Theory and Practice of Agent-Based Modeling

Goals

What is an agent-based model?

Why construct agent-based models?

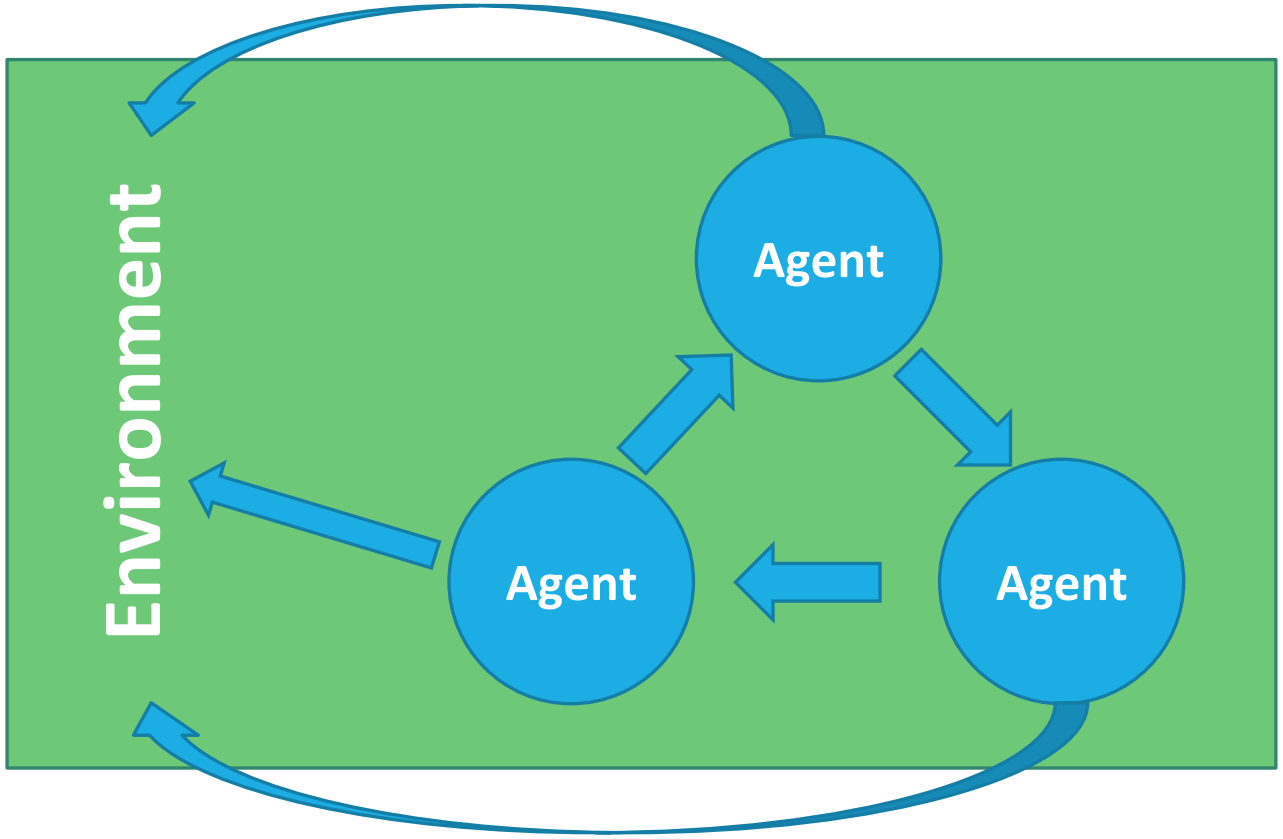
What are the parts of an agent-based model?

How does one construct agent-based models?

What is an agent-based model?

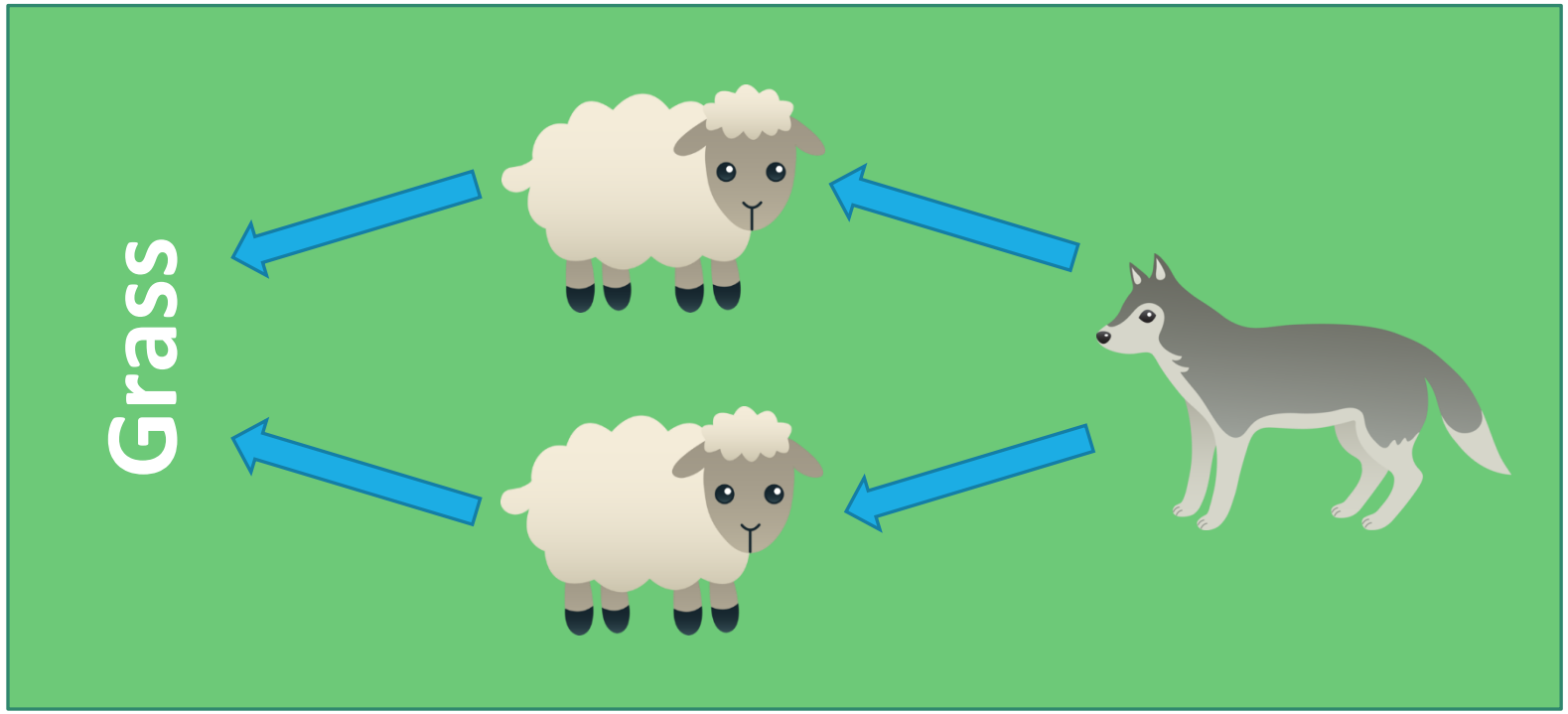
What is an agent-based model?

Computer simulation



What is an agent-based model?

Predator-prey models



Why construct agent-based models?

Why construct agent-based models?

What kinds of questions are agent-based models good for?

How do they help with those questions?

