COMS30127: Computational Neuroscience

Lecture 7: Modelling neurons (c)

Dr. Cian O'Donnell

cian.odonnell@bristol.ac.uk

What we will cover today

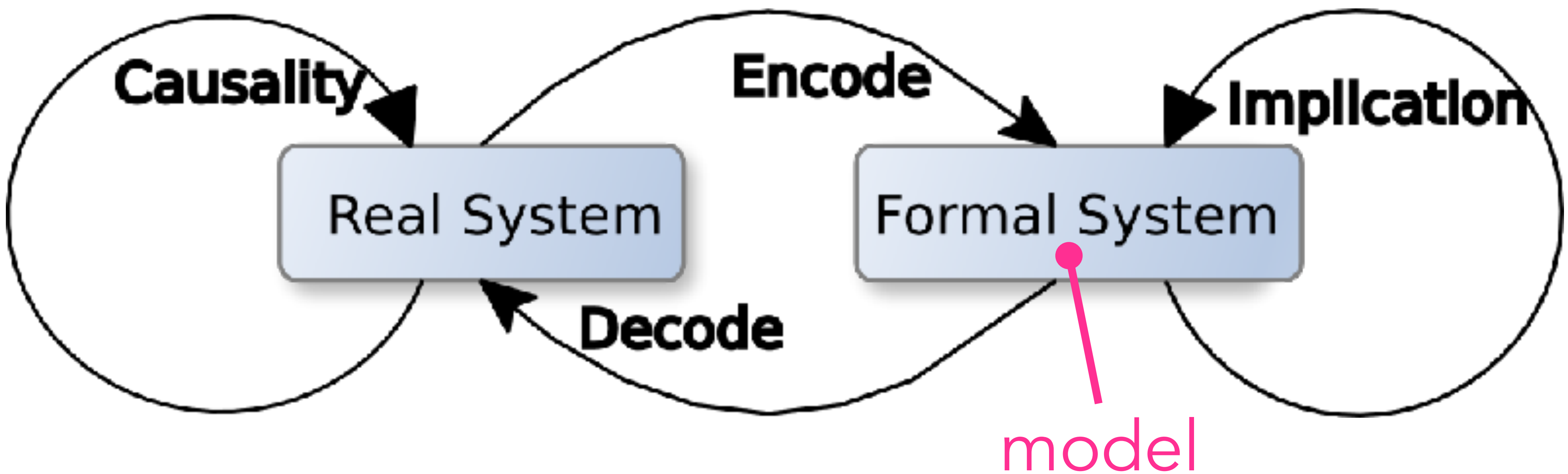
- What is a model?
- What is the purpose of computational modelling?
- Levels of abstraction (spatial, temporal and conceptual)
- Compare models of single neurons.
- How should we choose the ‘correct’ model for the problem at hand?

What is a model?

- A model is a simplified version of a real-world system.
- Models can be:
  - Physical (e.g. scale models of buildings)
  - Analogical (e.g. billiard-ball model of a gas)
  - Phenomenological (e.g. integrate-and-fire neuron)

    ↳ capture one particular phenomenon.
- Models can be represented by:
  - A physical object
  - Words
  - Mathematical equations
- Overview of the philosophy of models in science: https://plato.stanford.edu/entries/models-science/

What is a model?



https://commons.wikimedia.org/wiki/File:MathModel.svg

What is a computational model?

- Fundamentally, a computational model is just a mathematical model that is programmed and then solved or simulated using a computer.

- Technically speaking all computational models are phenomenological (for example, even in very detailed neuron models we ignore quantum mechanics).

- However in practice in neuroscience, most people consider phenomenological models to be those which abstract away all laws of (bio)physics.

What is the purpose of a computational model?

"All models are wrong, but some are useful."

