The IF-THEN Machine

A skeptic's guide to simulations

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What even ARE simulations?

- Are they **inductive** logic (like an experiment)?
- **Deductive** (like a mathematical proof)?
- Or something else?

Main source: Frank Varenne, *What does a computer simulation prove?* (2001).

Goals of this talk:

- Present three different viewpoints
- Stimulate discussion among new students
- Get opinions from simulation experts
- Figure out how much we can trust the results of simulation

Some definitions:

- Inductive reasoning: using observations and inference from data to generate new knowledge.

- Deductive reasoning: using prior knowledge, definitions and logic to generate new knowledge.

- Simulation: A mathematical model that describes or creates computationally a system process.
  (Other definitions may insist that simulations are discretised/ have no analytic solution/involve stochastic elements)

Simulations… as *real experiments*

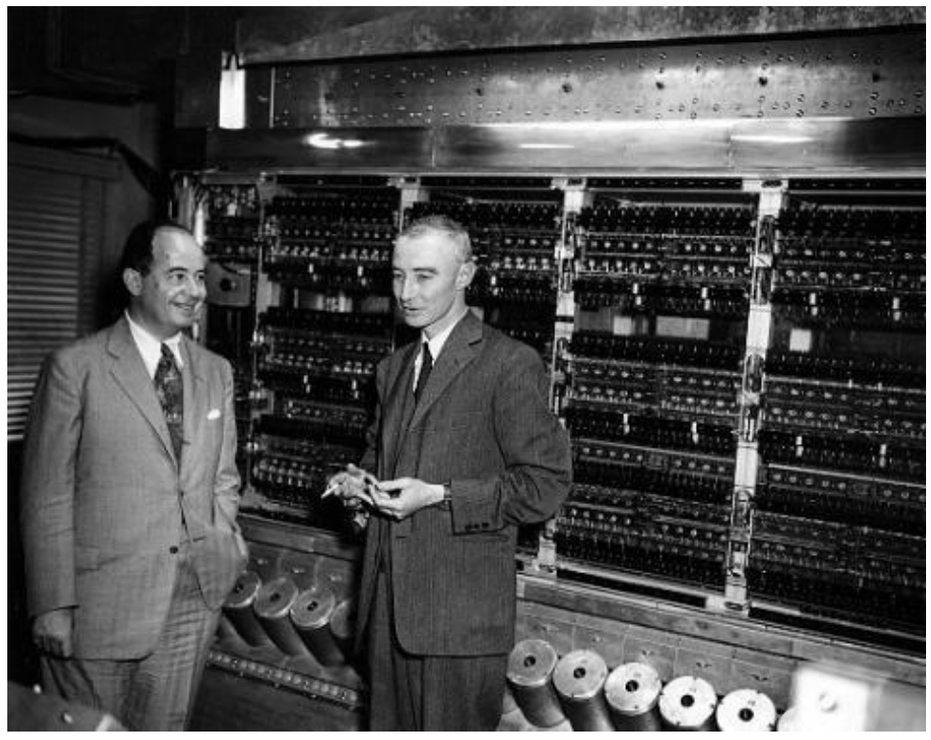
- Things are more than we can observe! (Durkheim, 1895)
    - Eg. What is an atom?
    - We can talk about the properties it has, but not what it **is**.
    - So doing experiments on synthetic things with these properties is as good as doing them in reality.