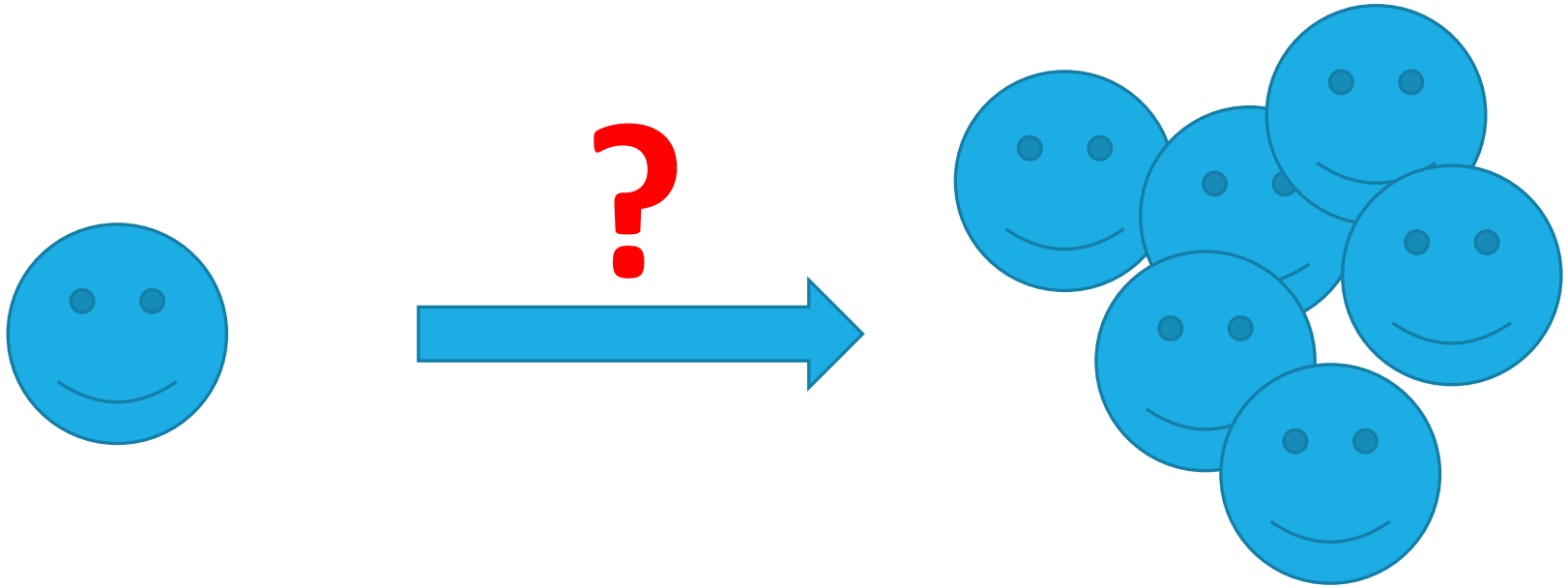
What questions are agent-based models good for?

Wilensky and Rand (2015):

- Integrative questions
- Differential questions

Integrative questions

How does some psychology extrapolate out at group level?

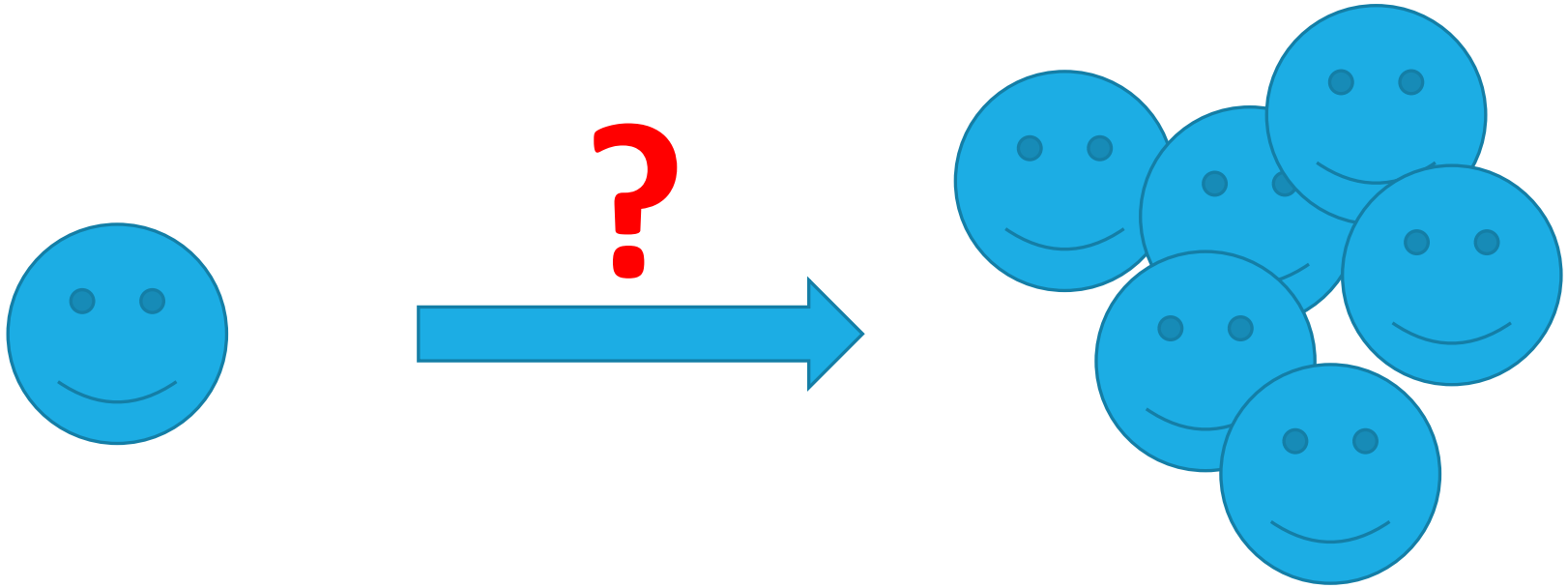


Racial Bias

Racial Inequality

Integrative questions

How does some psychology extrapolate out at group level?

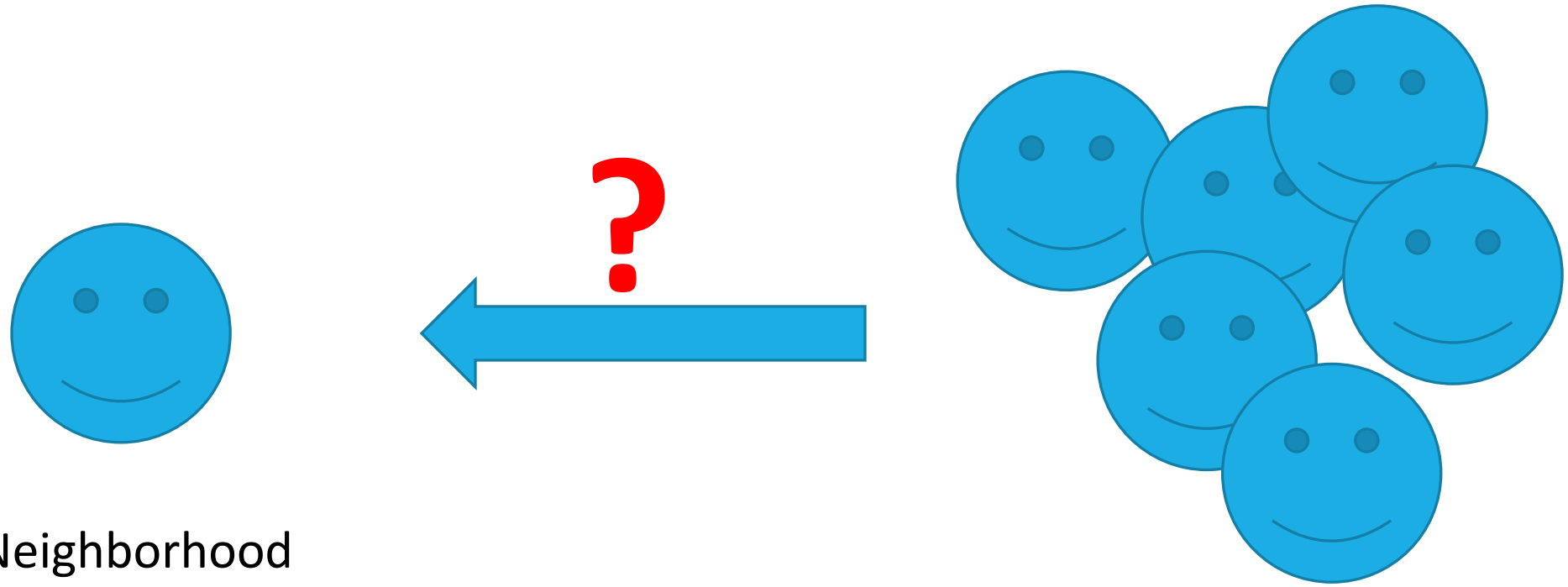


Conformity

Emergence of norms

Differential questions

What psychologies can explain some observed phenomenon?