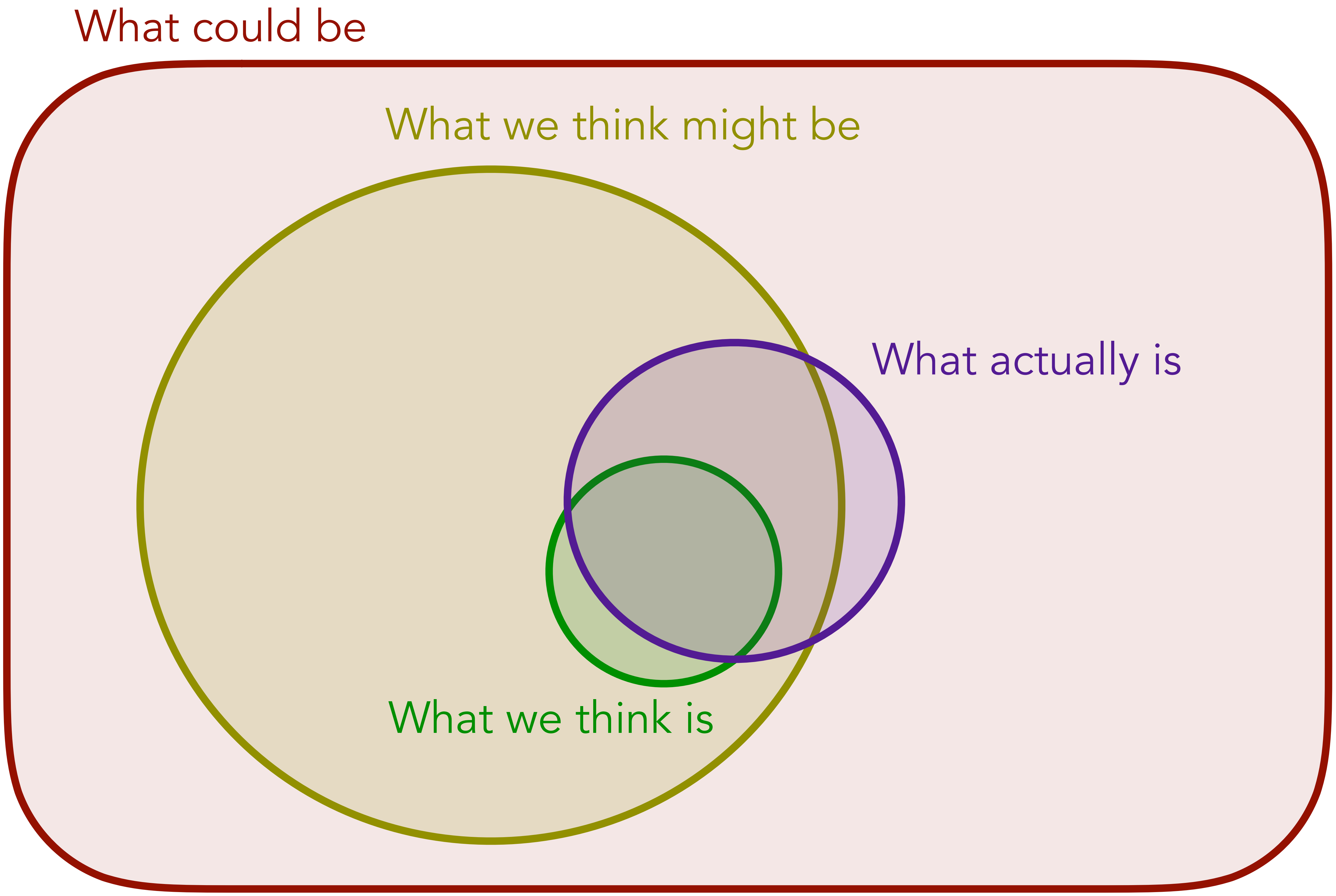
— George Box

What is the purpose of a computational model?

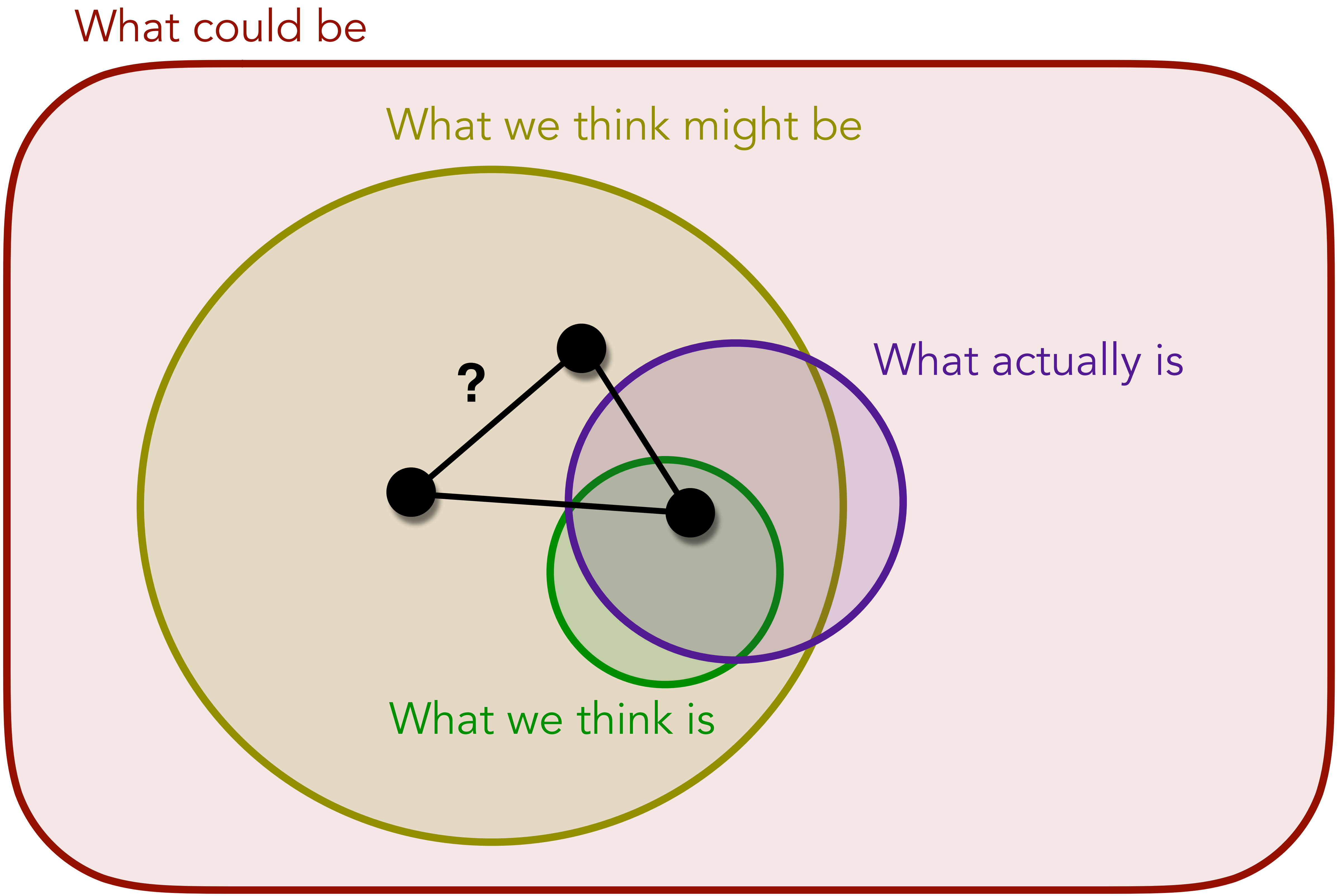
To gain an understanding of a system beyond what we could achieve via word models alone.

Computational models can be used to: Uncover flaws in reasoning.

