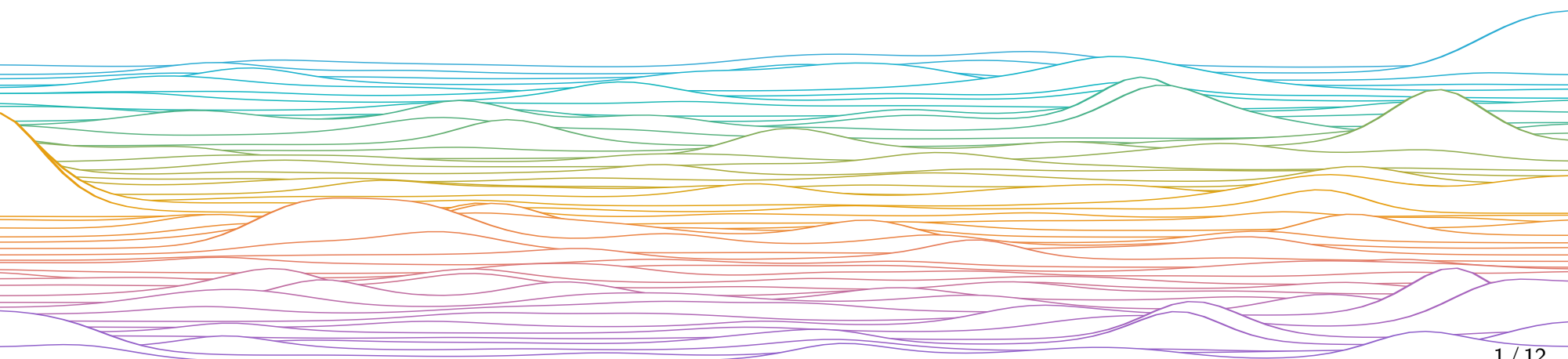
Models

Computational Neuroscience
University of Bristol
Slides adapted from C O'Donnel
M Rule

Learning outcomes:

- Become inspired to creatively imagine models that are entirely phenomenological, provably wrong from the outset, — yet interesting, and maybe even useful.
- Be aware of some models we will cover in this course



What is a model?

Word models

Describe system's components and their interactions

Describe connections, causality, effect directions, magnitudes, & timescales

Often all you need!

Math/computational models: Tools for

Scientific Enquiry

- A logical, specific, and falsifiable type of word model
- Computer code ~ executable mathematics

Data visualization, inference

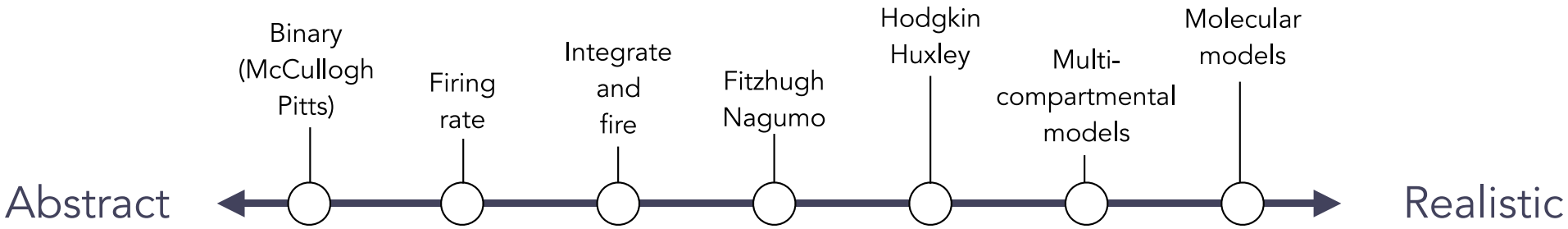
- A compact summary of experimental results

Engineering (neurotechnology, medicine)

- Accurate, quantitative modelling of collective dynamics in epilepsy used to design closed-loop neurotechnology devices