Mate choice example

What is known:

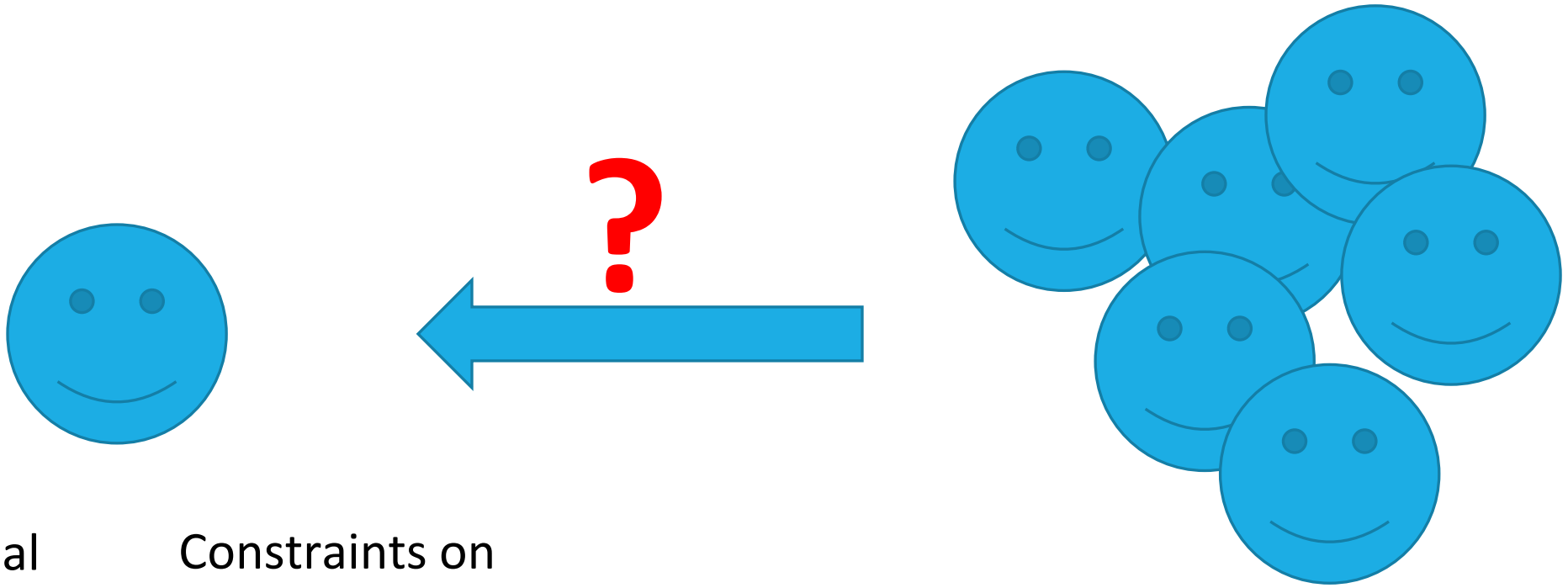
- 1. People have mate preferences
- 2. People select mates
- 3. People's mates do not strongly match their preferences

What could explain this?

- 1. People do not act on their mate preferences
- 2. People attempt to fulfill their preferences, but are constrained

Differential questions

What psychologies can explain some observed phenomenon?



Ineffectual preferences

Constraints on mate choice

Weak preference fulfillment

How do agent-based models help?

An agent-based model is a way of:

- Expressing a hypothesis
- Deriving predictions

How do agent-based models help?

Usually:

- **Hypotheses:** Words
- **Predictions:** Reasoning

Hypothesis 1:

- "**If people do not act on their preferences, then mates will not fulfill preferences**"

Hypothesis 2:

- "**If people are constrained, then mates will not fulfill preferences**"

Agent-based model:

- **Hypotheses:** Computer code
- **Predictions:** Observation

Hypothesis 1:

- **Create world where agents do not act on preferences**
- **Observe**

Hypothesis 2:

- **Create world where agents act on preferences but are constrained**
- **Observe**

Then: compare **predictions** to **data**

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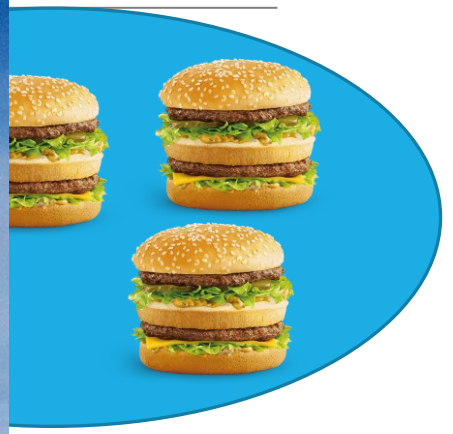