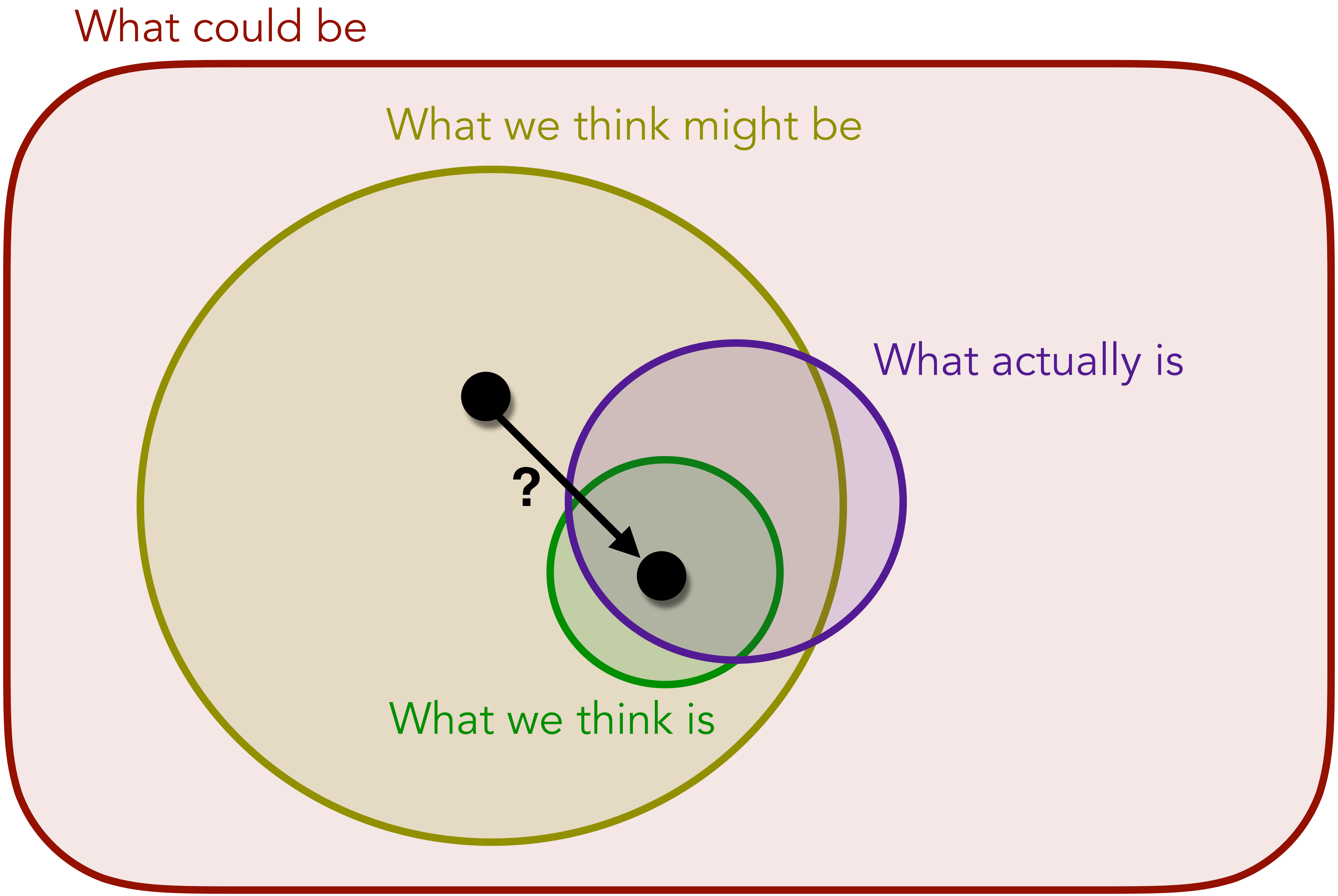
1. test if a set of concepts are mutually consistent. If not, why?
2. "link levels", i.e. to ask if a mechanism at one level of description can account for a phenomenon at another level.
3. simulate experiments that are technically difficult or impossible to do in the lab.
4. explore "what if?" scenarios that may never occur in the natural world. eg – multiple sexes!
5. validate a formal mathematical analysis.


What could be
What we think might be
What actually is
What we think is

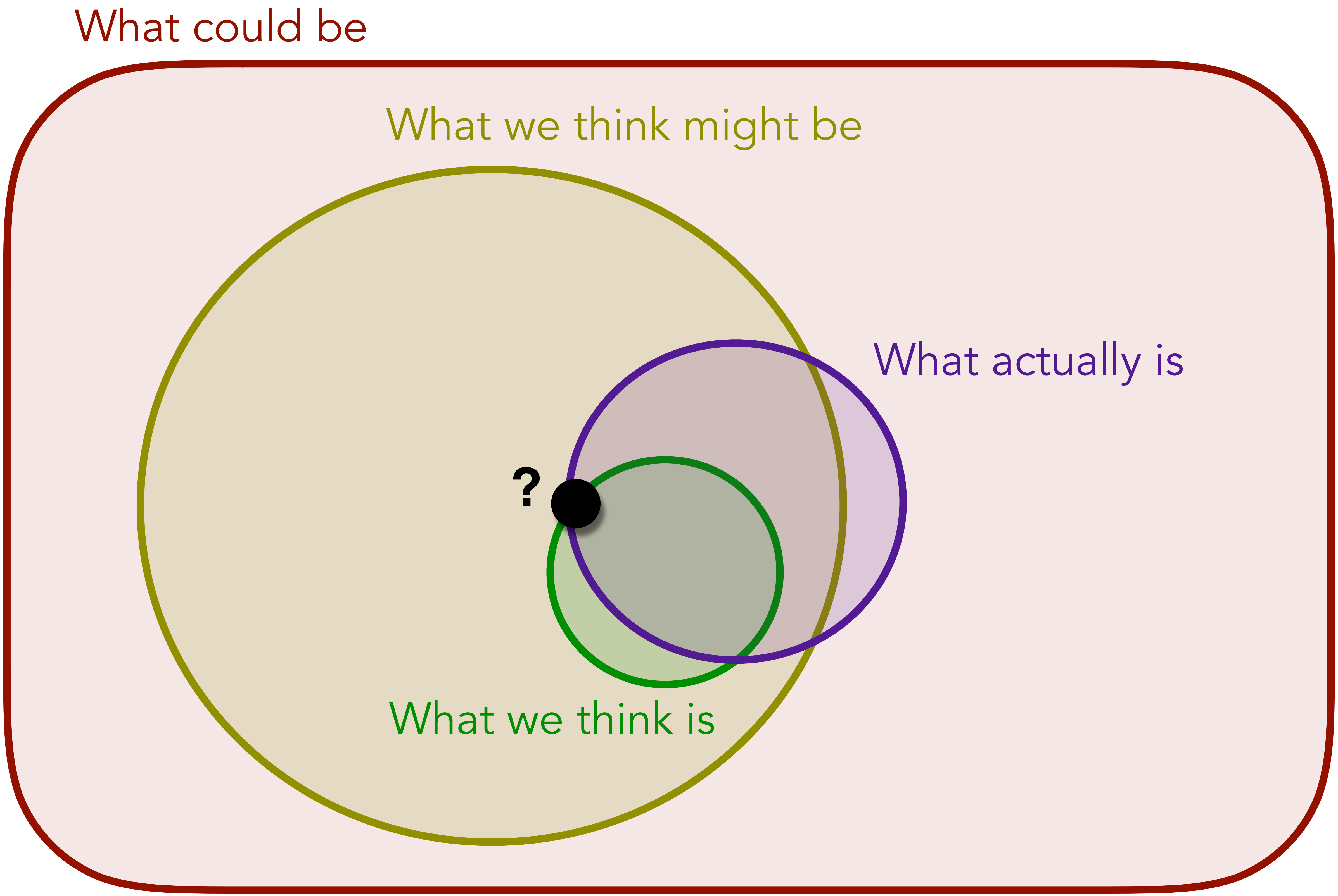
1. are these ideas mutually consistent?