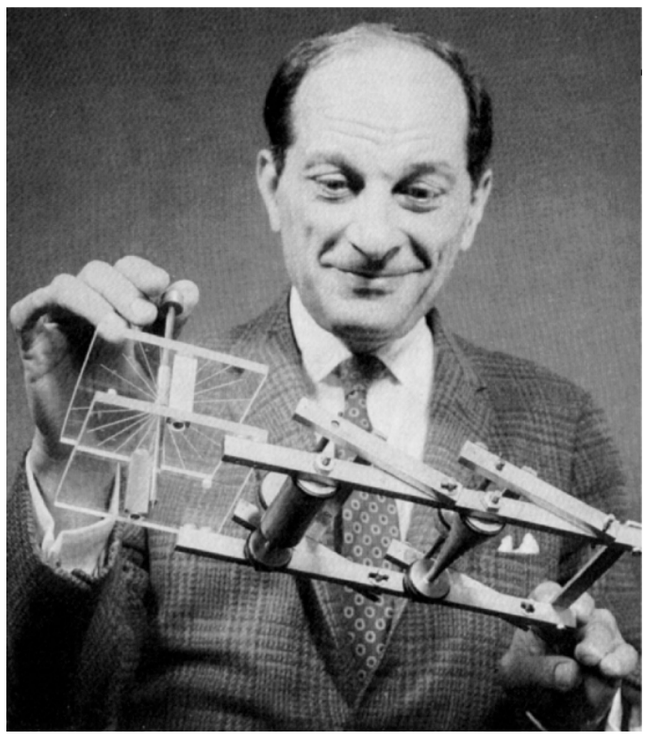
Simulations... as *real experiments*

The First Monte Carlo Simulation

- Invented by Ulam and von Neumann to study nuclear disintegration during WWII.

- Objects studied are discrete and stochastic - so the simulation is a true experiment on discrete, stochastic things!





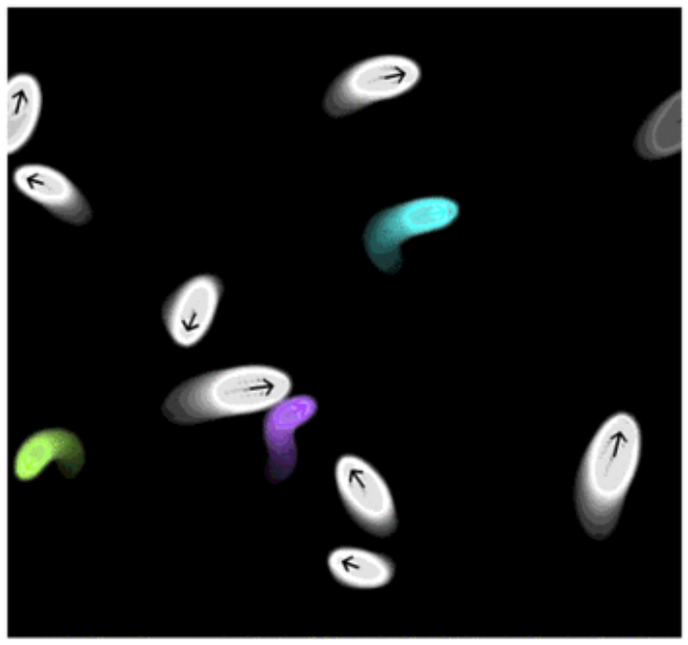
Simulations… as *real experiments*

Artificial life

- Definition of life: something that eats, evolves, reproduces…

- Different opinions about whether creatures in sim are alive.

- Researchers study **life as a process**



Simulations… as *tools for reasoning*

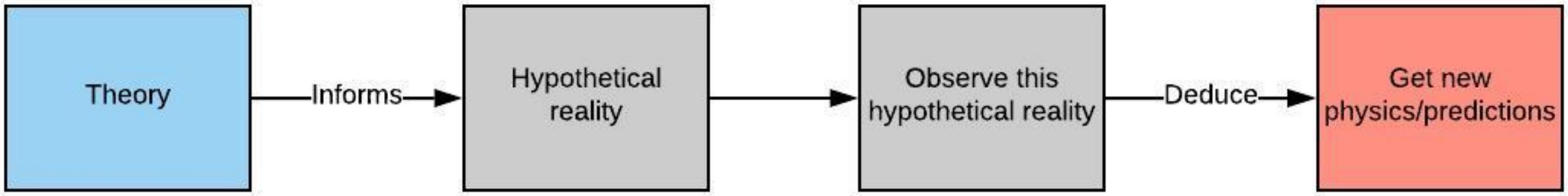
- **Thought experiments** are a valid form of deductive reasoning

- A simulation is a thought experiment, but with a computer doing the “thinking”

