Philosophy of computational modelling

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Brains vs Computers

Brains	Computers
Asynchronous	Synchronous
Slow (ms — hours)	Fast (ns)
Parallel	Serial
Analogue	Digital
Noisy	Deterministic
Low power	High power
Evolved	Designed
Unknown circuit diagram	Known circuit diagram
Unknown principles	Known principles

Why we need models!

What we will cover here

- What is a model?
- What is the purpose of computational modelling?
- Levels of abstraction (spatial, temporal and conceptual)
- 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 represented by:

Physical objects

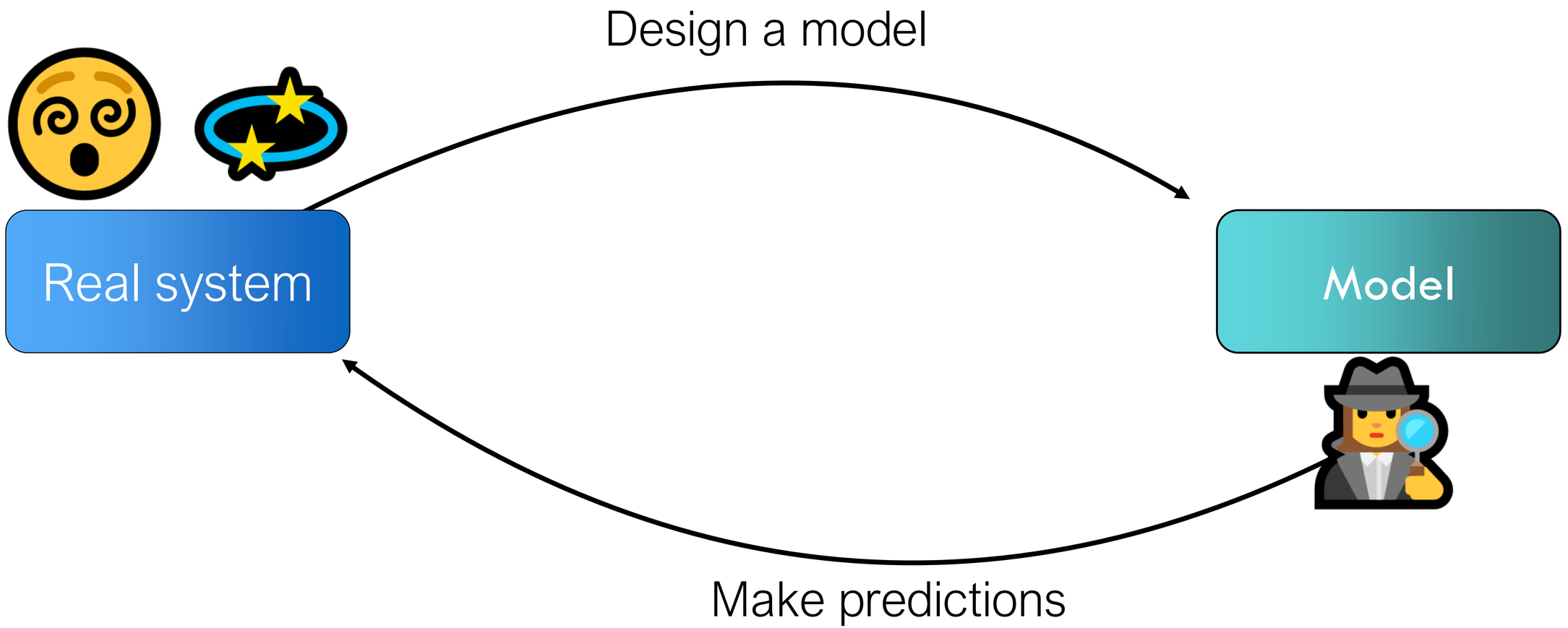
Words

Mathematics

$$\frac{dx_i}{dt} = -x_i/\tau + f(\sum_j w_j x_j)$$

- 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 (e.g. in neuroscience models we usually ignore quantum mechanics).
- However in practice in neuroscience, people often distinguish between ‘phenomenological’ vs ‘biophysical’ models (or sometimes ‘normative’ vs ‘process’ models).

What is the purpose of a computational model?

“All models are wrong, but some are useful.”

