A Model Is A Model Is A Model

EES 4760/5760

Agent-Based and Individual-Based Computational Modeling

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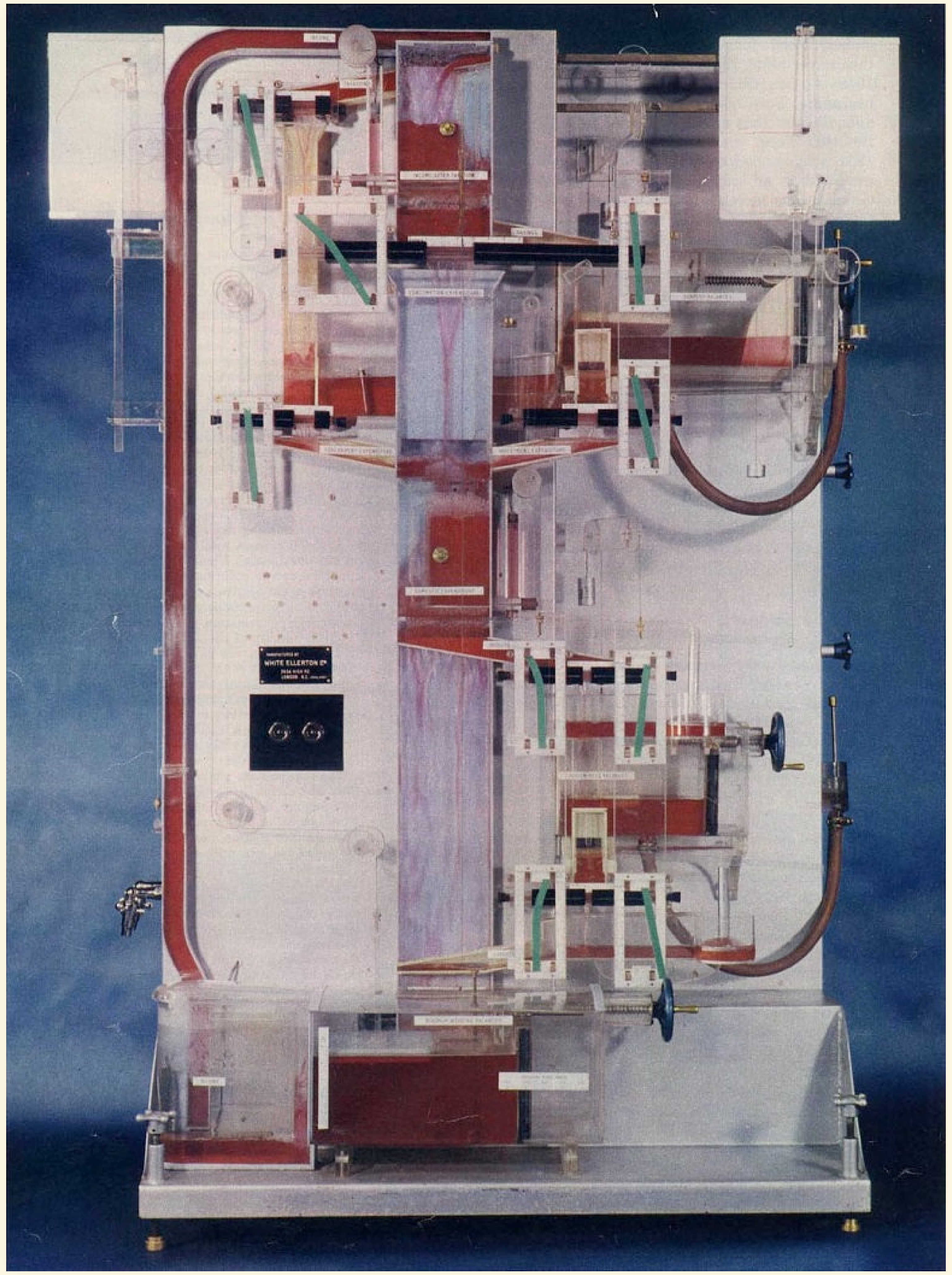
Modeling

- There are many “modelings”:
  - Agent-Based Models
  - Mathematical Models
  - Statistical Models
  - System-Dynamics Models
  - Discrete-Event Models
  - Stochastic Dynamic Models
  - Physical Models
  - ...



