

COMS30127: Computational Neuroscience

Lecture 7: Modelling neurons (c)

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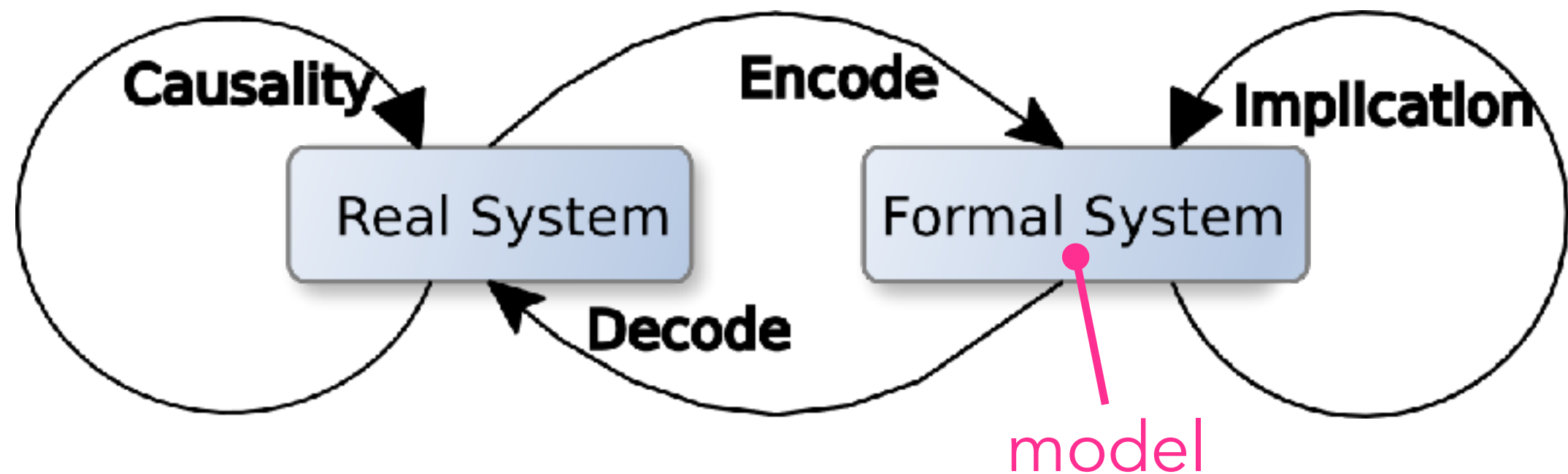
What we will cover today

- 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)
- 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?



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:

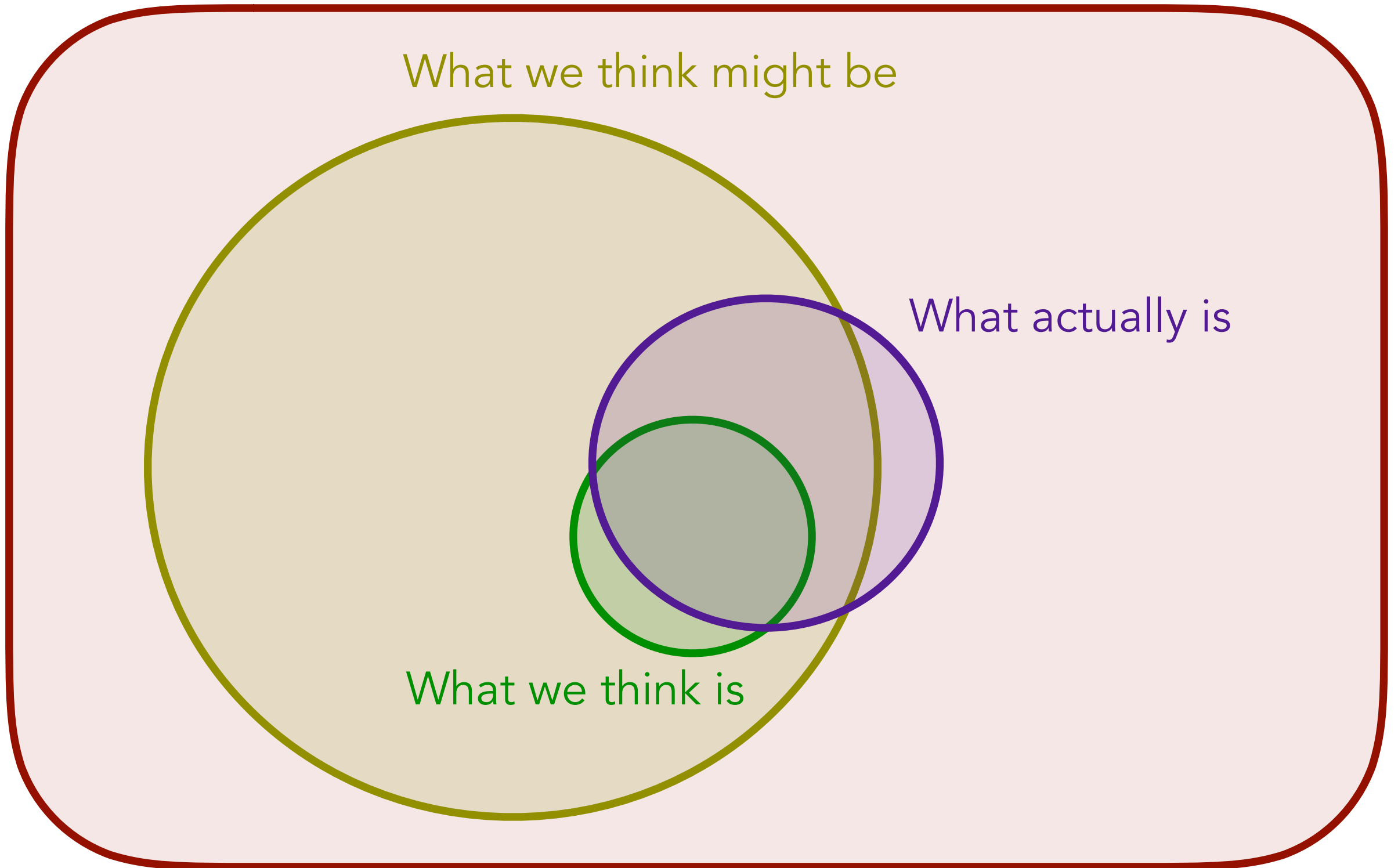
1. test if a set of concepts are mutually consistent. If not, why?
2. “link levels”, i.e. to ask if a mechanism at one level of description can account for a phenomenon at another level.
3. simulate experiments that are technically difficult or impossible to do in the lab.
4. explore “what if?” scenarios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

