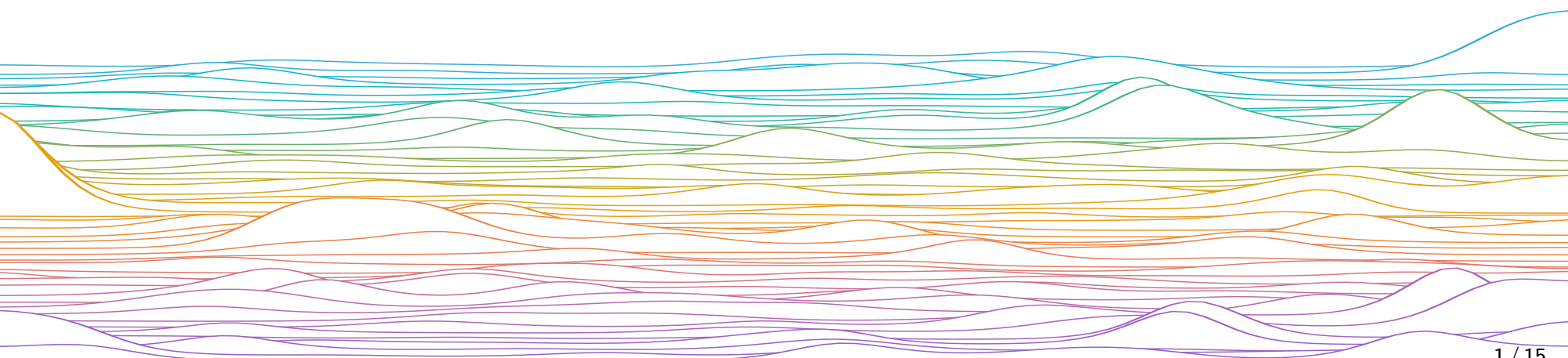
Hello and Introduction

Computational Neuroscience
University of Bristol

M Rule

Learning outcomes:

- Know where to find course material on Github
- Know that exam material will be drawn from lecture slides, homeworks, and coursenotes
- Schedule and Contacts
- Broader course context



Course materials on Github

github.com/ engmaths/SEMT30003_2025

- Slides/labs/coursework/everything

Textbooks and Reading

Material will be accompanied by reading or exercises taken from

- *Conor Houghton's Coursenotes (on course github)*
- *Neuronal Dynamics* (Gerstner, Kistler, Naud, Paninski), free online.
- *Theoretical Neuroscience* (Abbott, Dayan)

Exam material will be drawn from lecture slides, homeworks (i.e. labs, formative coursework), and coursenotes

Unit variants

CS minor:

- *Topics in Computer Science* exam question (lectures & labs, term weeks 1–8).

SEMT:

- 50% Final (lectures & labs term weeks 1–8)
- 50% extended coursework (term weeks 9–11)

Staff Contacts (via Teams/Email)

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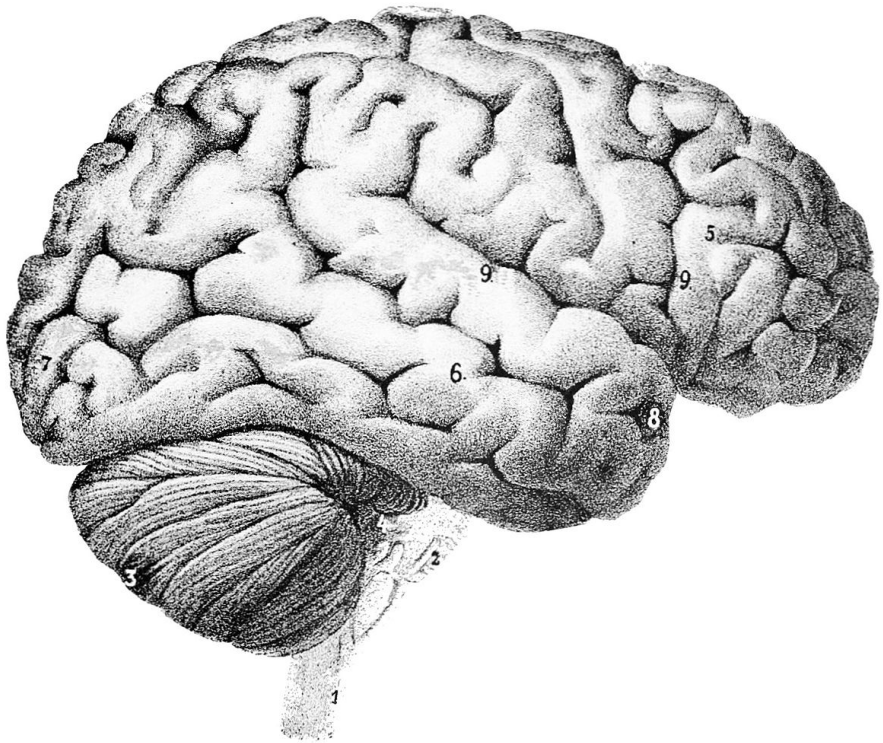
Why Brains?