Trivers, 1972

Dawkins, 1976

Coleman and Gross, 1991

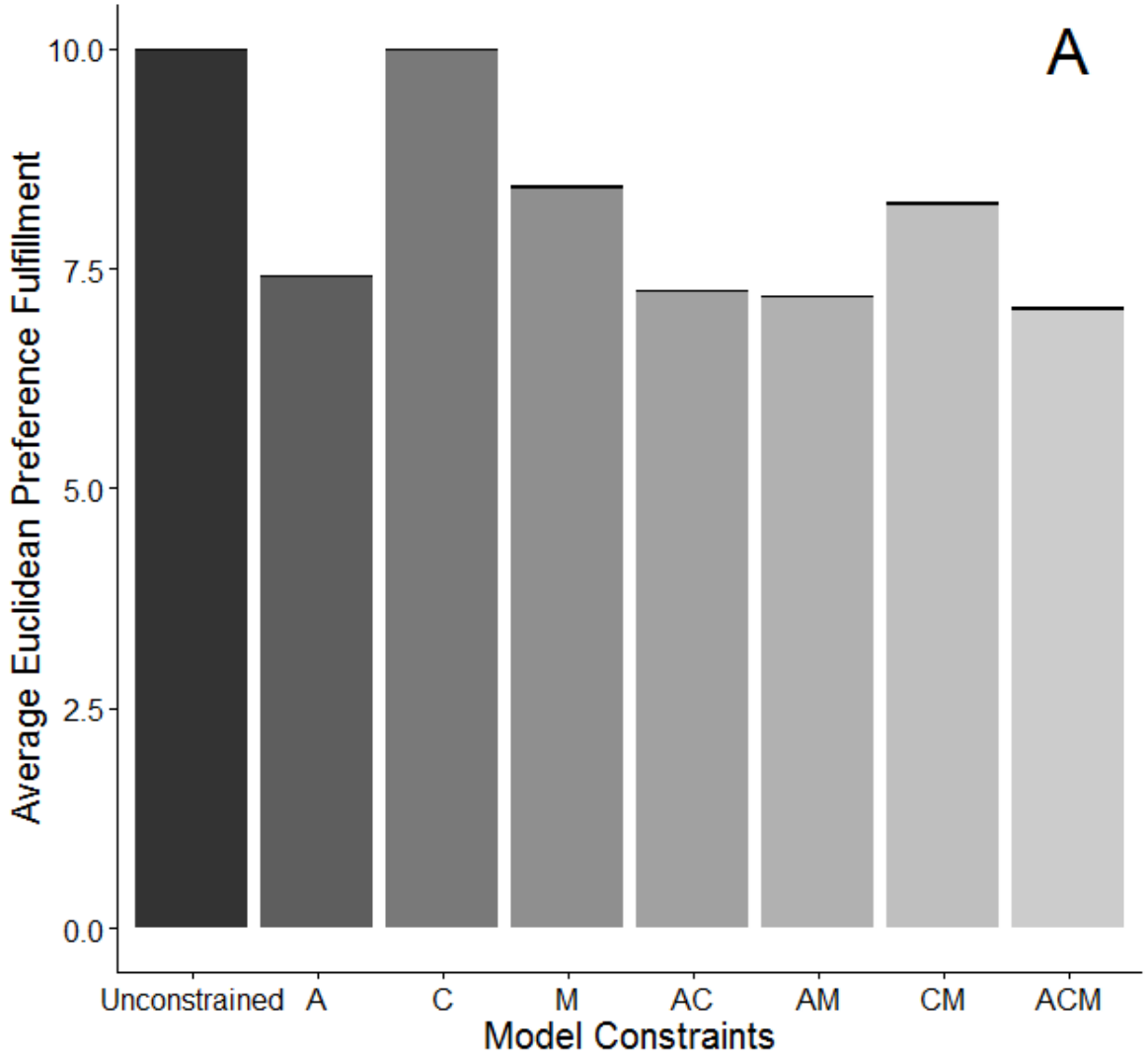
Human reasoning is fallible

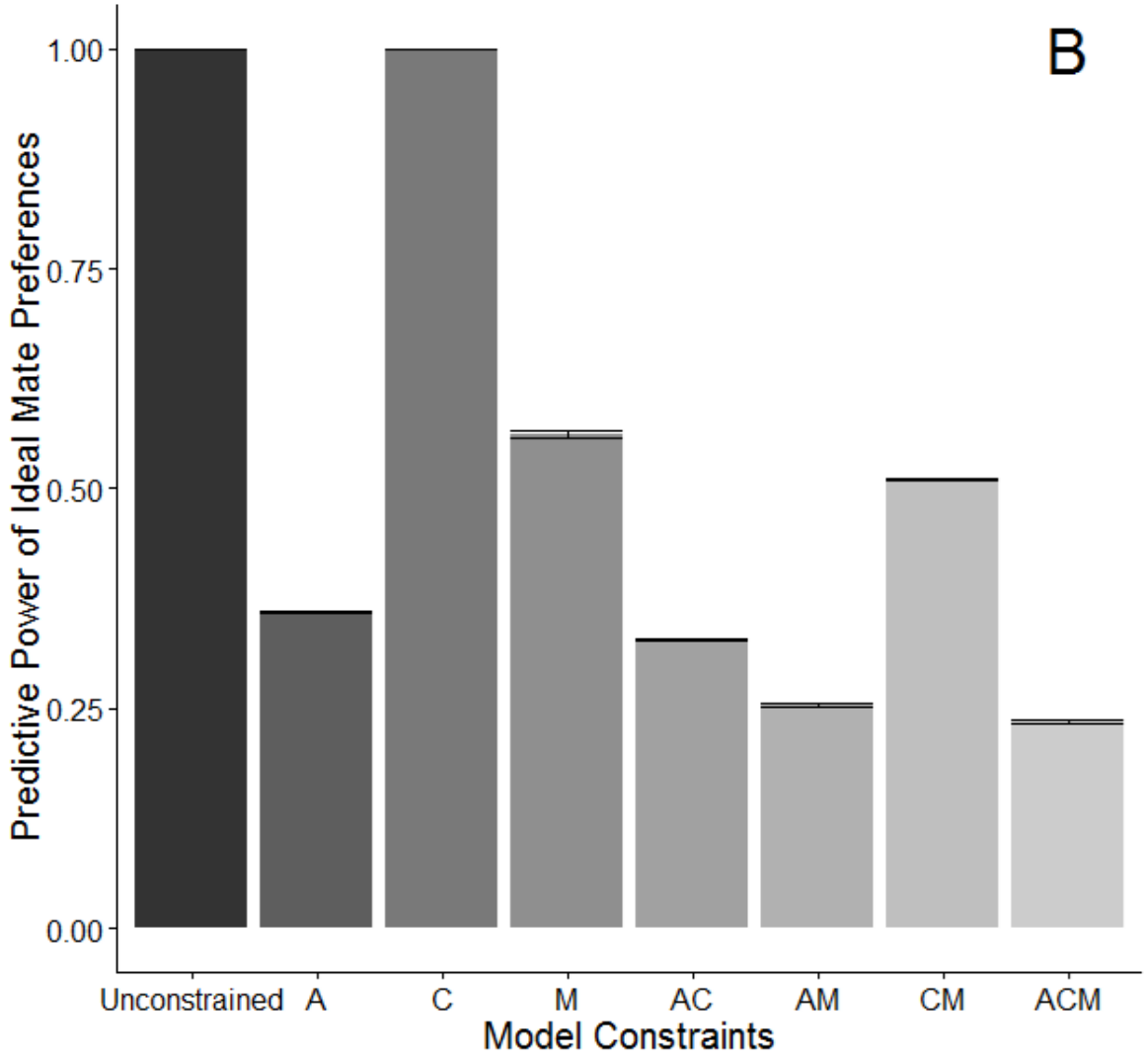
Some hypotheses are too complex to reason through

Mate choice constraints:

- Availability of preference-fulfilling mates
- Presence of competitors
- Requirement of mutual attraction

How predictive should mate preferences be?