What could be

What we think might be

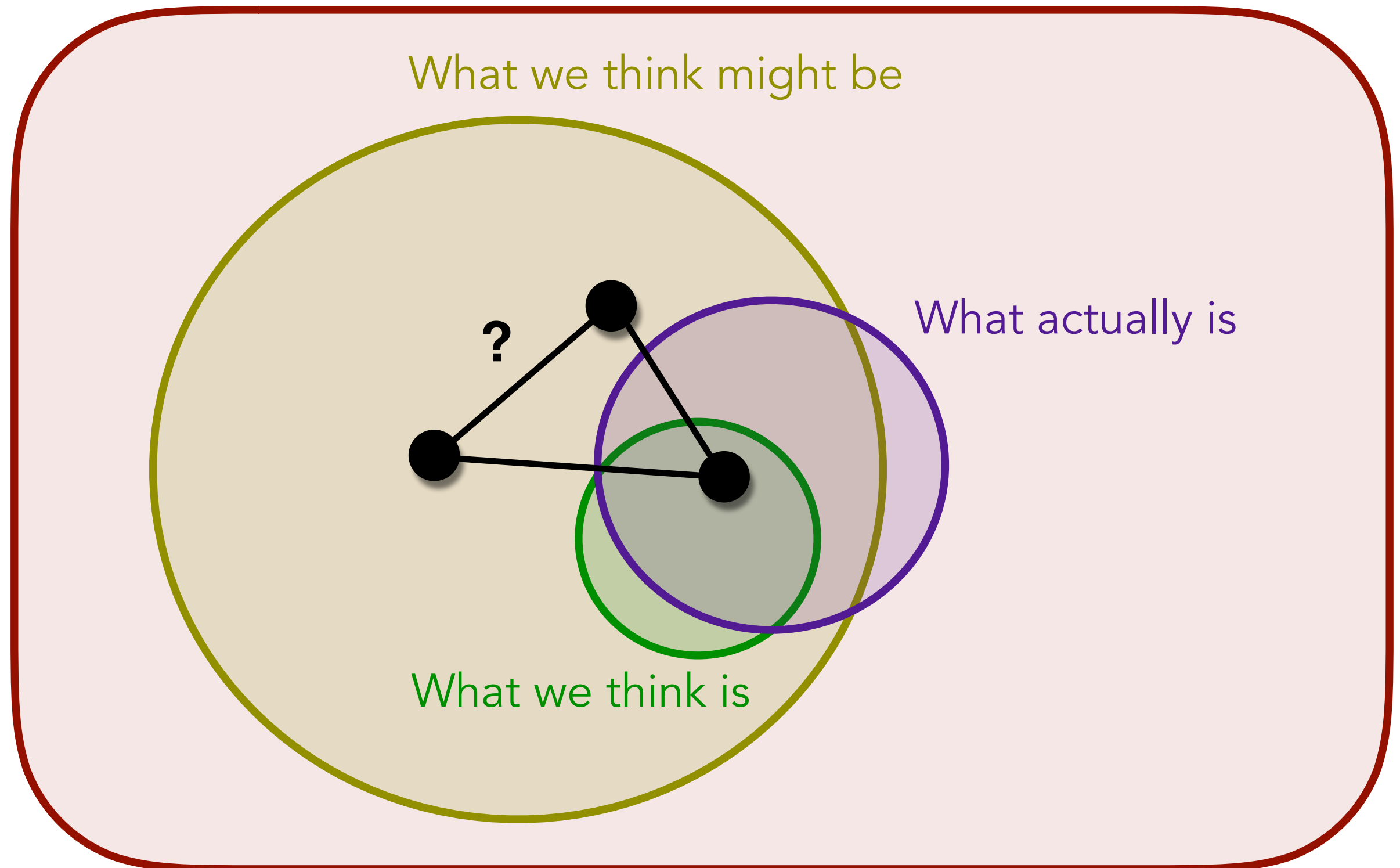
What actually is

What we think is



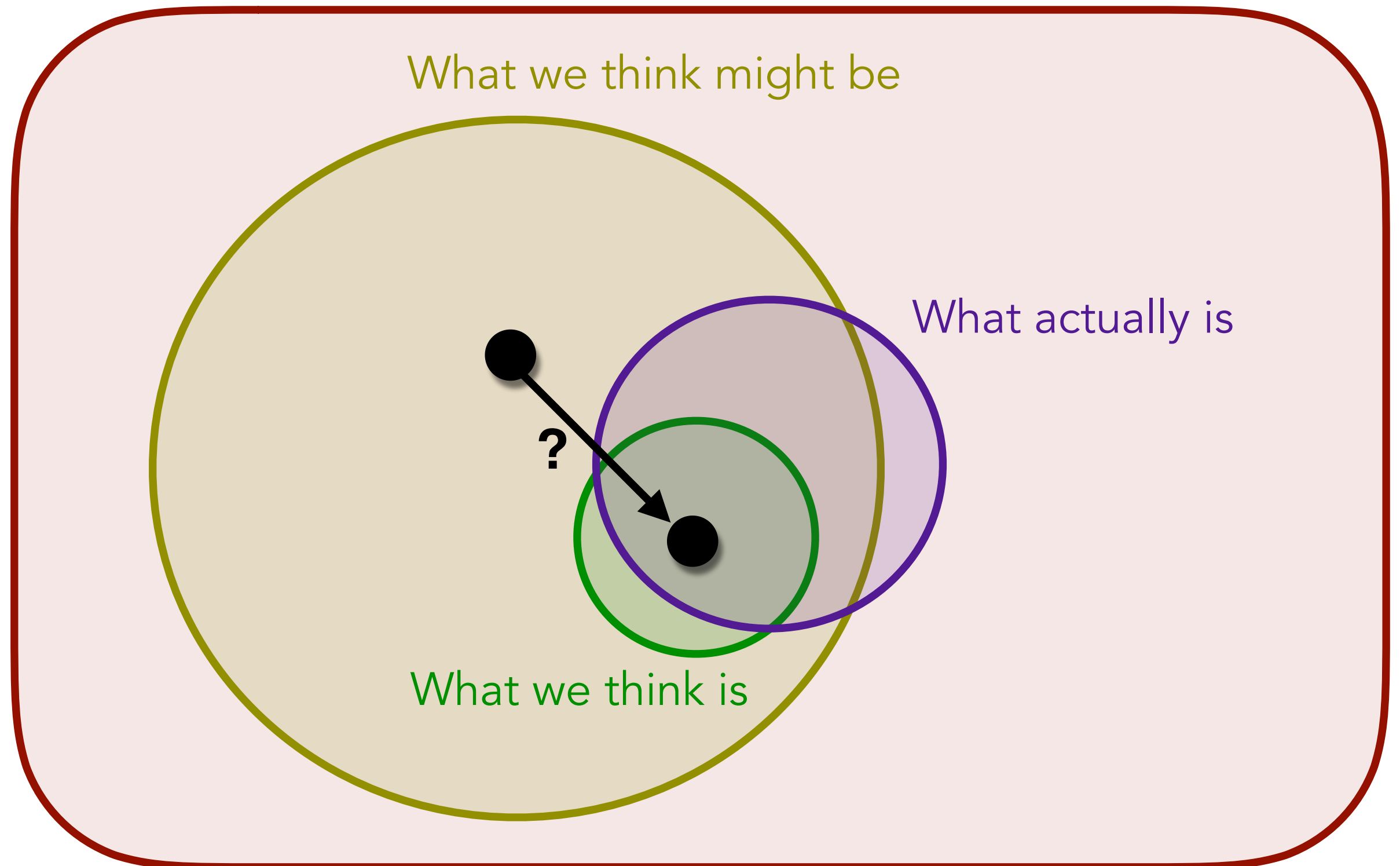
1. *are these ideas mutually consistent?*