1–2 kg (≈ 2% body weight)

20% of caloric expenditure

Azevedo et al. 2009[1]:

- $\sim 86 \cdot 10^9$ neurons in human brain



Outer surface of the human brain, Sanger Brown, c. 1894, Wikimedia

[1] Azevedo, Frederico AC, et al. "Equal numbers of neuronal and non-neuronal cells make the human brain an isometrically scaled-up primate brain." Journal of Comparative Neurology 513.5 (2009): 532-541.

Why Brains?

> *La fixité du milieu [intérieur] suppose un perfectionnement de l'organisme tel que les variations externs soient à chaque instant compensées et équilibreées.*
>
> *Bien loin, par conséquent, que l'animal élevé soit indifférent au monde extérieur, il est au contraire dans une étroite et savante relation avecc lui, ...*
>
> — Claude Bernard (1878) *Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux, Tome I*

Paraphrasing:

- The stability of an organism's internal environment requires physiological processes that compensate for external disturbances.
- Organisms with higher cognitive capacities are not more removed from the external world, but rather more attuned to it.

⋮

< 1900 Mathematical Physiology

Harvey (1628) Fick (1855) Frank (1895) Starling (1896)
1878: Claude Bernard, *Milieu Intérieur*

1932 Homeostasis

Walter Cannon

1924 Quantitative Experiments

Hans Berger, Electroencephalography (EEG)

1952 Mathematical Neurophysiology

Hodgkin & Huxley

1940–60 Cybernetics

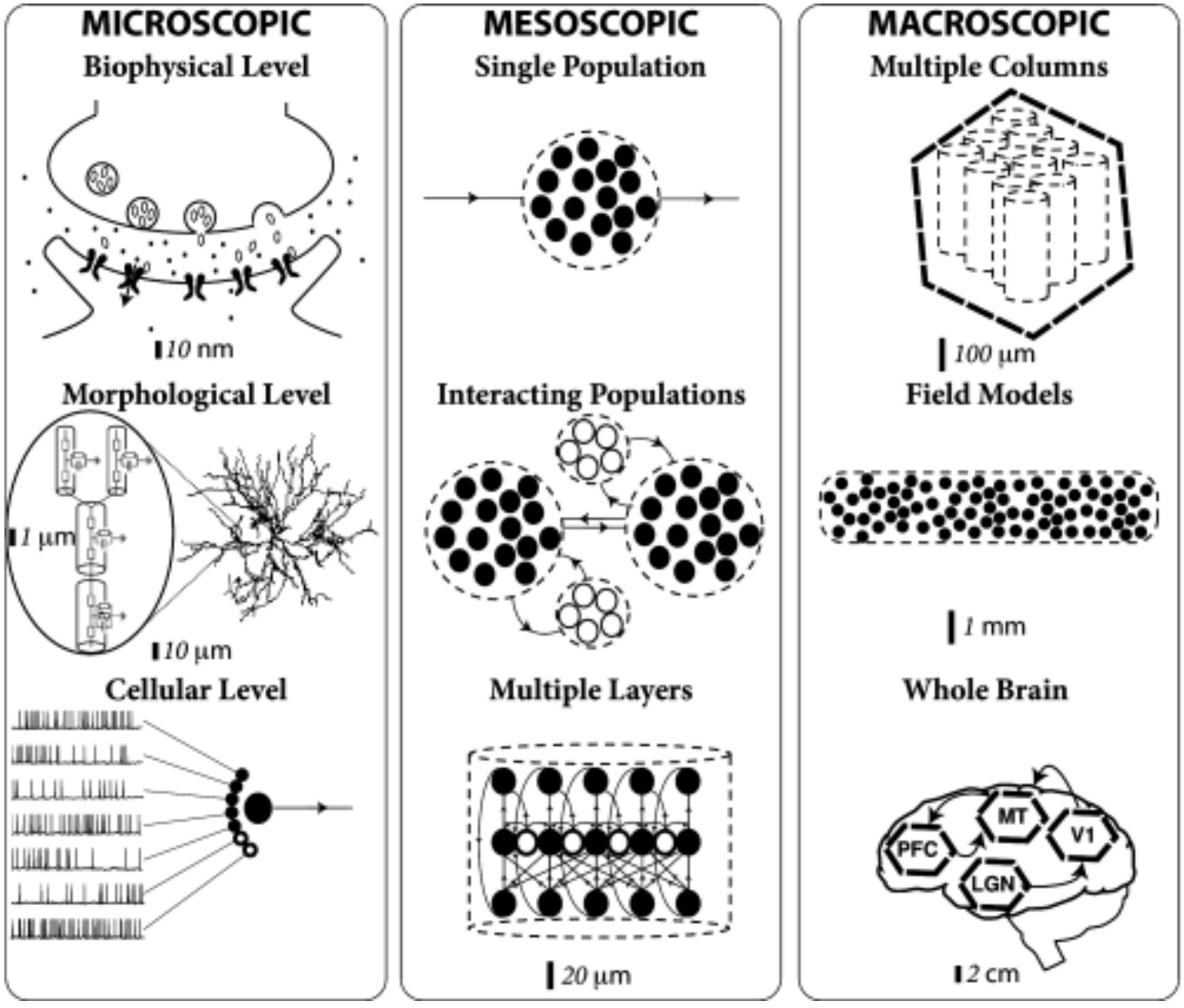
Wiener ('48), McCulloch & Pitts ('43), Rosenblatt ('58), Turing, von Neumann, Minsky