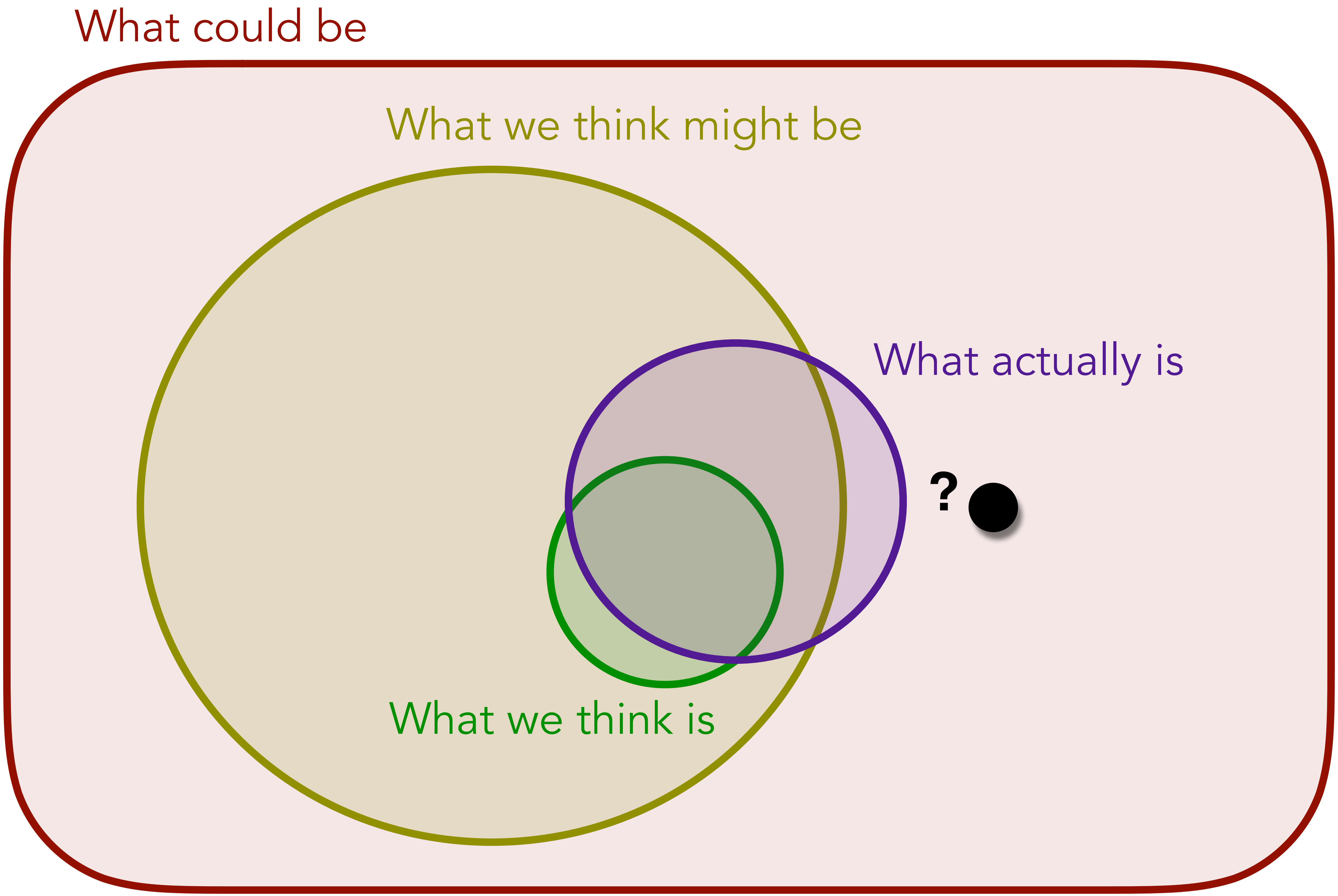
2. can 'this' explain 'that'?