What could be



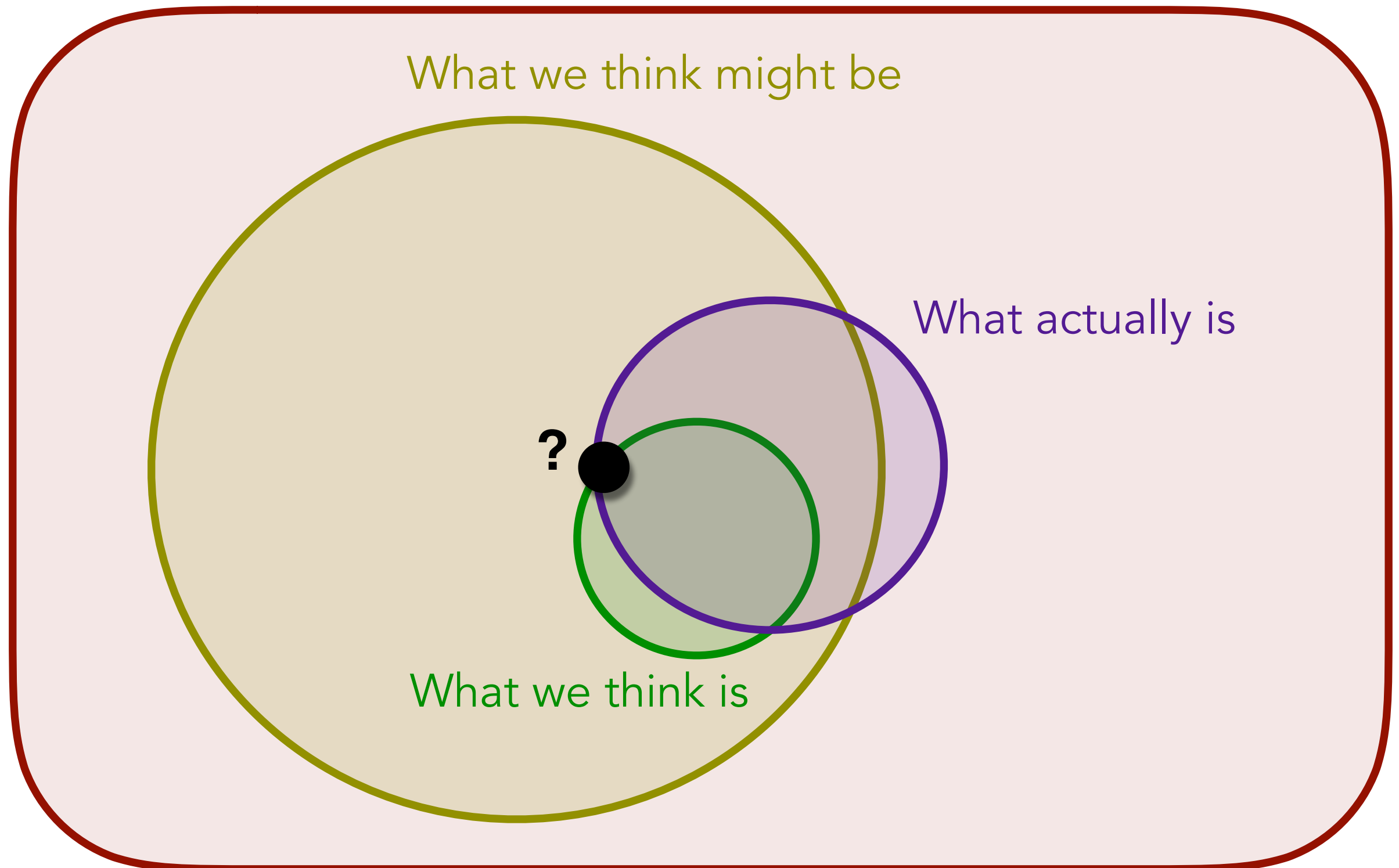
2. can 'this' explain 'that'?

What could be



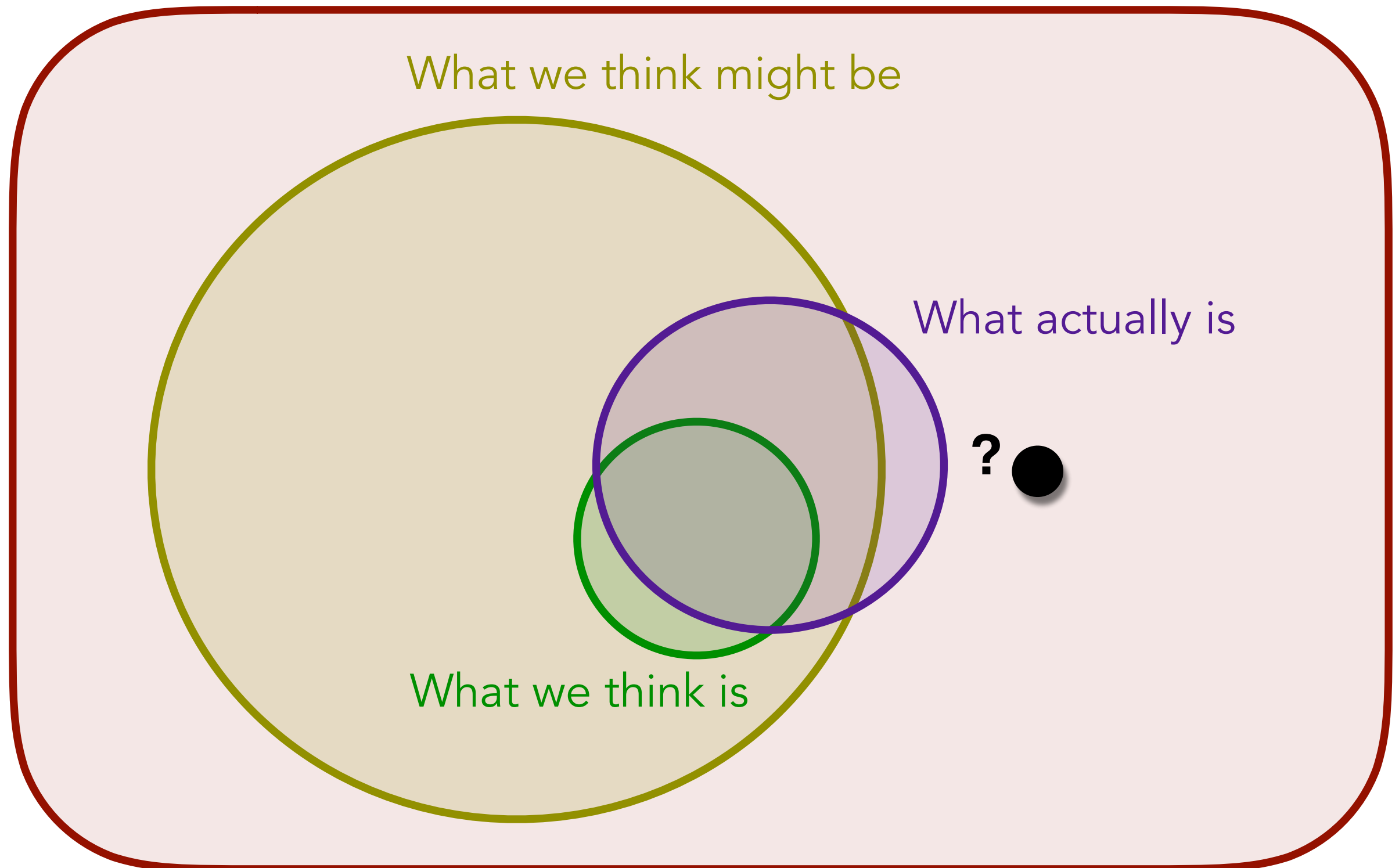
3. *simulate difficult experiments*

What could be



4. *simulate 'what if?' scenarios*

What could be



What is the purpose of a computational model?