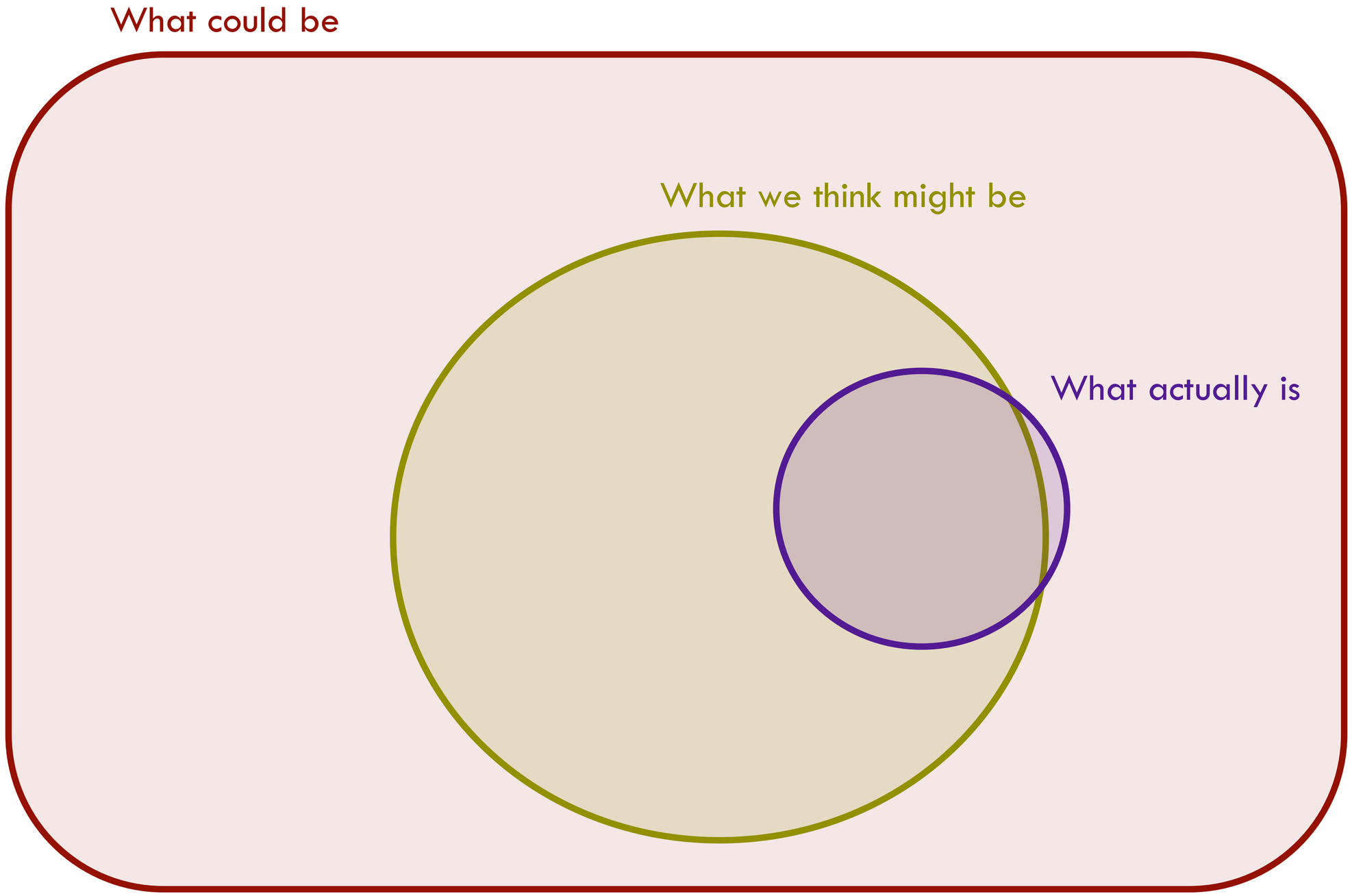
— George Box

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. link levels, i.e. to ask if a mechanism at one level of description can account for a phenomenon at another level.
2. rigorously test your word model: ‘put your money where your mouth is’.
3. simulate experiments that are technically difficult to do in the lab.
4. explore ‘what if?’ scenarios.
5. validate a formal mathematical analysis.


