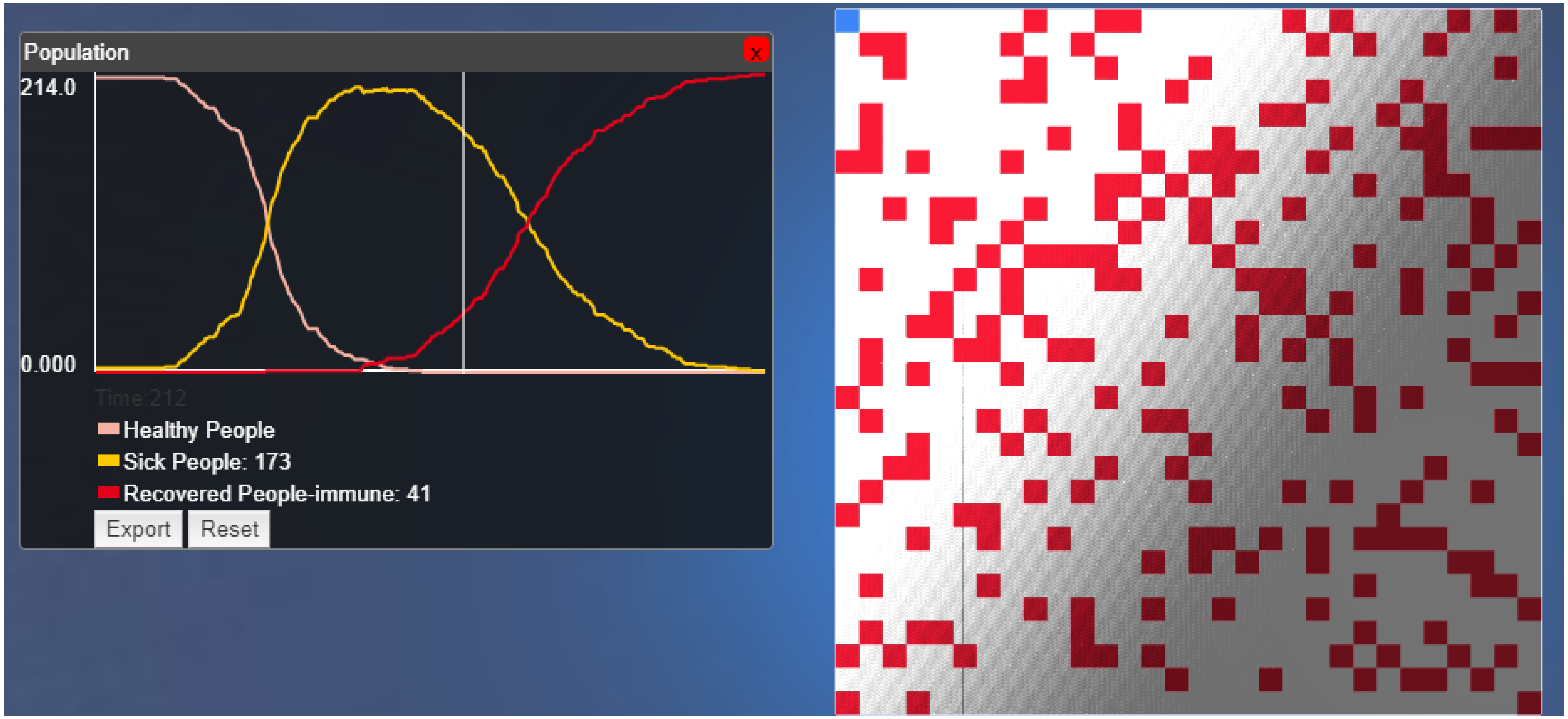
Infection & Recovery Simulation

- Results:



Infection & Recovery Simulation

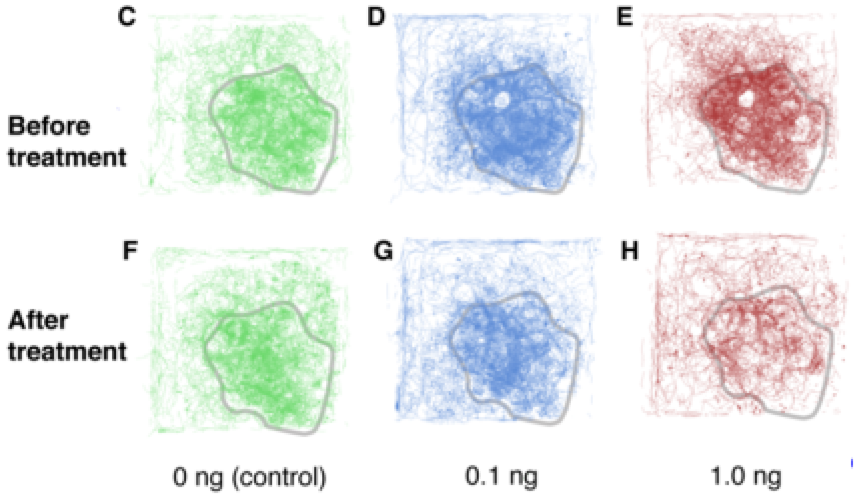
- Results:

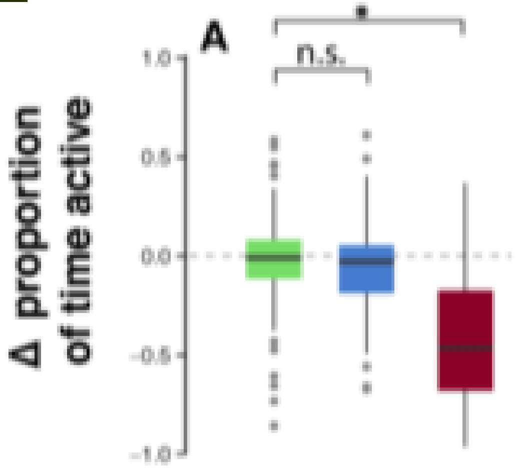


▬ Healthy People
▬ Sick People: 173
▬ Recovered People-immune: 41

Agent-Based Models Case Study

Bumblebees exposed to pesticides





Properties Modeled for Bumblebees

- Stored in a 3D matrix with a column for each bee, a row for each property, and a page for each time step
- X, Y, and Z positions
- Speed
- Angle
- Activity (moving or not)
- Dose of pesticide
- Distance to other bees
- Distance to nest structures
- Probabilities for various rules

Rules for Bumblebees

- Primarily “if statements” that update properties probabilistically
- Bump
  - If the bee is in the nest & less than BeeBodyThreshold from another bee, the two bees are close enough to be in contact
  - All bees have some probability to start moving/keep moving (active) or to stop moving/stay still (inactive)
  - The probabilities are different if they are bumped
  - The probabilities are different before and after pesticide exposure
- Move
  - If the bee is active, it can move with a certain velocity and angle over a certain time frame to its new position

Rules for Bumblebees

- Velocity update
  - Bees can speed up or slow down over time, so this is represented through a velocity distribution function that the bees can sample from
- Angle update
  - The bees may be attracted to nest structures or other bees or may move randomly
  - We adjust factors that modify their attractions and influence the angles as weighted averages of all the attractions