Conroy-Beam & Buss, 2019

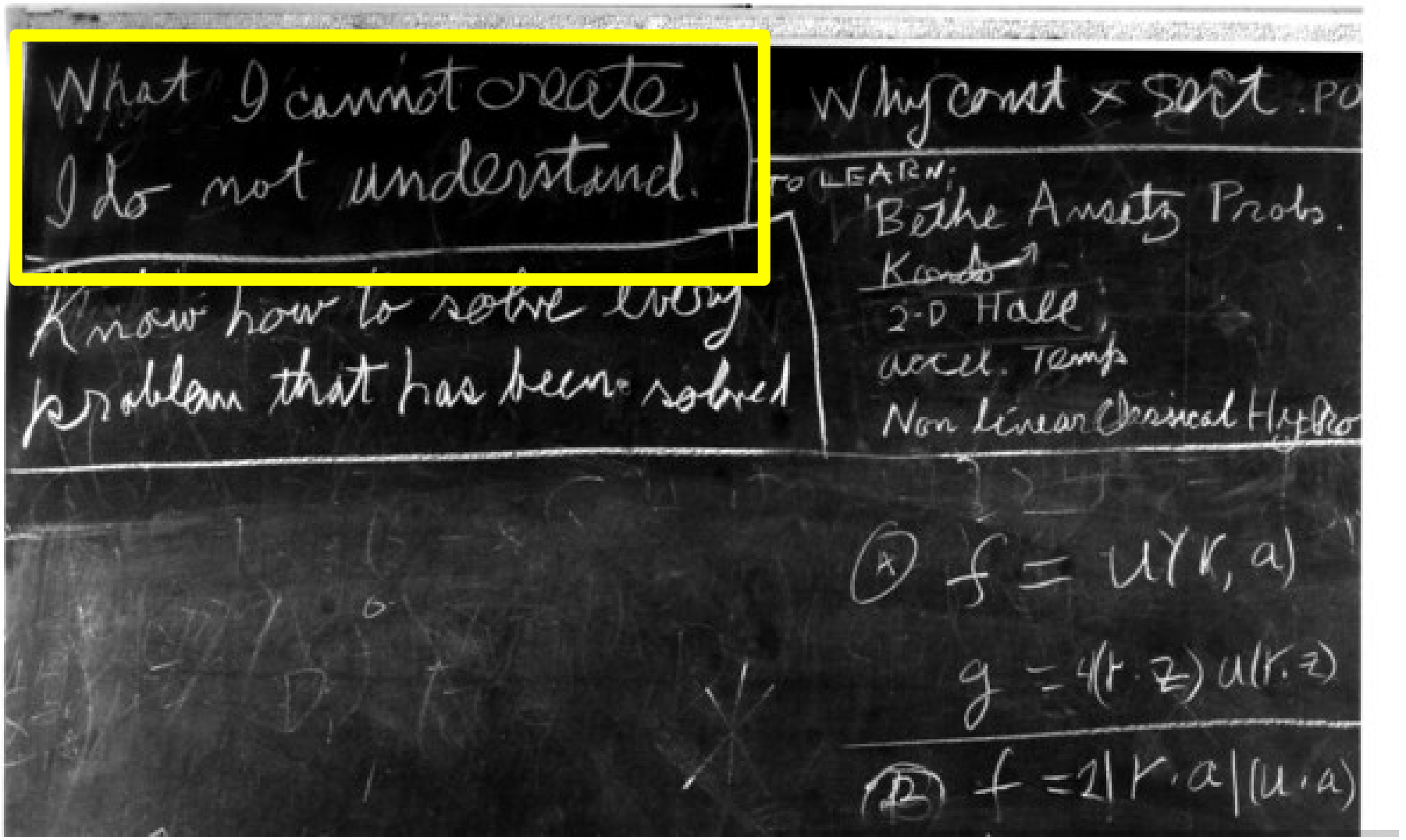
Models facilitate communication

Our assumptions are often implicit

- Computer code forces assumptions to be explicit
- Computer code can be shared with others

Verbal arguments can be misleading

- Computer code speaks for itself
- Computer code can be manipulated


What I cannot create,
I do not understand.
Know how to solve every
problem that has been solved
Why const × sort
TO LEARN:
Bethe Ansatz Probs.
Kondo
2-D Hall
accel. Temp
Non Linear Classical Hydro
(A) f = u(r, a)
g = 4(r·z) u(r·z)
(B) f = 2|r·a|(u·a)

What are the parts of an agent-based model?

What are the parts of an agent-based model?

Key components:

- Agents (and Environments)
- Life cycle

Agents

- Autonomous entity

What is an agent?

Autonomous entity:

- People
- Psychological mechanisms
- Groups of people
- Etc.

Agents

- Autonomous entity
- Decision rules

What are agents like?

Decision rules:

- If hungry, search food
- If find food, then eat
- If not food, then die
- If alive, reproduce
- Etc.

Agents

- Autonomous entity
- Decision rules
- Features

What are agents like?

Features:

- States (Hunger: 0 = Hungry; 1= full)
- Traits (Movement Speed: 0-10 steps/tick)
- Identities (Sheep vs. wolf)

Agents

- Autonomous entity
- Decision rules
- Features
- Environment

What are agents like?

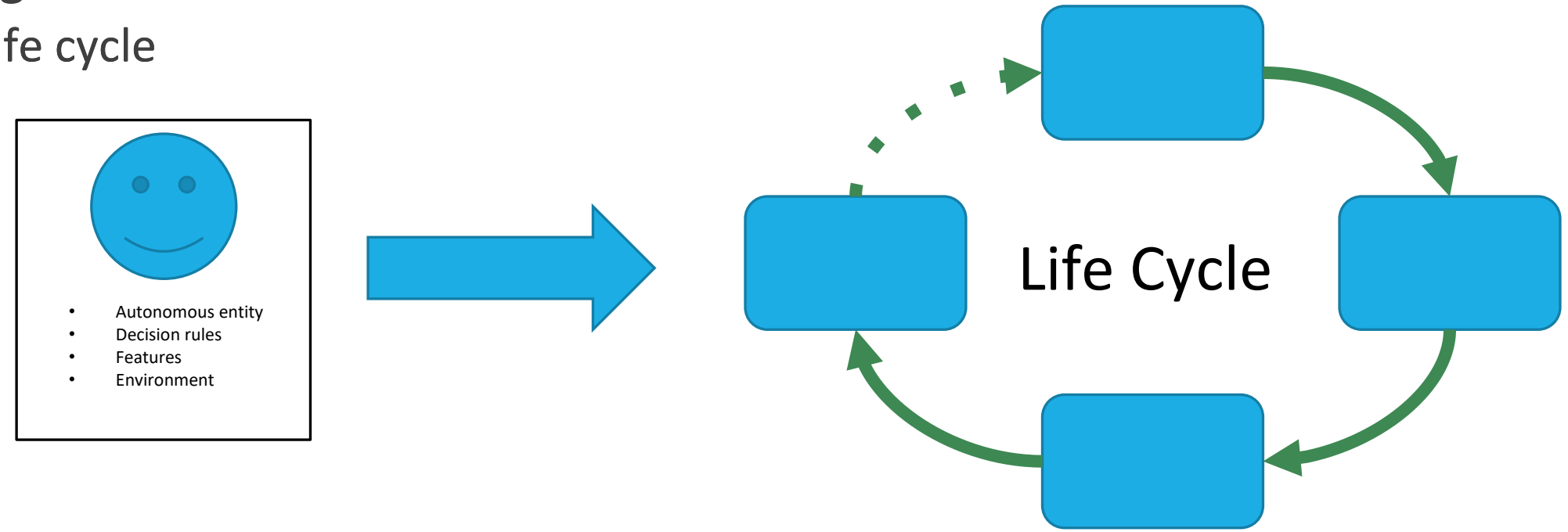
Environment:

- Other agents
- Space
- Opportunities (food, shelter)
- Challenges (barriers, traps)

What are the parts of an agent-based model?

Key components:

- **Agents**
- Life cycle



Life cycles

Repeated series of decisions and behaviors

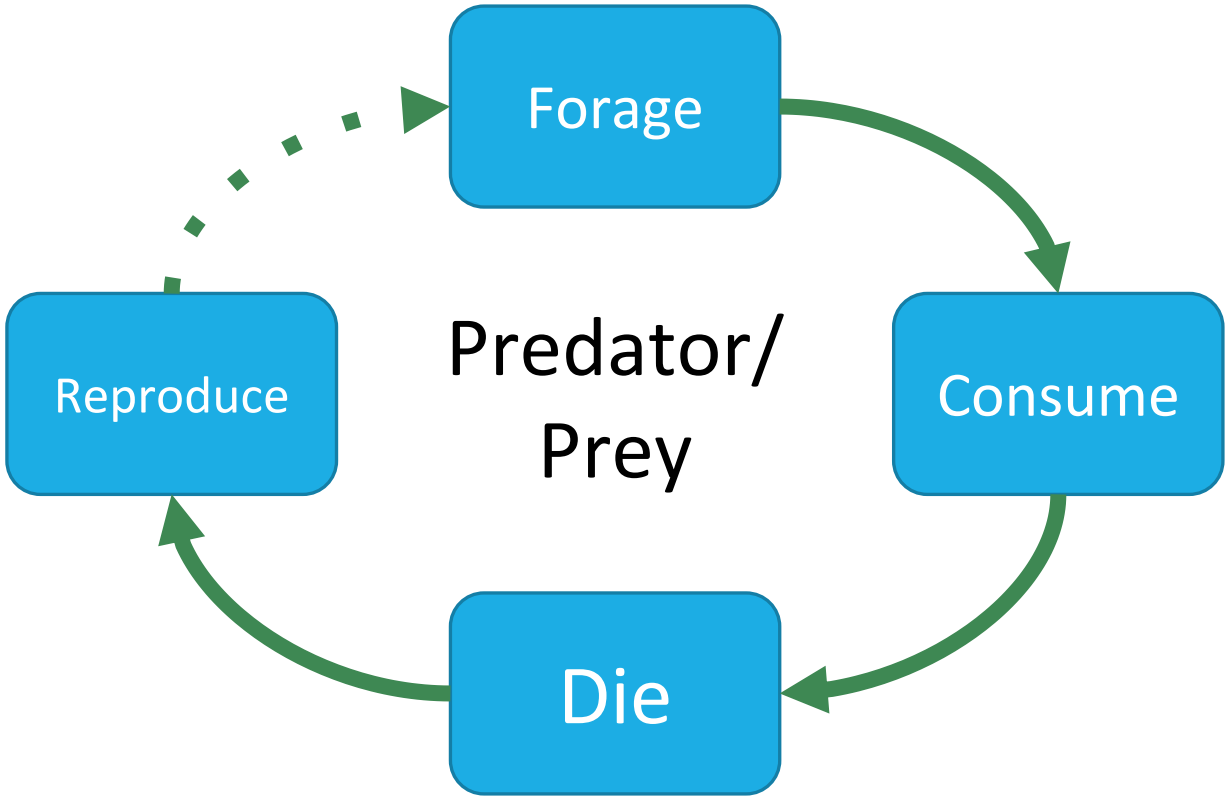
- Broken into discrete stages

Each stage:

- Agents behave/Environments update
- Typically do so:
  - In response to previous stage
  - In preparation for next stage

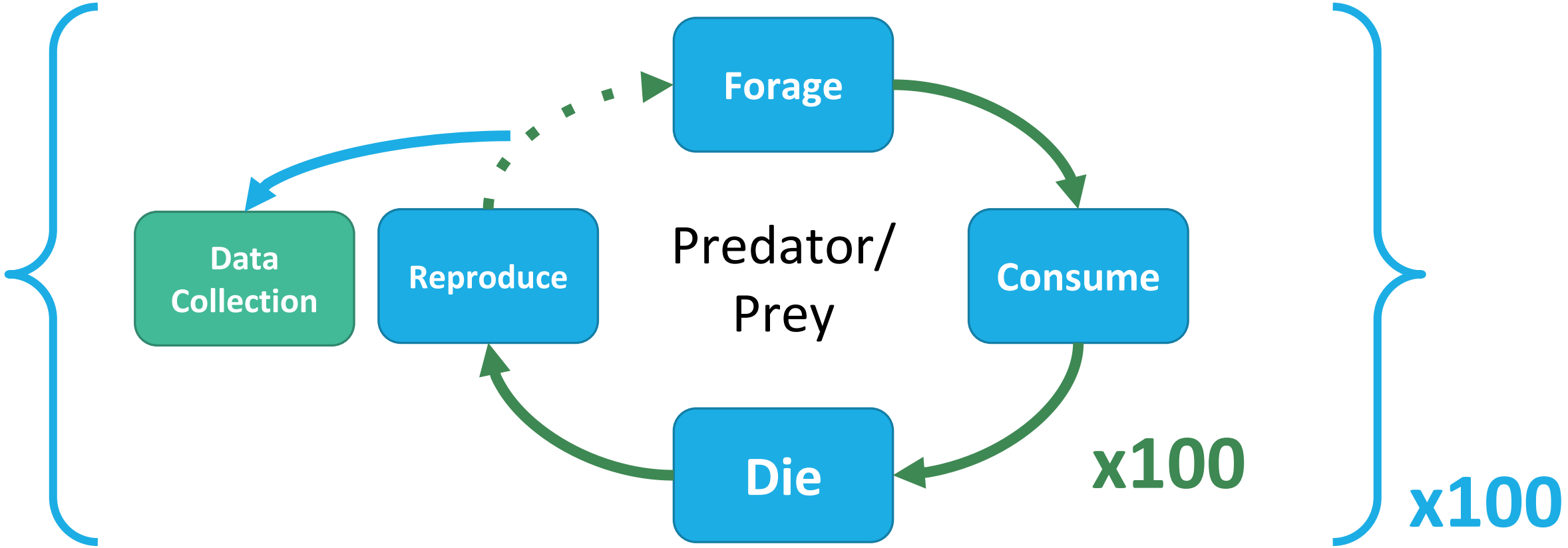
All agents pass through each stage in a specified order

Life cycles



- Forage: Move around and check for food
- Consume: If you find food, eat it
- Die: Die if you didn't find food
- Reproduce: Reproduce if you are still alive

Life cycles


Forage
Consume
Die
Reproduce
Data Collection
Predator/ Prey
x100
x100

How does one create agent-based models?

How does one create agent-based models?

What works for me:

1. Develop a model outline
2. Implement that model outline
   - Languages and software

Model Outline

A thorough but abstract description of your agent-based model

Should be complete enough for another person to write your model for you

Should include:

- Purpose
- Agents and Environment
- Life cycle
- Analysis

Model Outline

Purpose

- 1-3 sentences long
- What psychological process do we think extrapolates into a complex downstream phenomenon?
- What downstream phenomenon do we think is explained by some psychological process?
- What, roughly, will the model do?

Model Outline

Purpose

- Two parts:
  - **1. One-sentence description of the purpose for writing this model**
  - **2. Brief, high-level description of what will happen in the model**

Mate choice:

- "**Determine whether human mate choice is better explained by preference-random mate choice or preference-driven but constrained mate choice. Agents will select mates from a simulated mating market incorporating realistic constraints; mate choices will be either random or based on simulated mate preferences**"

Model Outline

Agents and Environment:

- A complete description of the agents and their environment
- Everything necessary to generate your agents

Should include:

- Population size and characteristics
- Agent features
- Environment features

Model Outline

Agents and Environment:

- A complete description of the agents and their environment
- Everything necessary to generate your agents

Predator/prey model:

- “A population of 100 agents will be generated; 90 of these agents will be “sheep”, 10 will be “wolves.” Agents can be hungry or sated; all agents will start off hungry. Each agent will have a unique location in a 2-D field of grass, specified by X and Y coordinates. Agents will also have a food check variable that indicates whether there is food at their current location. For sheep, only grass counts as food; for wolves, only sheep count as food.”

Model Outline

Life cycles:

- A description, stage-by-stage, of what will happen throughout the life cycle

Mate choice:

"1. Compute attraction
2. Select mates
3. Reproduce
4. Die

#Computing attraction#

Each agent will compute how attracted they are to all opposite-sex agents. Attraction will be calculated as the summed product of agent preferences and potential mate traits"