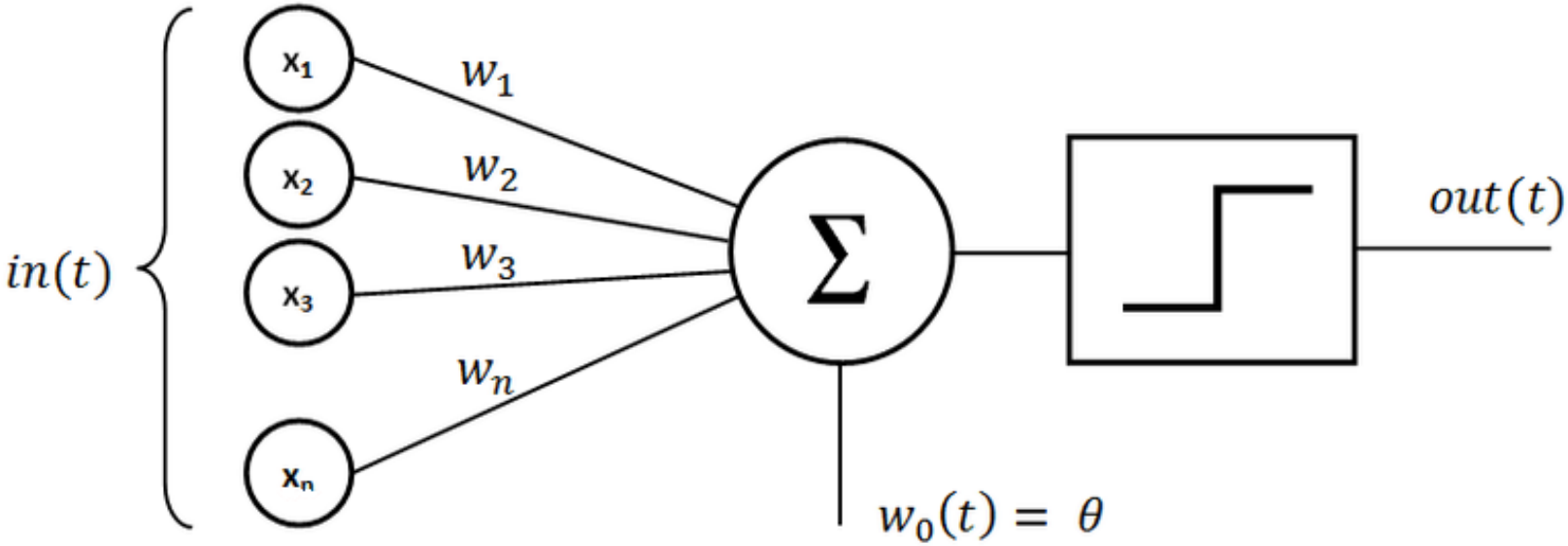
All models are, in some way, phenomenological