MONIAC: A physical model of the British national economy

(Photo: Wm. Vandivere, Fortune, March 1952, p. 100)

Agent-Based Modeling (ABM)

- Two elements:

1. Agent-based
2. Modeling

- Certain principles apply to all kinds of modeling
- First, consider modeling
- Then consider what distinguishes agent-based modeling from other kinds.

What Is A Model?

- Definition (first try):
  - A model is a simplified representation of reality
- Why do we simplify?

Modeling

- Developing a model:
  - Problem solving under constraints
- Most important constraints:
  - Incomplete information
  - Lack of time
  - Lack of resources (people, money, computing power, etc.)

Example

- You bought a six-pack of a tasty beverage last night,
  - but when you get home this evening, you realize that you forgot to put it in the refrigerator.
- So you put it in the fridge, and now you want to know, without trial and error, when it will be cool enough to drink.
- How do you approach the problem?

Heuristics

- Mental shortcuts
- Rules of thumb that experience has shown to be useful.
- When solving problems under constraints, apply heuristics in modeling:
  - Simplified representations

Typical Heuristics

- Rephrase the problem
- Draw a simple diagram of the system
- Imagine that you are inside the system
- Identify essential variables
- Identify simplifying assumptions
- Use “salami tactics”: slice space and time

What Is A Model

- Definition (second try):
  - A model is a purposeful (simplified) representation
- Modeling is something we all do all the time because we never have enough data and time!

- Thinking = problem-solving = modeling

What Is A Model?

- Modeling adaptive behavior means trying to model the models used by adaptive agents (plants, animals, humans, organizations, etc.)
- A model is a model is a model

Is Modeling Essential?

- When trying to solve a problem, we keep asking ourselves, “is this aspect of the real system essential for solving my problem?”
- How can we know whether something is essential?
  - We cannot know
  - In science, we keep developing the model to test our assumptions

Example: Model A Forest

- Without a clearly stated question or problem we cannot formulate a simplified representation.
  - We don’t know the purpose of the model
- The strategy:

  Model first, then think about what problems we can solve with the model

  *does **not** work!*
- Forest model:
  - Timber extraction
  - Ecosystem preservation
  - Forest fires
  - …

Example: Checkout Queue

- Your purpose:
  - Minimize waiting time
- Manager’s purpose:
  - Minimize waiting time of all customers
- Manager’s solution:
  - Single queue for all customers
    - Airports, banks, etc.