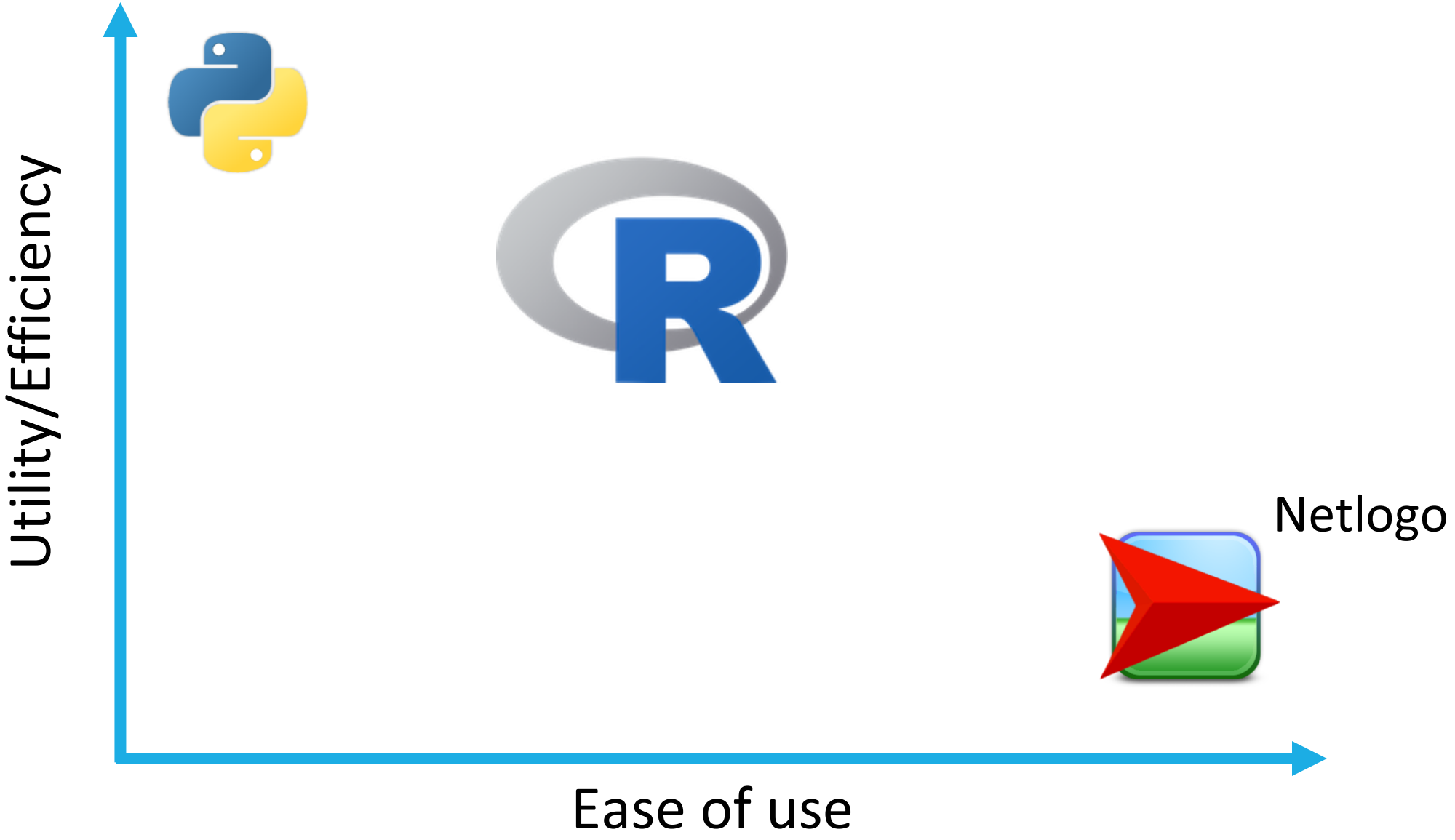
Model Outline

Analysis

- A description of what model criteria will be analyzed and how

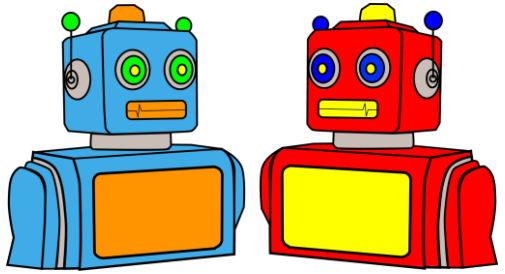
Predator/prey:

- “At the end of each generation, the model will save (1) the amount of grass remaining uneaten, (2) the population size of sheep, and (3) the population size of wolves. After all generations are complete, the model will plot changes in these values across generations.”

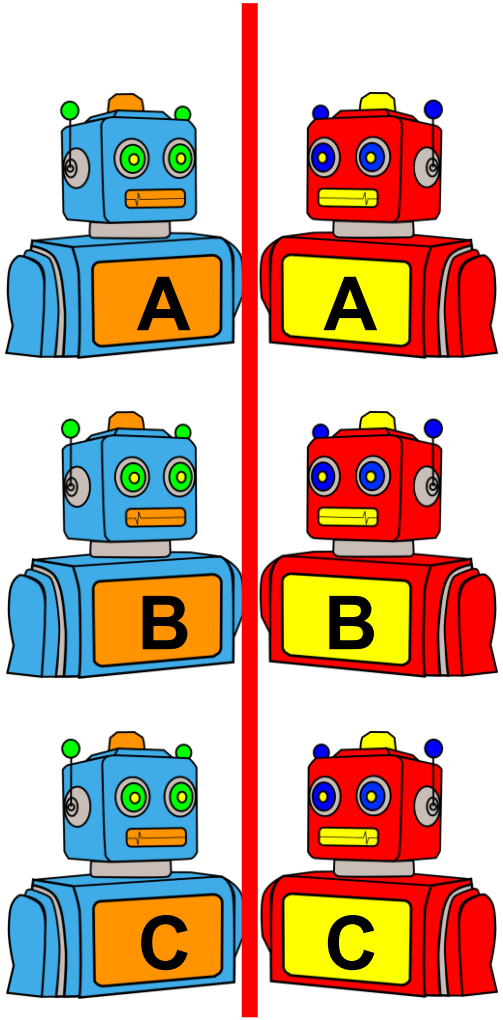

Utility/Efficiency
Ease of use
Netlogo

“Couple Simulation”