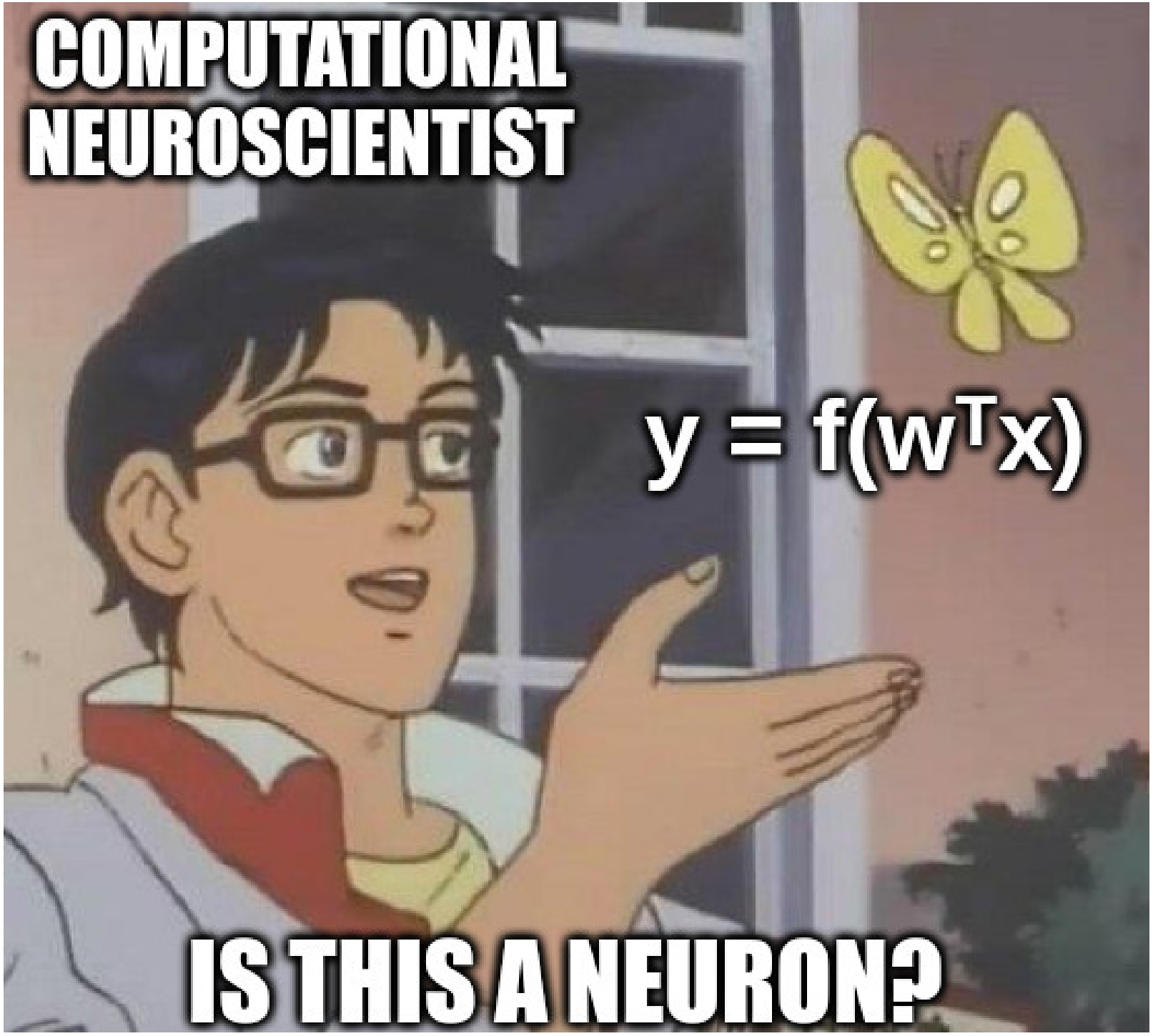
Models of Single Neurons



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

C. O'Donnel (2022)


in(t)
x1
x2
x3
xn
w1
w2
w3
wn
Σ
w0(t) = θ
out(t)


COMPUTATIONAL NEUROSCIENTIST
$y = f(w^T x)$
IS THIS A NEURON?

Which model is best for my problem?

"It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience"

— Einstein (1933) *Lecture at the Royal Albert Hall*

Choose the model that best matches the granularity of your scientific question

Choice dictated by:

- Available data
- Phenomena of interest
- Computational practicalities
- ~~Historical precedent~~

"Am I allowed to do that?"

Usually, yes

Modelling Scales

... Quantum Chemistry, Molecular dynamics

Molecules
Gillespie, Master Equation

Concentrations
Mass-Action Kinetics

Conductance Models
Hodgkin–Huxley

Spiking Models
Leaky Integrate and Fire

Rate Neurons
Neural Mass/Field Models

Poisson Neurons
Generalized Linear Models

Binary Neurons
McCulloch–Pitts, Hopfield, Perceptron

Cognitive Neuroscience, Psychology ...