Example usages of computational models in neuroscience:

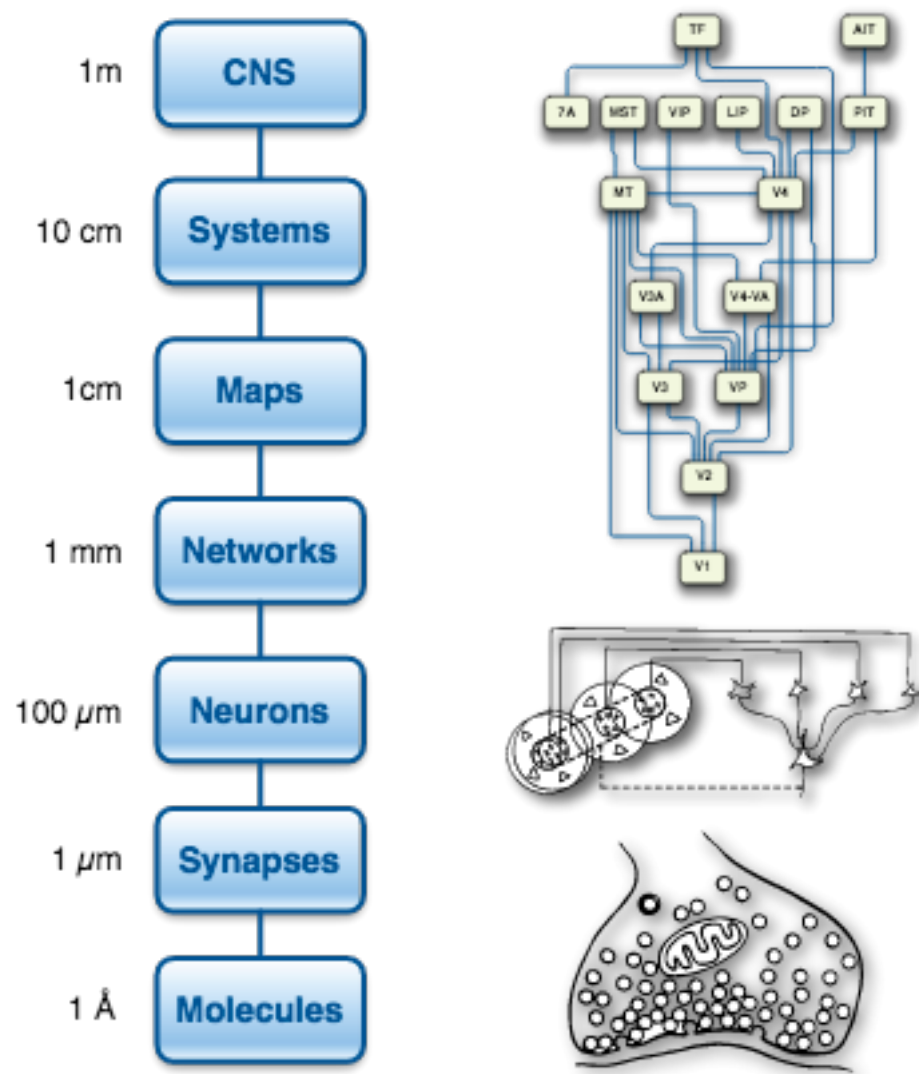
- Hodgkin-Huxley model
(to ask if the squid axon action potential can be explained by the voltage gating dynamics of sodium and potassium conductances).
- Simulation of recurrent hippocampal networks with synaptic plasticity
(to ask if synaptic plasticity could mediate memory recall from partial cues).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