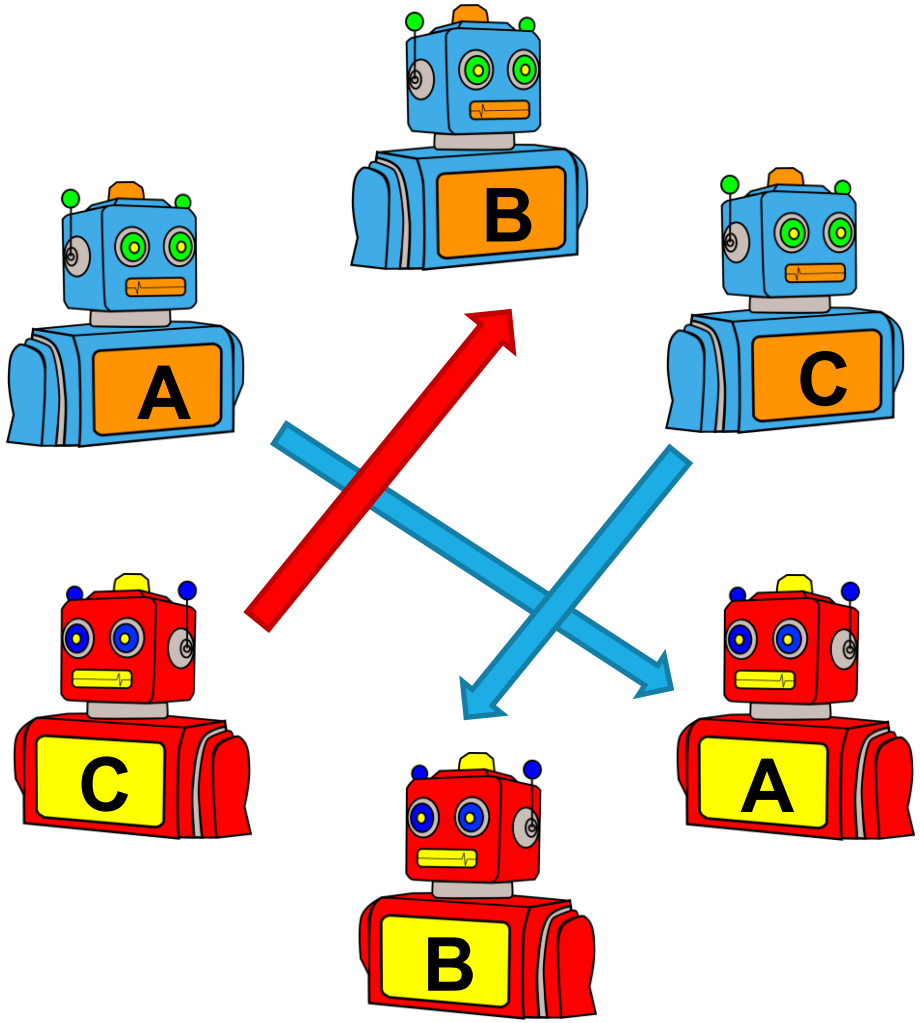
P T P T



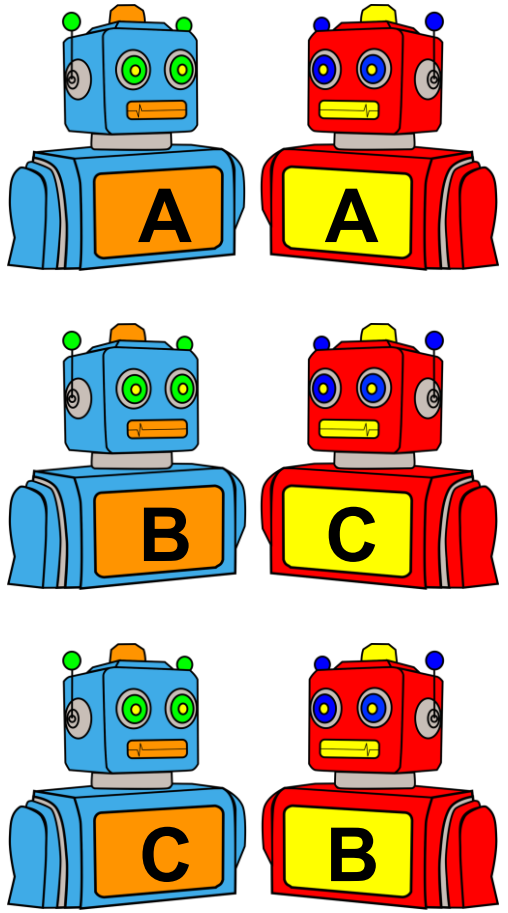
P T P T



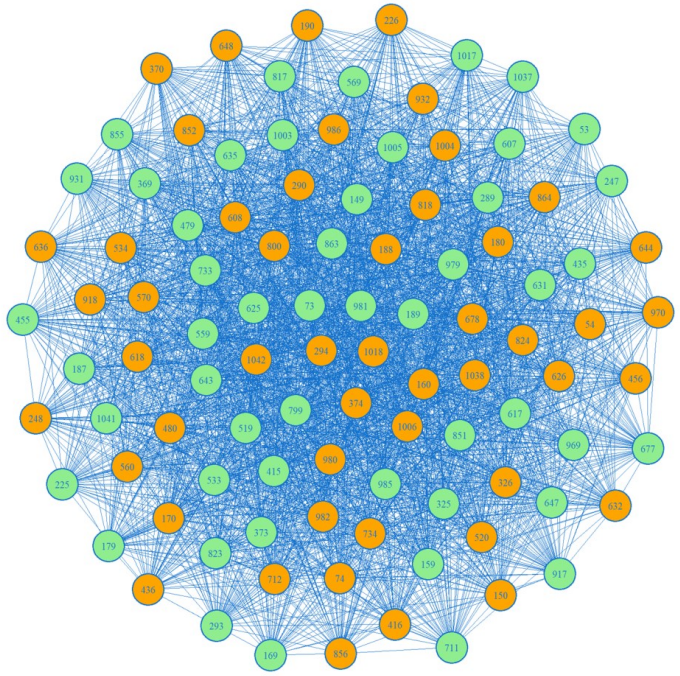
1. Observe True Relationships



2. Simulate Mating Market



3. Assess Accuracy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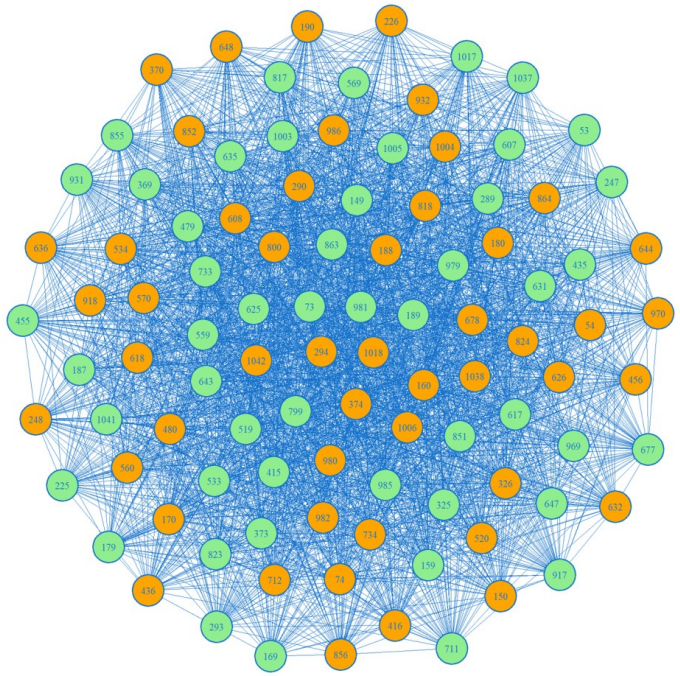

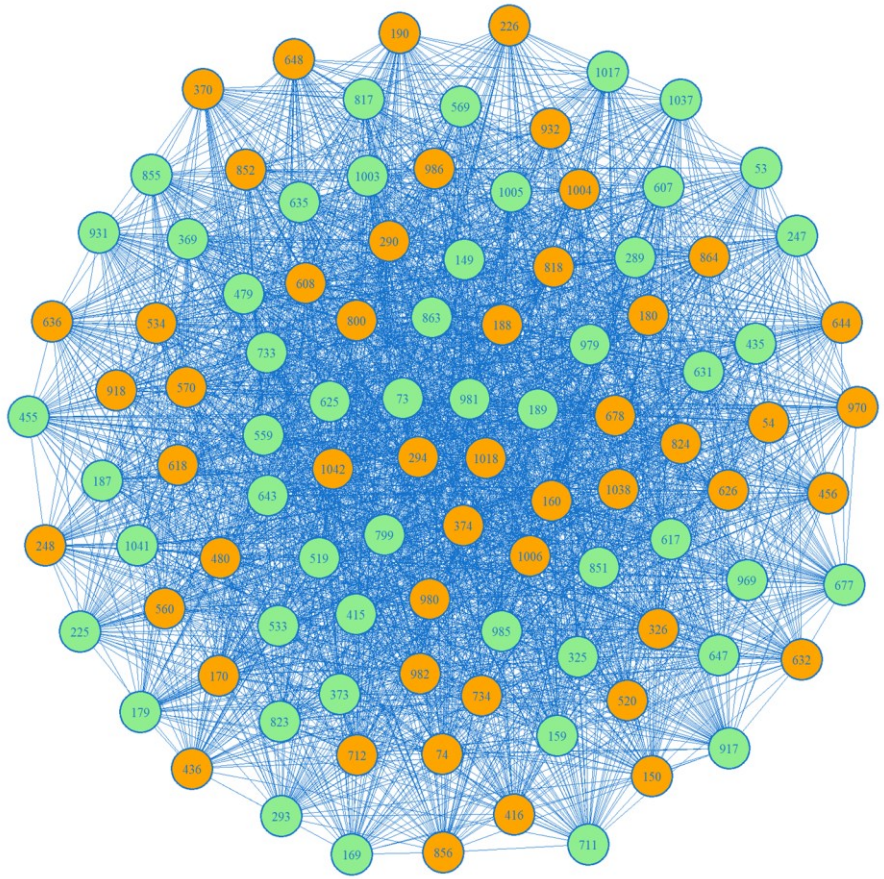

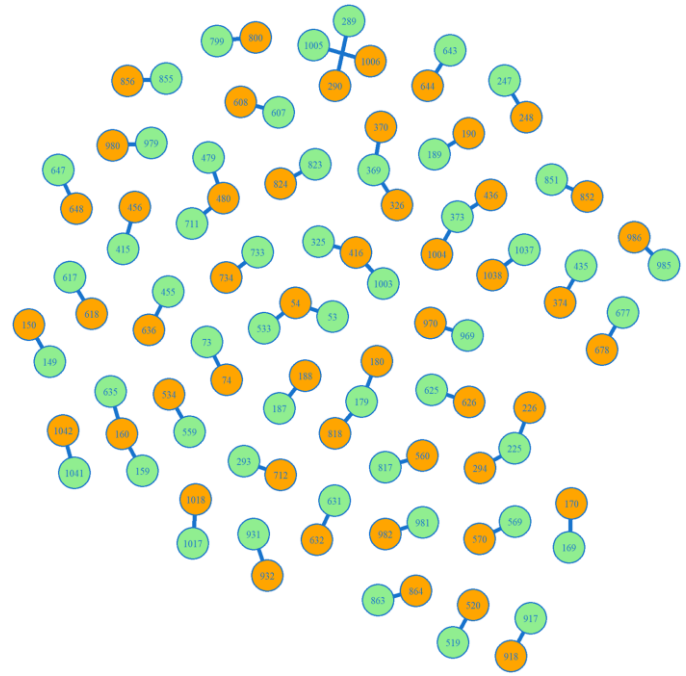

~76% simulation accuracy