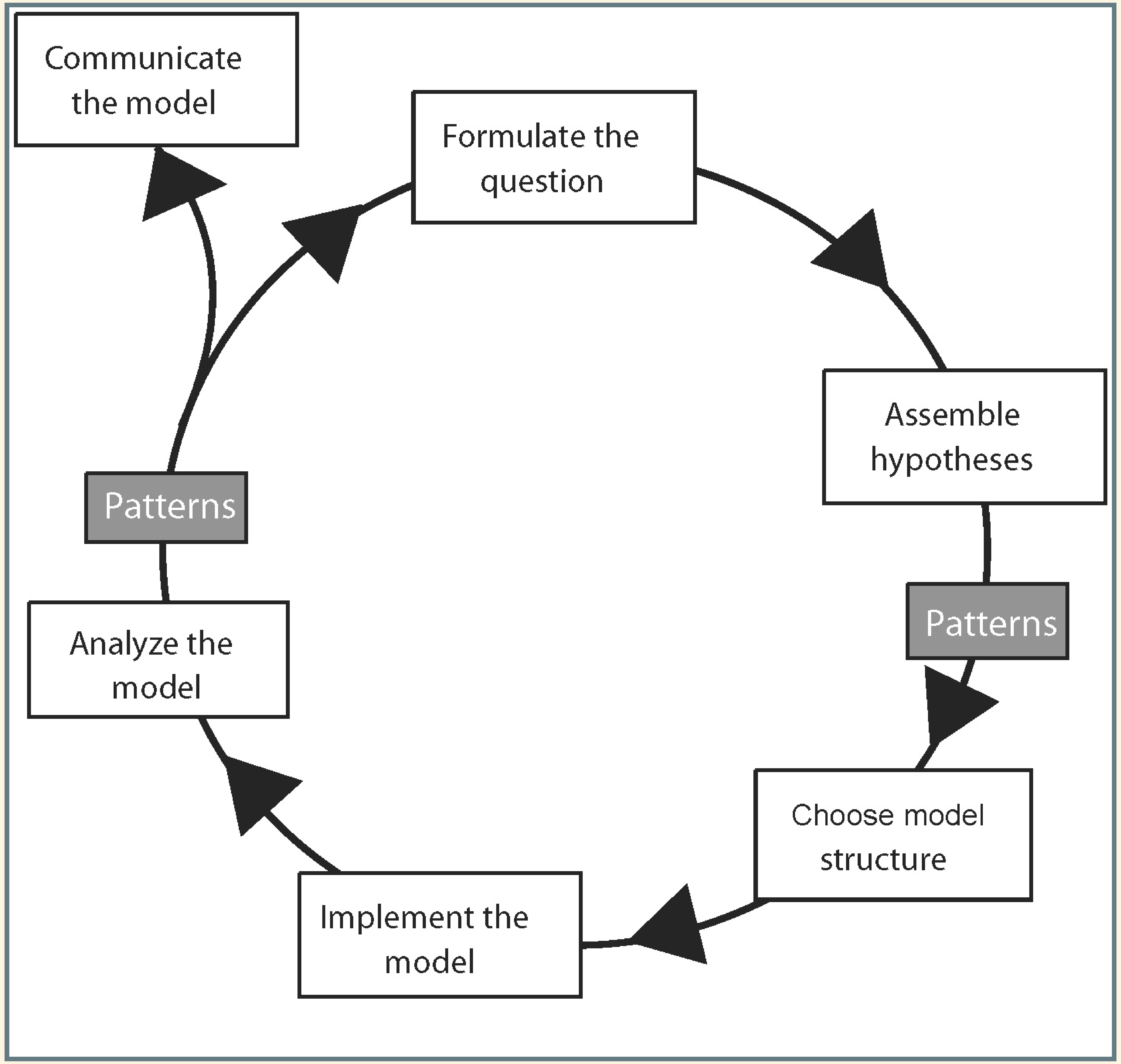
Lessons for Agent-Based Modeling

- ABM requires some specific techniques (programming, math, statistics)
- But general modeling principles apply.
  - Scientific modeling explicitly states heuristics, simplifying assumptions
  - **Use math & computer logic to rigorously explore consequences of assumptions**

Lessons for Agent-Based Modeling

- We must start with a clearly formulated research question
- We need to **simplify**
- Iterative process:
  - Formulate question
  - Create simplified representation
  - Implement model as program
  - Test program
  - Analyze output
  - Start over with modified question/model/program/etc.
- Modeling cycle

The Modeling Cycle



Modeling Cycle Tasks

Formulate the Question

- Question or problem serves as filter for what to include in the model.
- Modeling the system first and then specifying the question *does not work*

Assemble Hypotheses

- We need a **conceptual** (often verbal, graphical) **model** of how the system works and what the answer is.
- This conceptual model can be based on: empiricial experience, theory, feeling
- Discuss and revise the conceptual model thoroughly, but not forever.
  - *It can’t be tested in your head!*

Modeling Cycle Tasks

Choose Model Structure

- What are the model's **entities**?
  - How are they characterized (state variables)?
- How do you represent the environment?
- What are temporal and spatial resolutions and extents?

Implement the Model

- Write down equations and/or implement model as computer program
- Choose appropriate software platform/system