Physiological, Quantitative

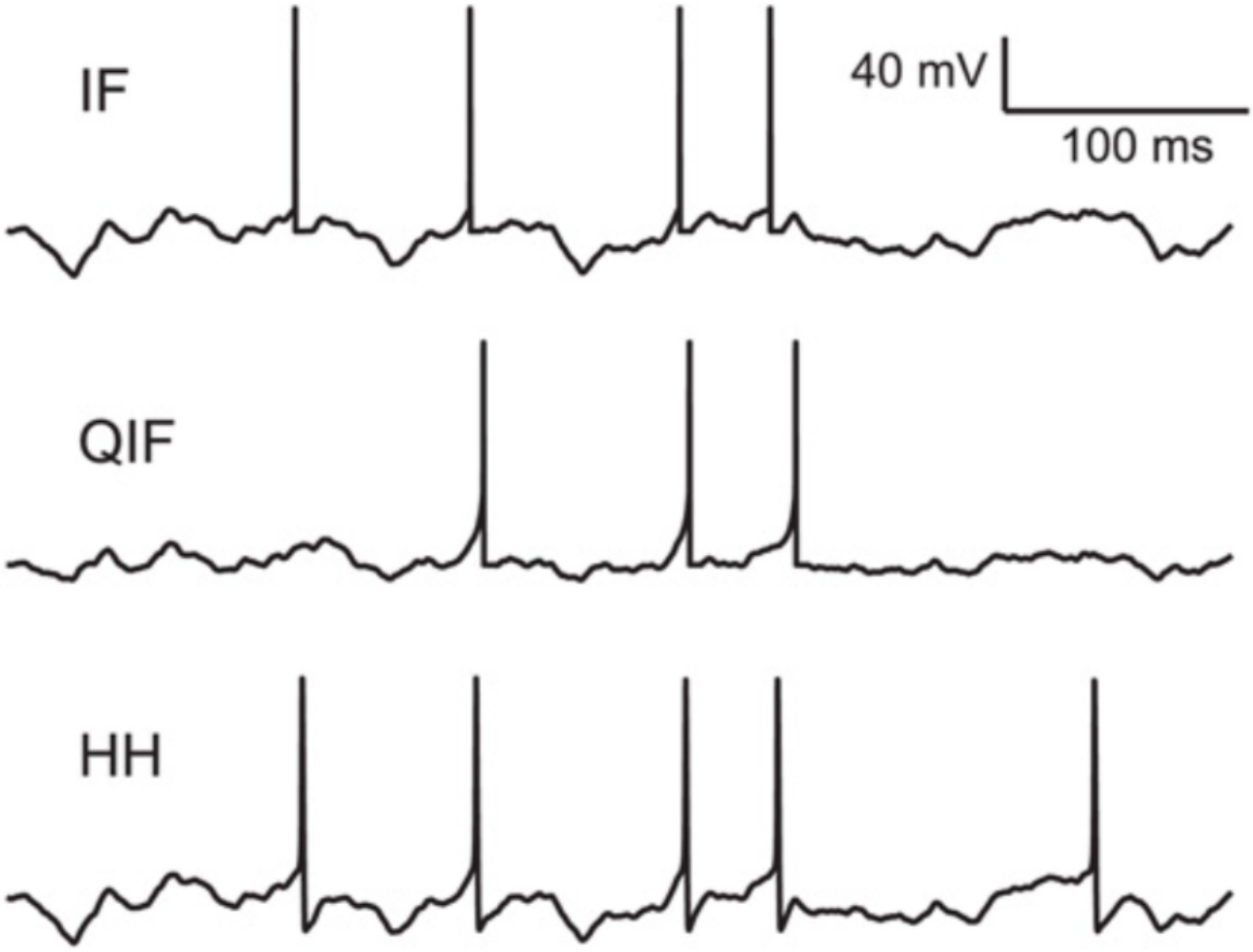
Biological Realism, Data needed to identify parameters

Computational Efficiency, Mathematical Tractability

Phenomenological, Qualitative

Where are we now? Where on this slide? which topics we will cover, when

How frustrated you would be be if you went to enormous lengths to robustly approximate a LIF neuron using messy ionic conductances, only to turn around and discover that some scientist had declared this model "not biologically plausible"?



Voltage from three different model neurons in response to the same identical input current; Brette (2015) PLoS Comput Biol

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