3. *simulate difficult experiments*



4. simulate 'what if?' scenarios



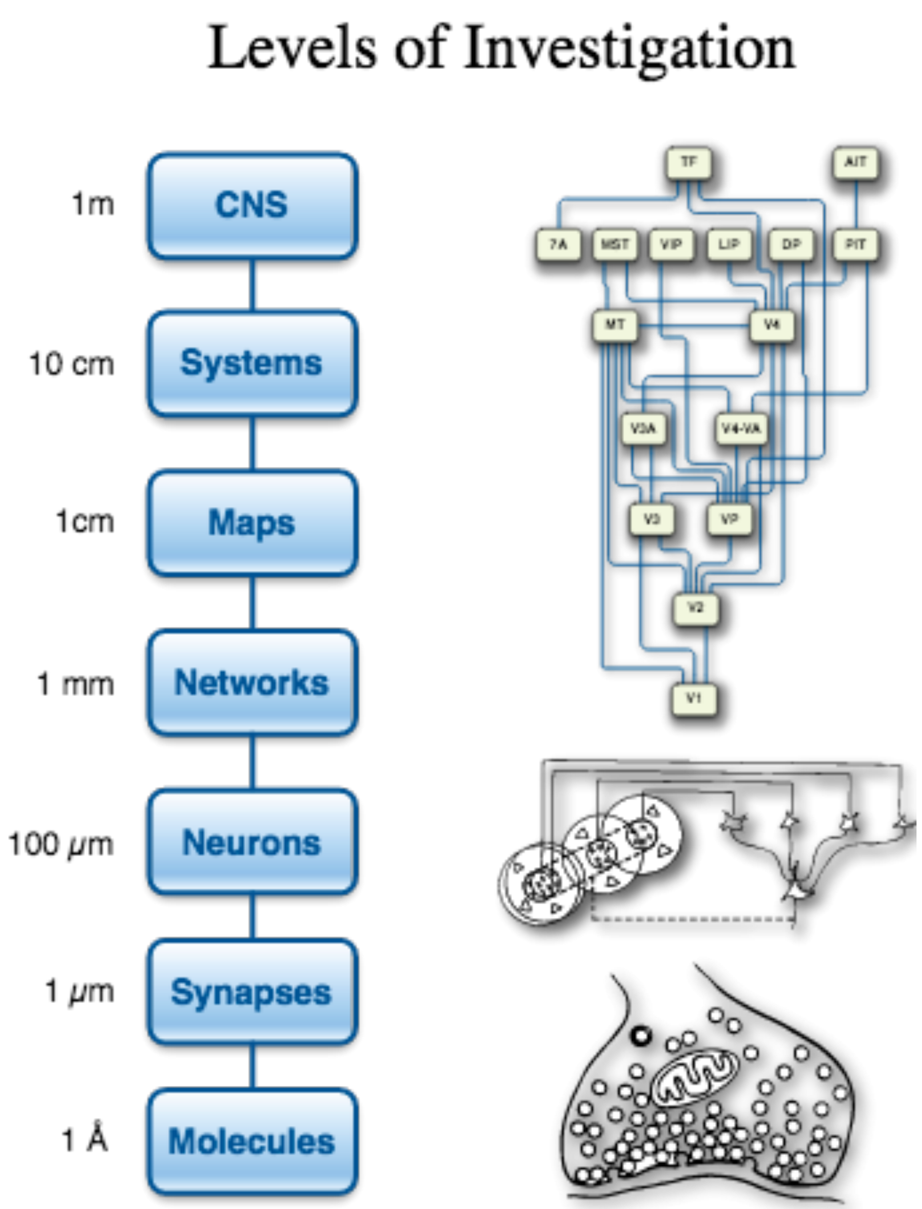
What is the purpose of a computational model?

Example usages of computational models in neuroscience:

- Hodgkin-Huxley model
  (to ask if the squid axon action potential can be explained by the voltage gating dynamics of sodium and potassium conductances).
- Simulation of recurrent hippocampal networks with synaptic plasticity
  (to ask if synaptic plasticity could mediate memory recall from partial cues).
- Simulating the biophysics of calcium signalling at a synapse
  (to explore what happens during synaptic stimulation).