Modeling Cycle Tasks

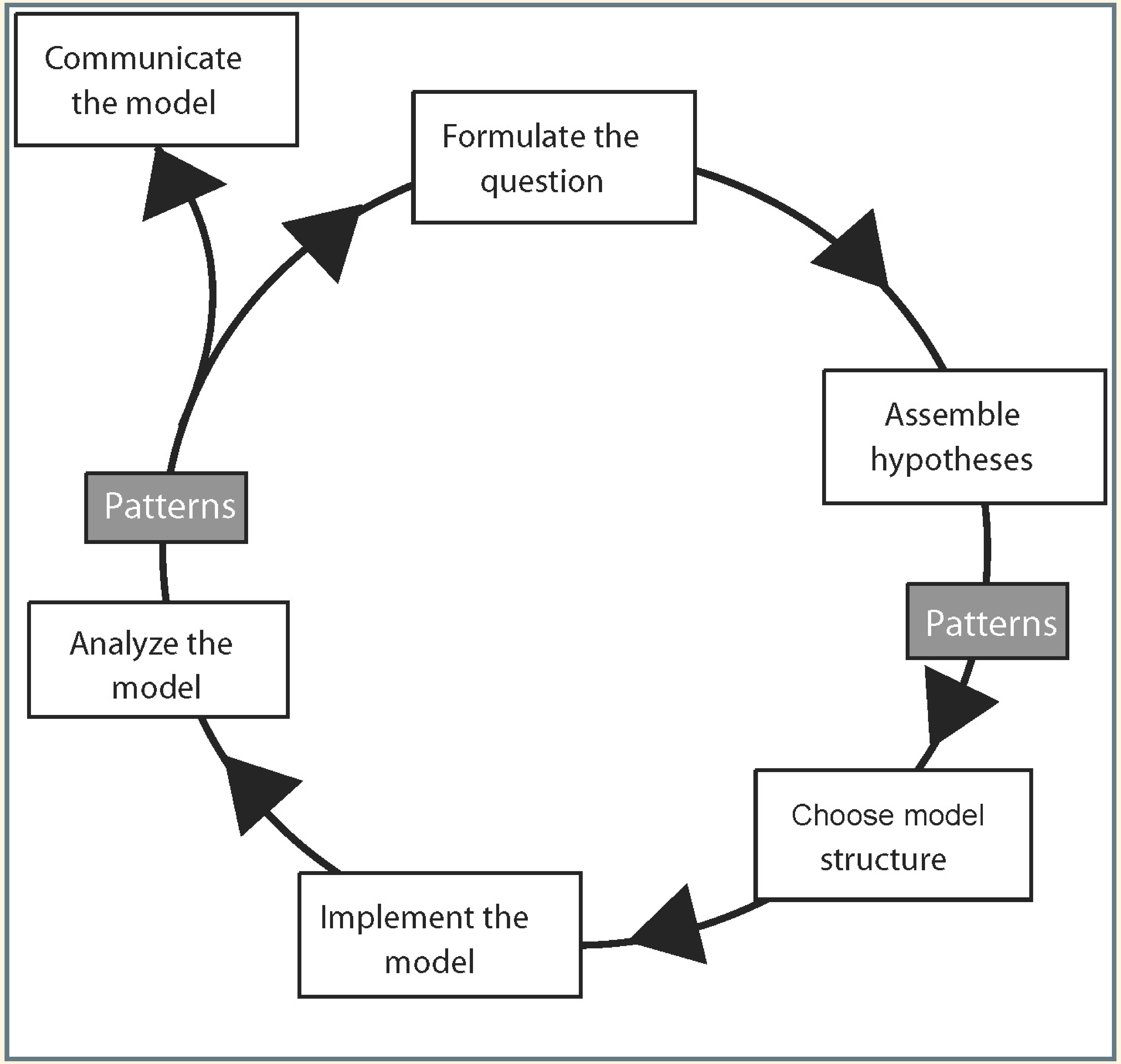
Analyze the Model

- Perform controlled experiments to understand your model
- Design & analyze simulation experiments just like real experiments
- This is the hard part (95% of the time)

Communicate the Model

- Like lab protocol: Model development has to be documented
- Keep a notebook of what y ou do.
- Keep old versions of your model
  - Name files `model_1.nlogo`, `model_2.nlogo`, etc.
  - Or use revision-control software (git, mercurial, etc.)
    (See “Reading Resources and Computing Tools” handout)
- Final documentation should enable peers to fully understand and re-implement model (ODD specification) (More on this next week)

The Modeling Cycle



Examples of Agent-Based Model Research at Vanderbilt

- Sustainable management of water in South Africa
- Impact of land-use change on Brazilian ecosystems
- Spread of solar-roof systems in California
- Adaptation to drought by rice farmers in Sri Lanka
- Land-use management to adapt to sea-level rise in Bangladesh
- Interaction of environmental change and population migration in Bangladesh
- Predicting traffic congestion for navigation apps
- Impact of Nashville gentrification on mobility & access to mass transit
- Can prediction markets affect belief in climate change?
- Teaching K-12 science

Other Examples of Agent-Based Model Applications

- Predator-prey interactions
- Preserving viability of threatened species
- Interaction of public belief in global warming, engineering projects, and future vulnerability of coastal communities.
- Impact of natural disasters on cities
- Designing effective political institutions
- Designing evacuation routes from buildings
- Predicting and managing disease epidemics
- Mechanisms of septic shock (bacteria in human body)
- Developing strategies for responding to mass shootings
- Effect of opium trafficking on Taliban insurgency in Afghanistan