Levels of abstraction

Spatial

Temporal

Levels of Investigation



years

Memories

weeks

Brain development

hours

Gene expression

mins

Cellular signalling

s

Neural circuit dynamics

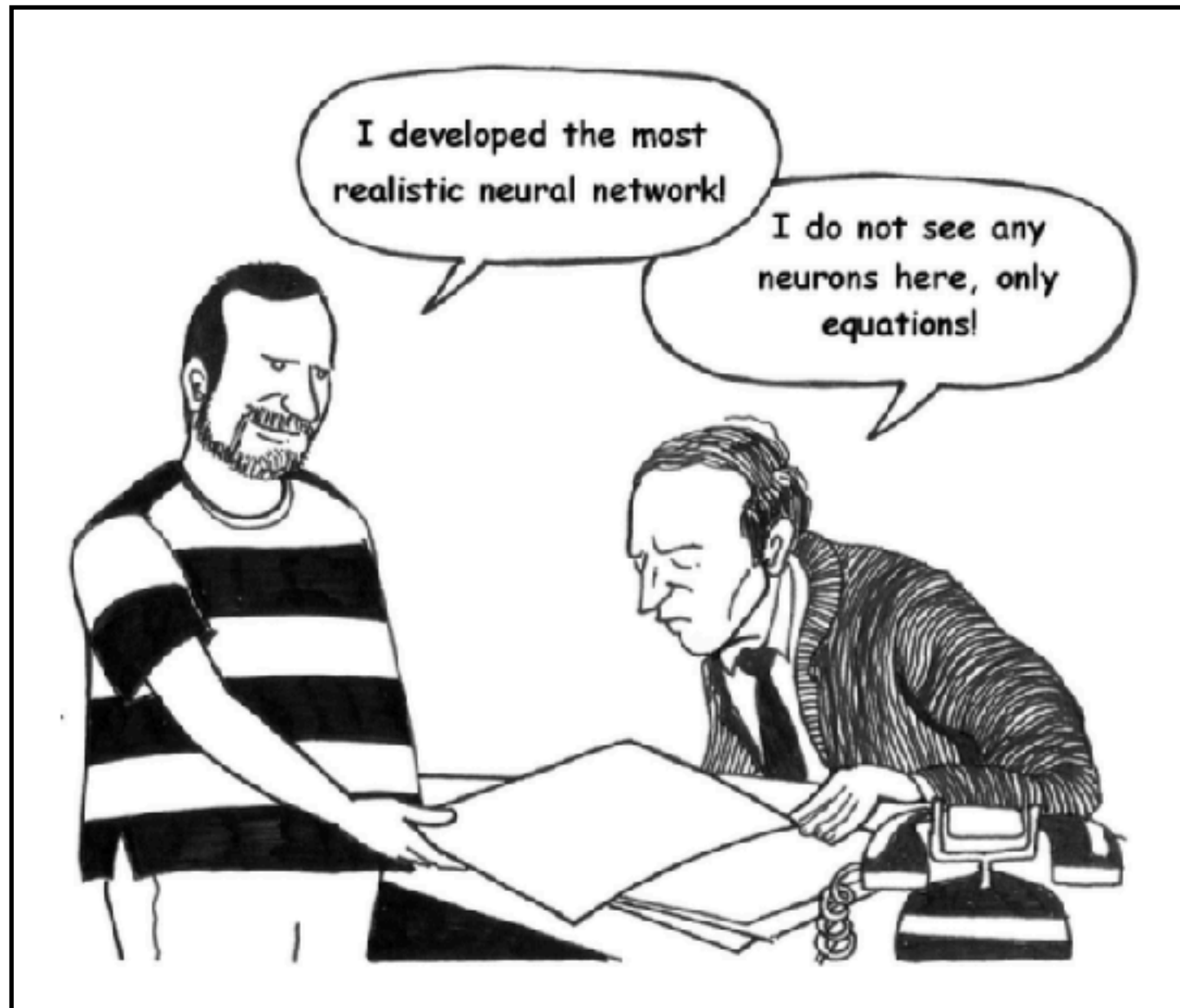
ms

Action potential

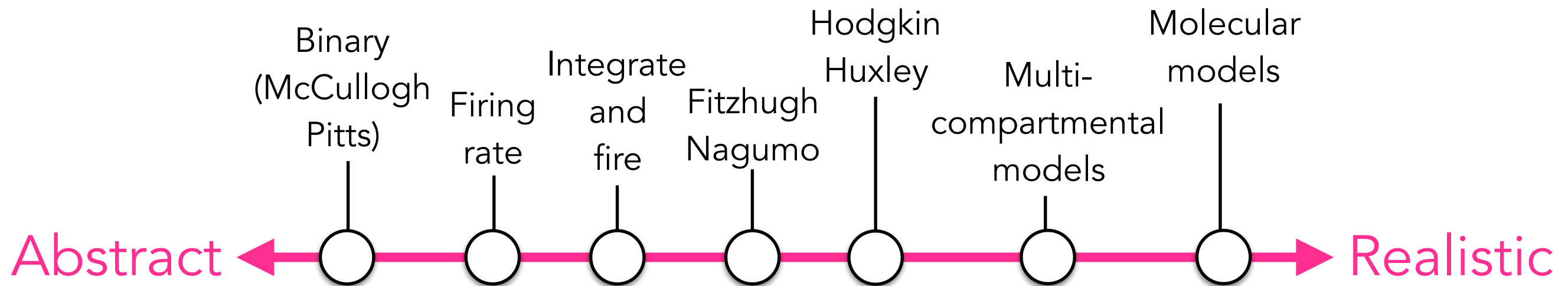