Levels of abstraction

Spatial

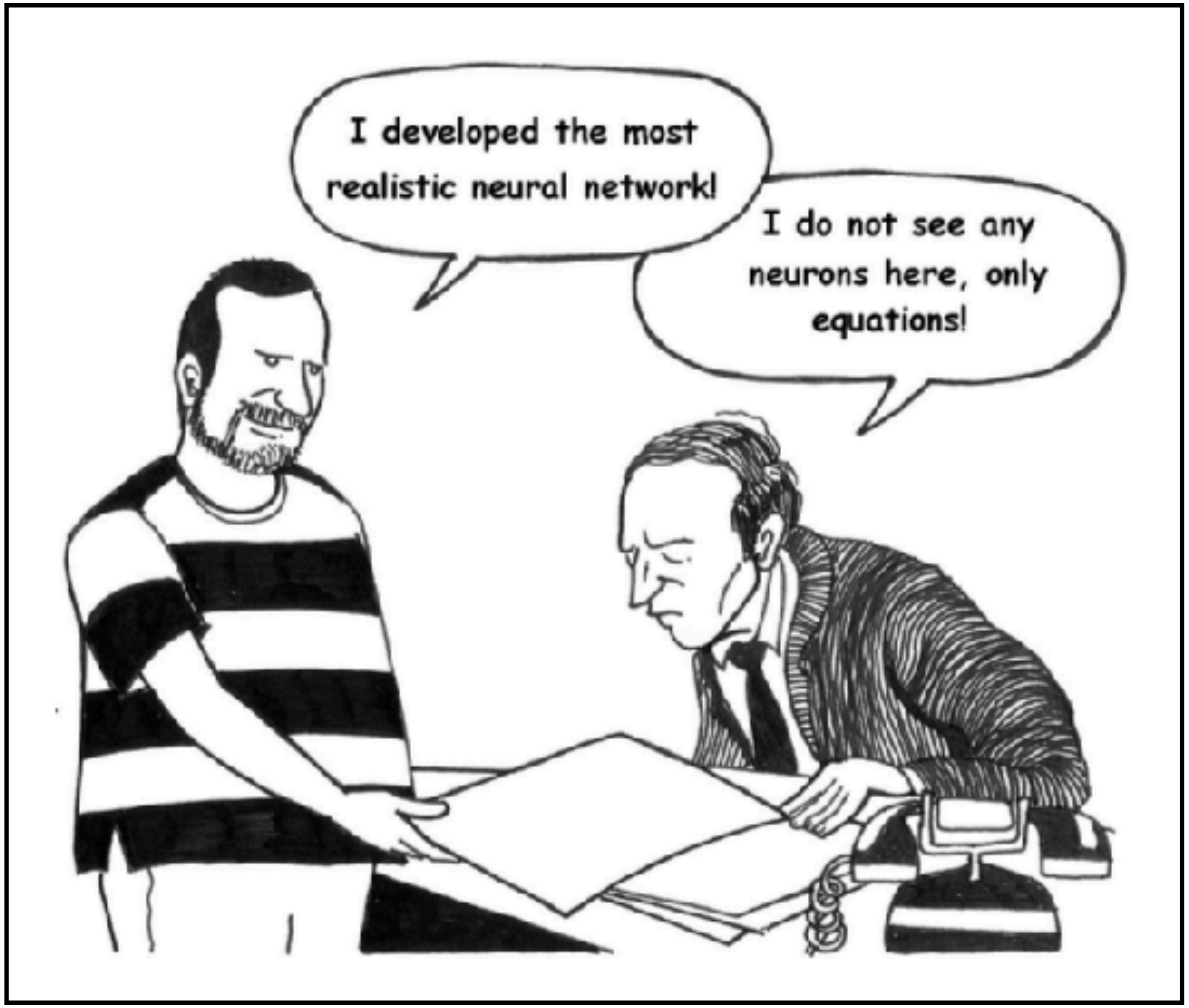


T. Sejnowski
http://cnl.salk.edu/

Temporal

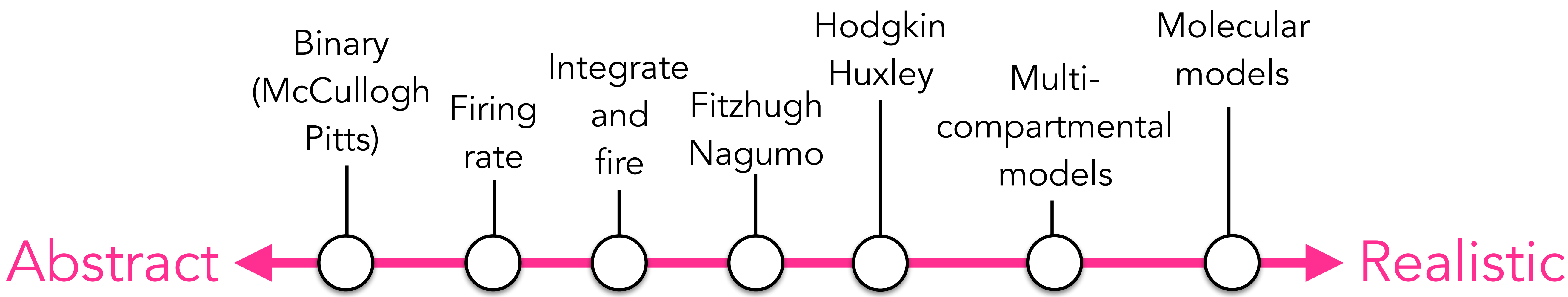
years	Memories
weeks	Brain development
hours	Gene expression
mins	Cellular signalling
s	Neural circuit dynamics
ms	Action potential

Models of single neurons



Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting.
Izhikevich E.M. (2007)

Models of single neurons



Abstract models		**Realistic models**
Simple	vs	Detailed
Hard to relate to biology	vs	Contains stuff you could measure
Few parameters	vs	Lots of parameters
Fast simulation	vs	Slow simulation
Mathematical analysis	vs	Intractable
Generic	vs	Specific

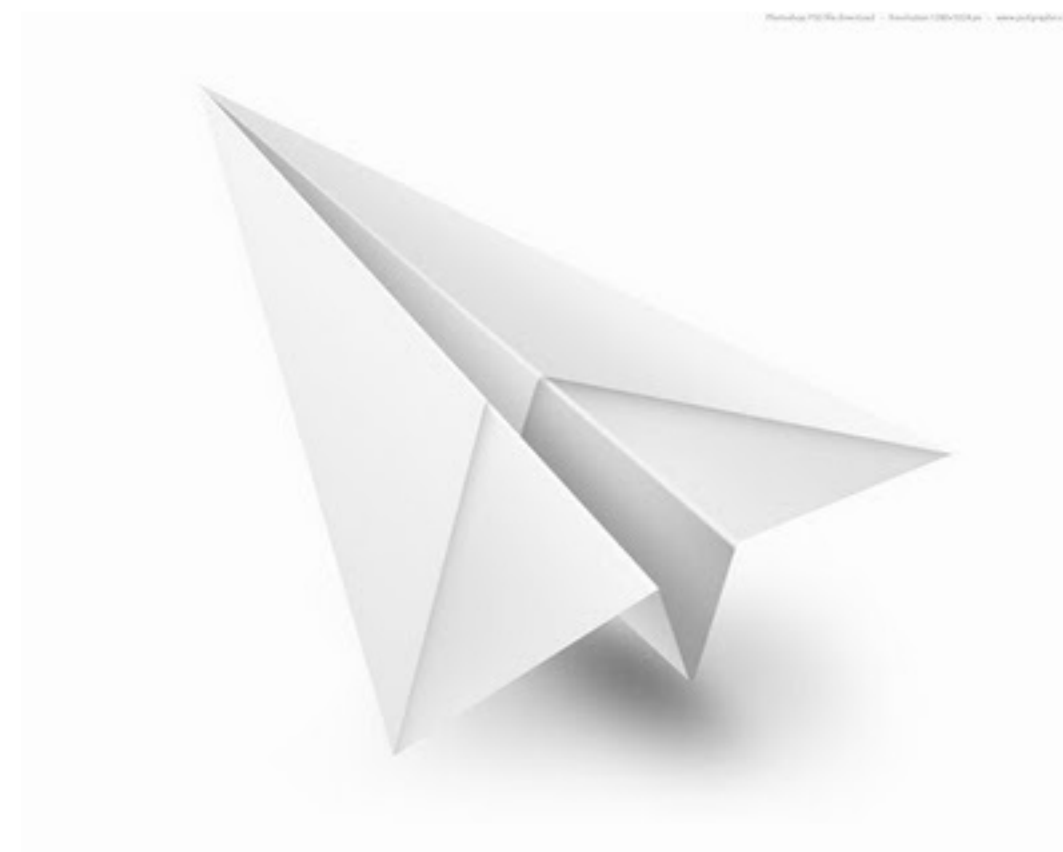
Which model is best for my problem?

- Choose the form of the model that best matches the granularity of your scientific question.