- *“Computers are like a bicycle for our minds”* - Steve Jobs

Simulations… as *tools for reasoning*

The IF-THEN Machine



Simulations… as *tools for reasoning*

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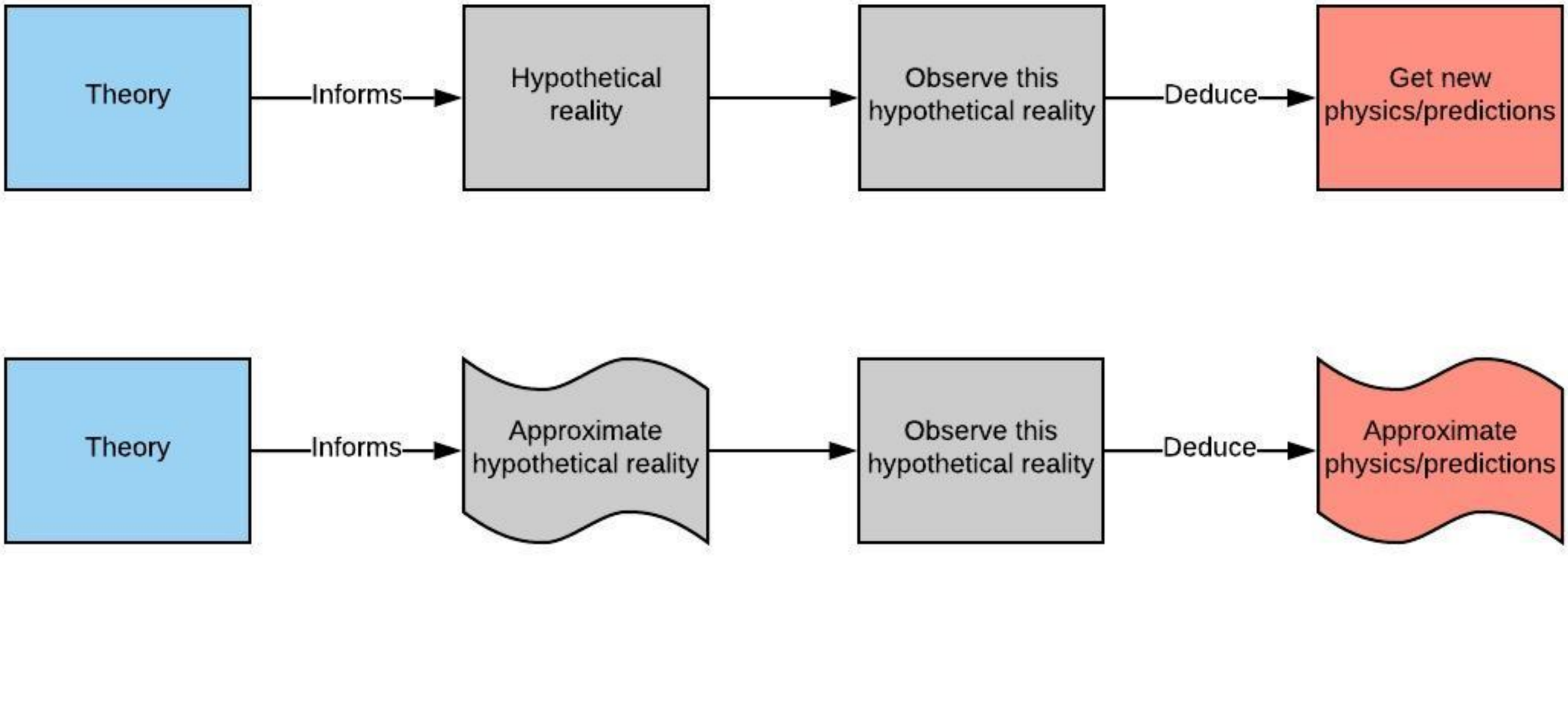