⋮

There are now in the world machines that think, that learn and that create. Moreover, their ability to do these things is going to increase rapidly until—in a visible future—the range of problems they can handle will be coextensive with the range to which the human mind has been applied.

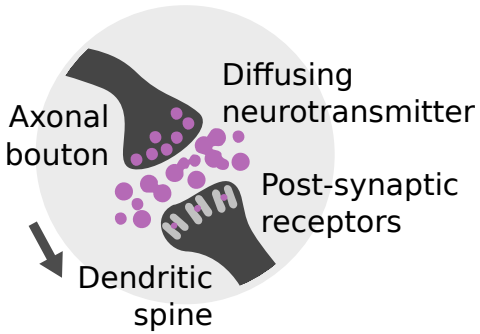
— Herbert A. Simon, Allen Newell (1958)[1]

[1] Simon, H.A. and Newell, A. (1958) "Heuristic problem solving". Operations Research 6(1), pp.1-10.

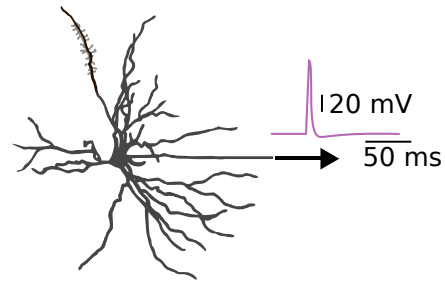


Gerstner & al. Neural Dynamics Fig 12.1

Biological

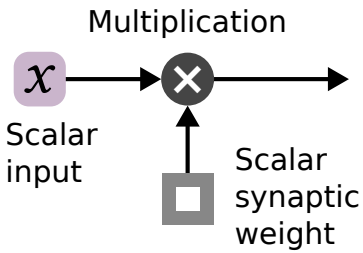


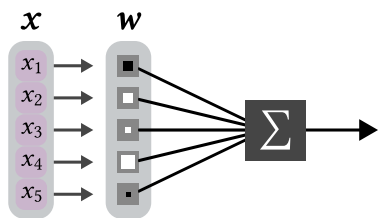
Dendritic integration



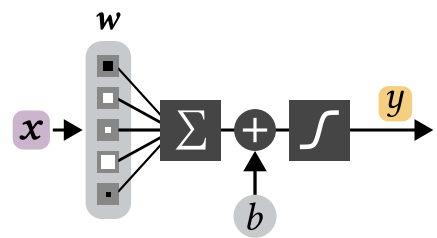
Firing threshold
+ Acton potential

Artificial





Linear summation



Additive bias
+ Saturating nonlinearity

discuss *phenomenological* vs. *mechanistic*

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

Scheduled Topics

Week

1. Intro to neuroscience & background
2. The action potential
3. Synaptic communication
4. Plasticity 1: Cerebellum & perceptron
5. Plasticity 2: Hippocampus & hopfield Networks

   (reading week break)
6. Rate models and vision
7. Statistical models and data analysis
8. (extended coursework — to be submitted 50% mark)
9. (extended coursework ...)
10. (extended coursework ...)

end