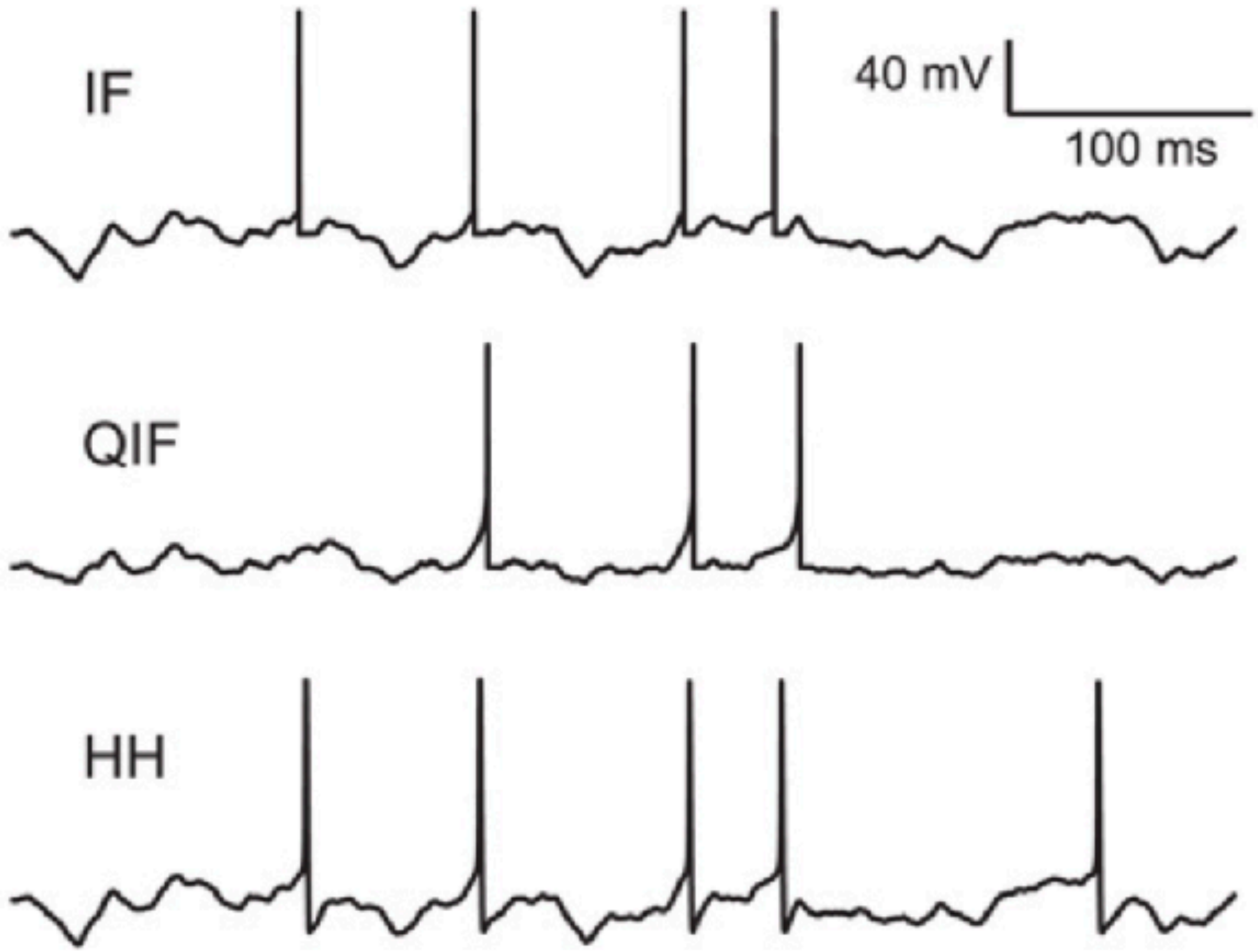
- *"A model should be as simple as possible, but no simpler"*
— Albert Einstein

- Often this choice is dictated by:
    - the data you have to constrain the model
    - the phenomenon you wish to explain
    - the computational resources you have available
    - how much maths/programming you know
    - ~~what someone else did previously~~