Simulations… as *something new*

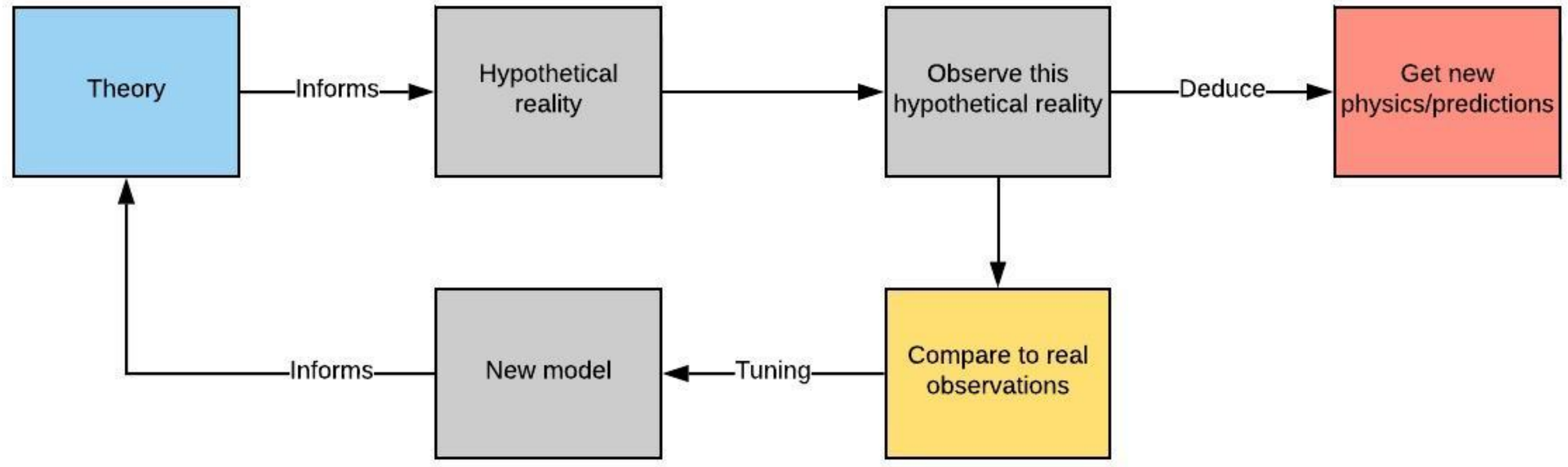
- Simulations belong in between theory and experimentation

- They can falsify a theory, but not an observation

- **“Trading zone”** between theory and experiment
  - Theory → observable predictions
  - Observations → new theory