T. Sejnowski

<http://cnl.salk.edu/>

Models of single neurons



Models of single neurons



Abstract models

Simple

Hard to relate to biology

Few parameters

Fast simulation

Mathematical analysis

Generic

vs

vs

vs

vs

vs

vs

Realistic models

Detailed

Contains stuff you could measure

Lots of parameters

Slow simulation

Intractable

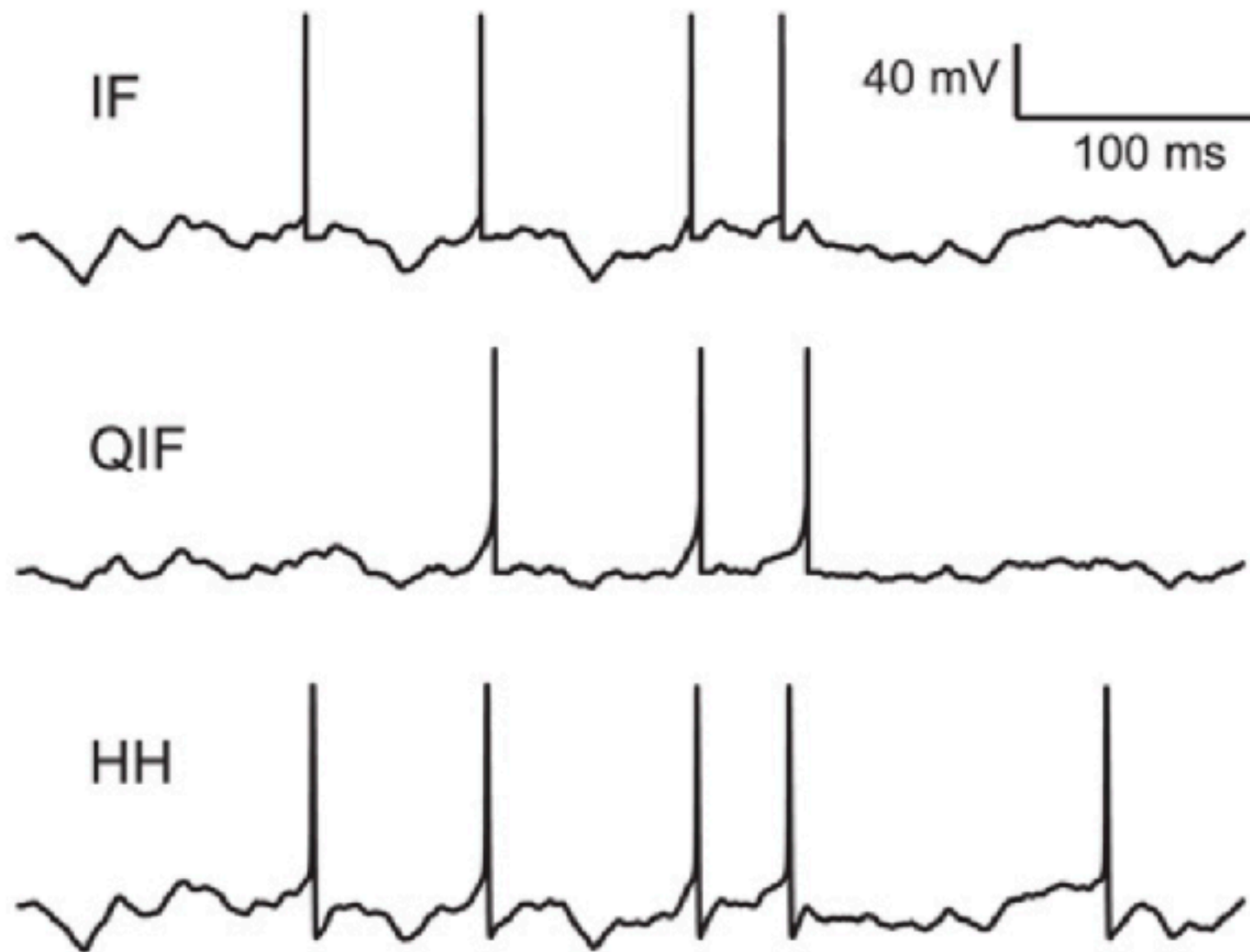
Specific

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

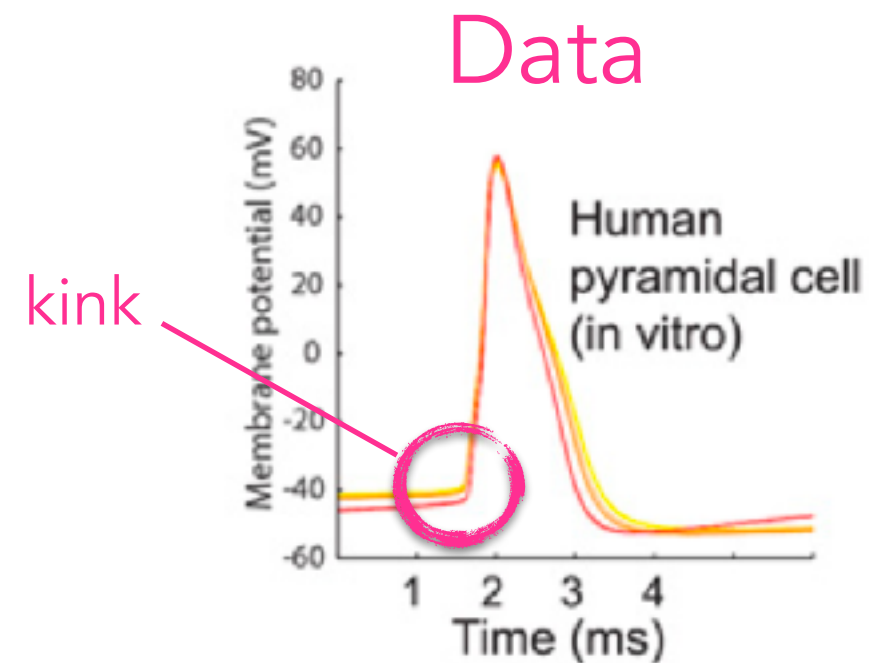
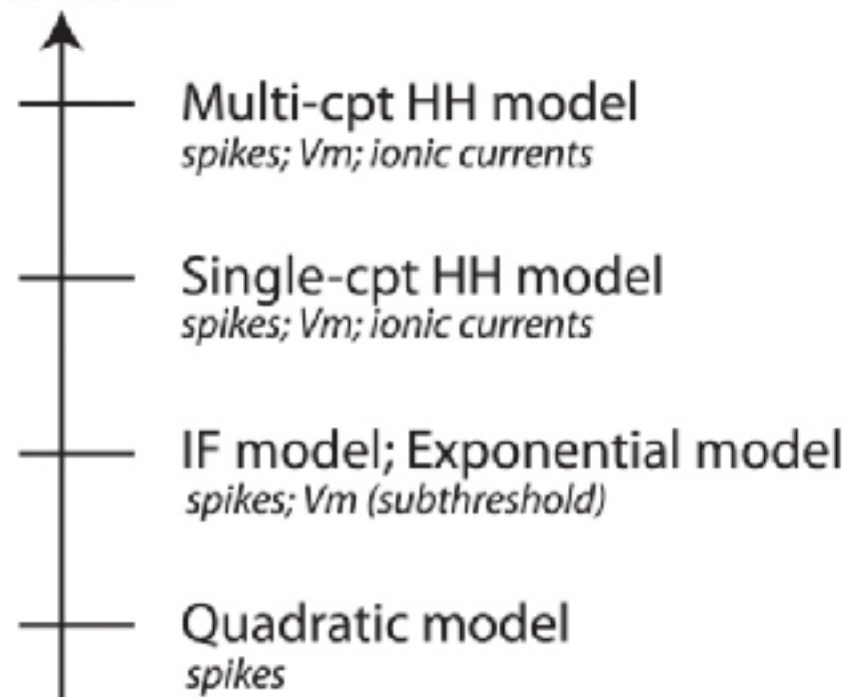