Details vs realism



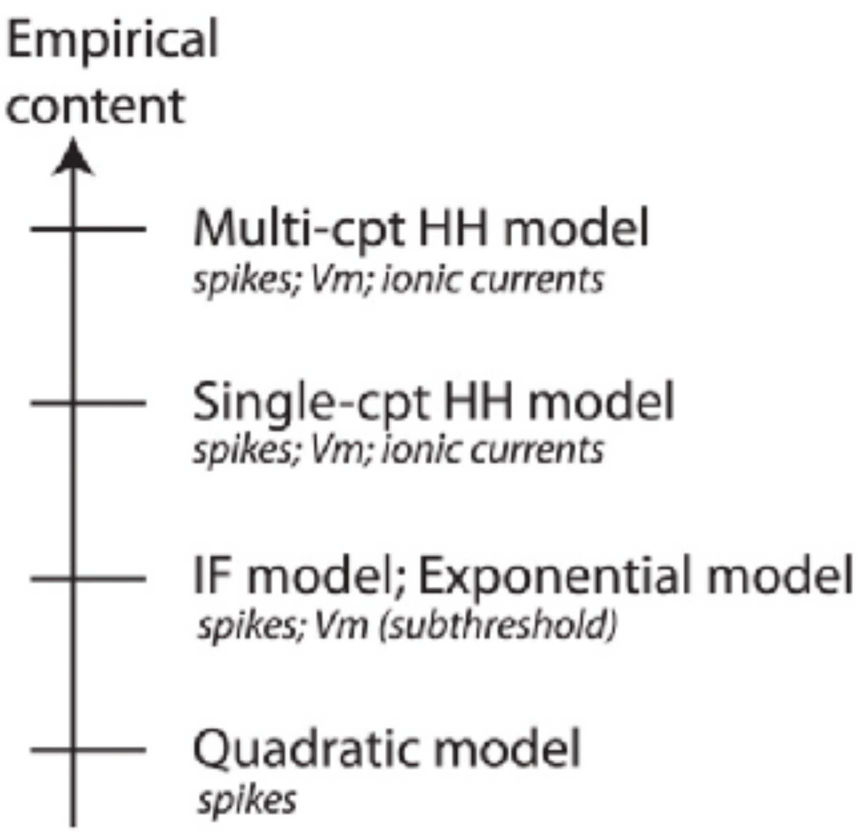
c.f. Brette, *PLoS Comput Biol*, 2015



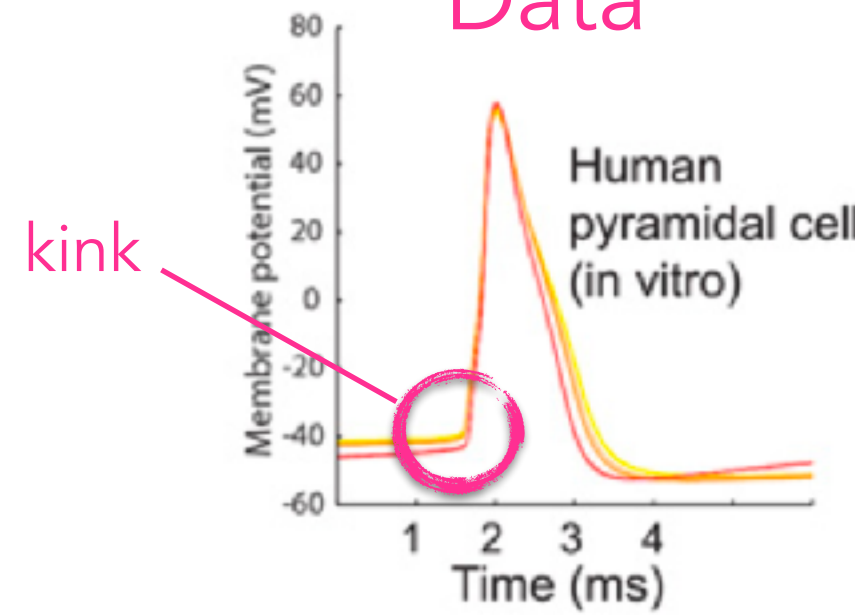
Voltage from three different model neurons in response to the same identical input current.

Brette, *PLoS Comput Biol*, 2015

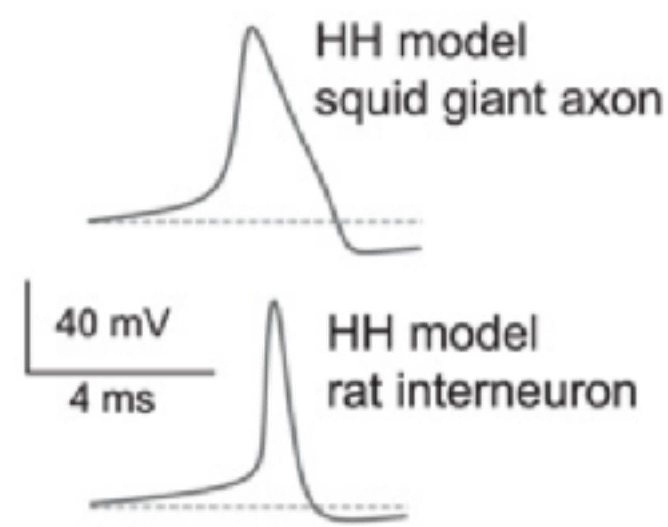
Empirical content vs empirical accuracy



Data



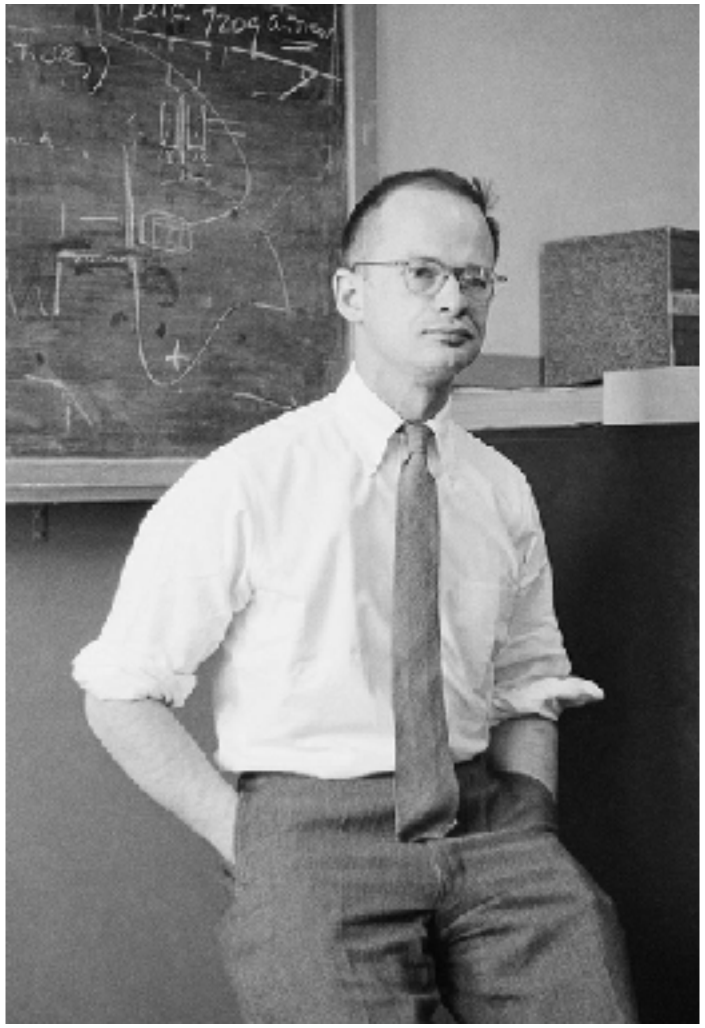
Model



Brette, *PLoS Comput Biol*, 2015

Next Thursday

- McCollough-Pitts neurons
- Classic binary neuron models that can do surprisingly powerful computations.
- Some nice pre-reading on Pitts: http://nautil.us/issue/21/information/the-man-who-tried-to-redeem-the-world-with-logic



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