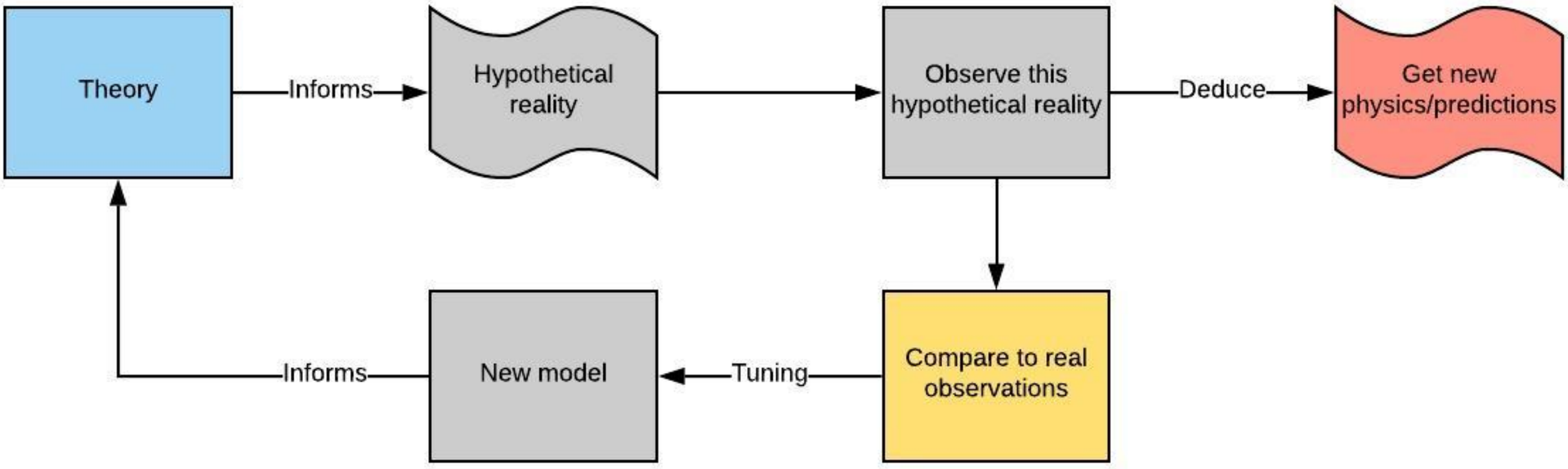
Simulations… as *something new*

The IF-THEN-BUT SINCE Machine



Simulations… as *something new*

The IF-THEN-BUT SINCE Machine



Simulations… as *something new*

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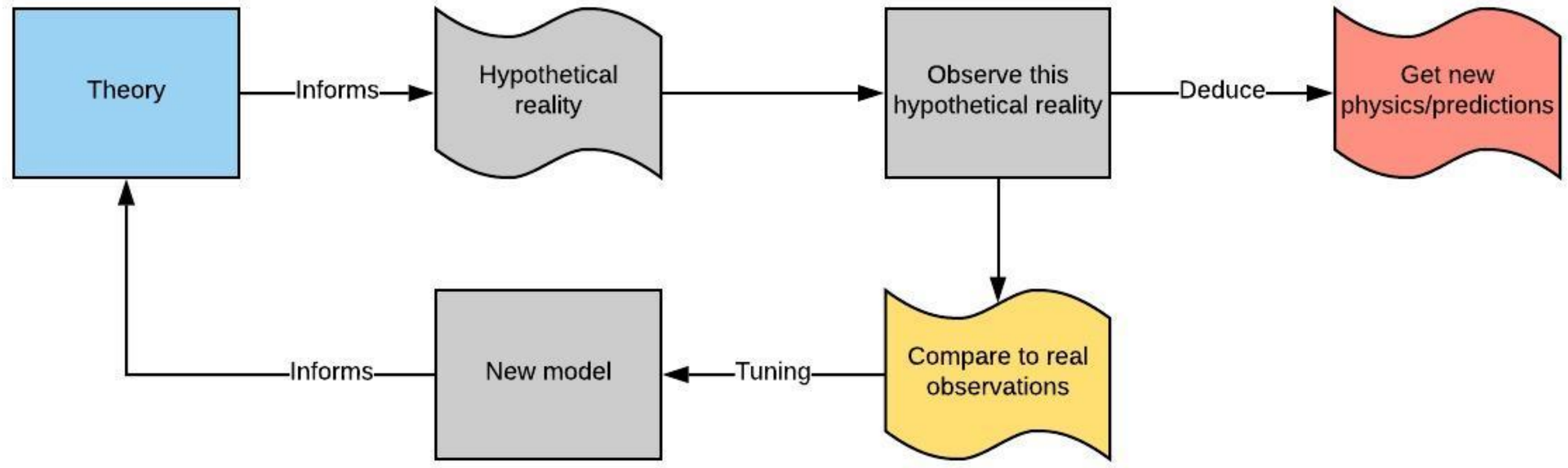

Simulations… as *pure fiction*

- There is no reason to believe that our models correspond to reality.

- When constructing a simulation, we construct a hypothetical reality that is only similar to our own.

- An experiment on the **model**, and not on the thing itself!

- Still, fictions can teach us important lessons.

Conclusions - a simulation is…

- A **real experiment** on the objects in your simulation, which are equivalent to the things that you are studying.

- A **deductive tool** like a thought experiment that does not suffer from the limitations of the human mind.

- A **trading zone** that allows new predictions to be made from theory, and inspire new theory from observations.

- Different simulations may be better described by different interpretations.

Conclusions - Know your “IF”s!

- Understand the assumptions that your simulation is making.

- Know what approximations are made, and how they may introduce uncertainties into your results.

- Other numerical issues - resolution, convergence…