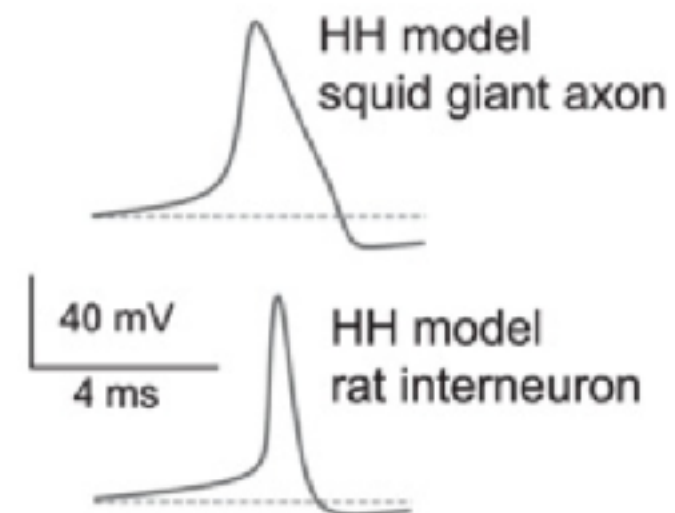
Voltage from three different model neurons in response to the same identical input current.

Empirical content vs empirical accuracy

Empirical
content

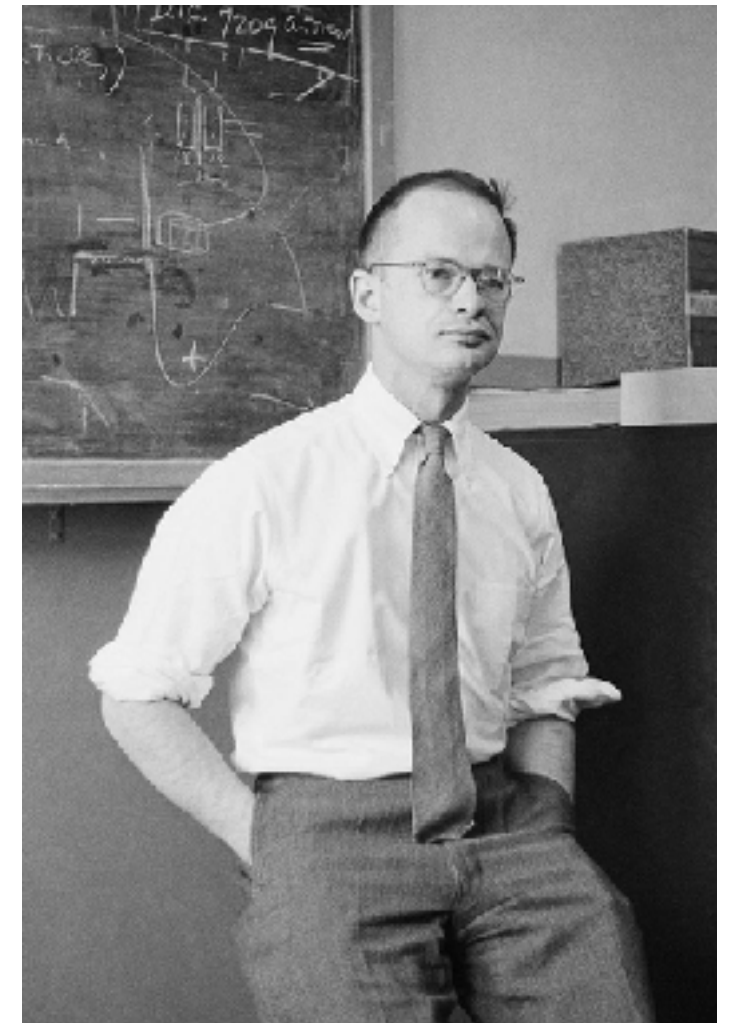


Model



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>



End