What could be
What we think might be
What actually is

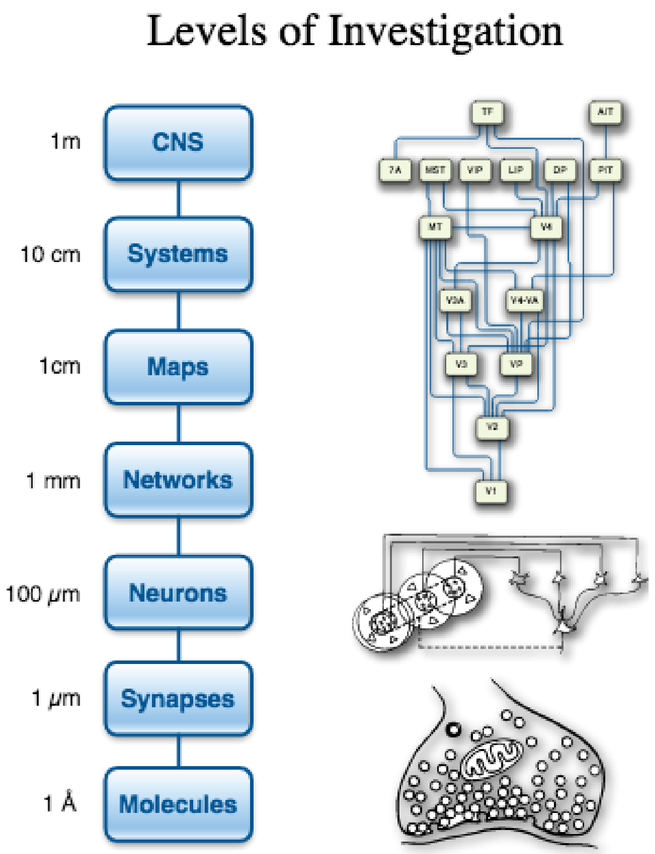
What is the purpose of a computational model?

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).

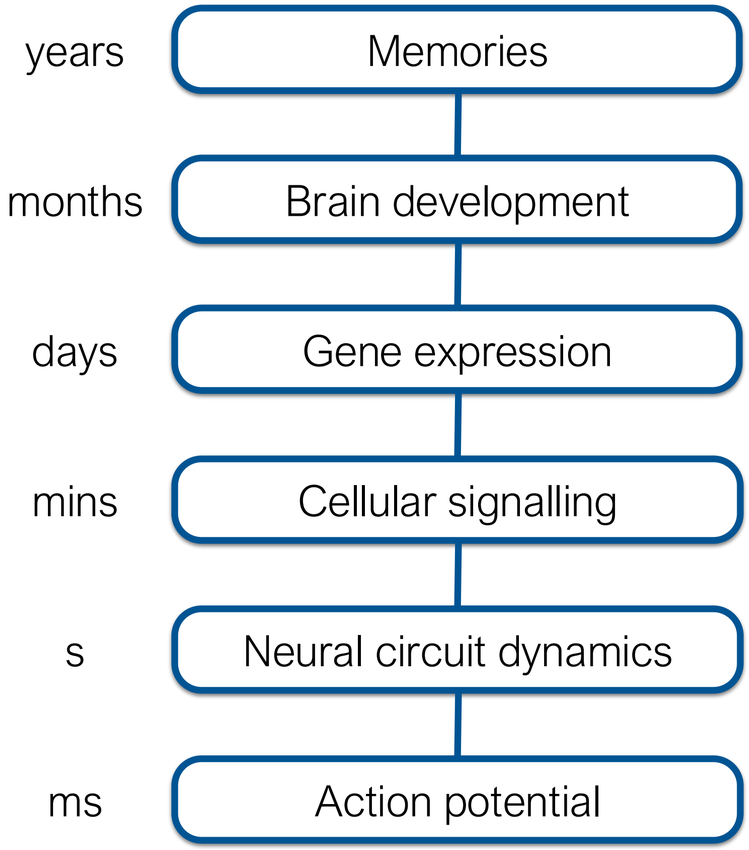
Levels of abstraction

Spatial



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

Temporal



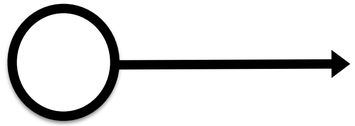
How detailed should a model be?

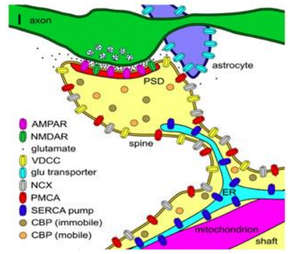
Details vs realism

c.f. Brette, PLoS Comput Biol, 2015

Models

Abstract ⟷ Realistic





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.
- "Everything should be made as simple as possible, but not simpler"
  — Albert Einstein
- Often this choice is dictated by:
  - the phenomenon you wish to explain
  - the data you have to constrain the model
  - the computational resources you have available
  - what maths or programming tools you know
  - ~~what someone else did previously~~

Thoughts? Questions?