COMS30017
Computational Neuroscience

Why brains?

Intended learning outcomes

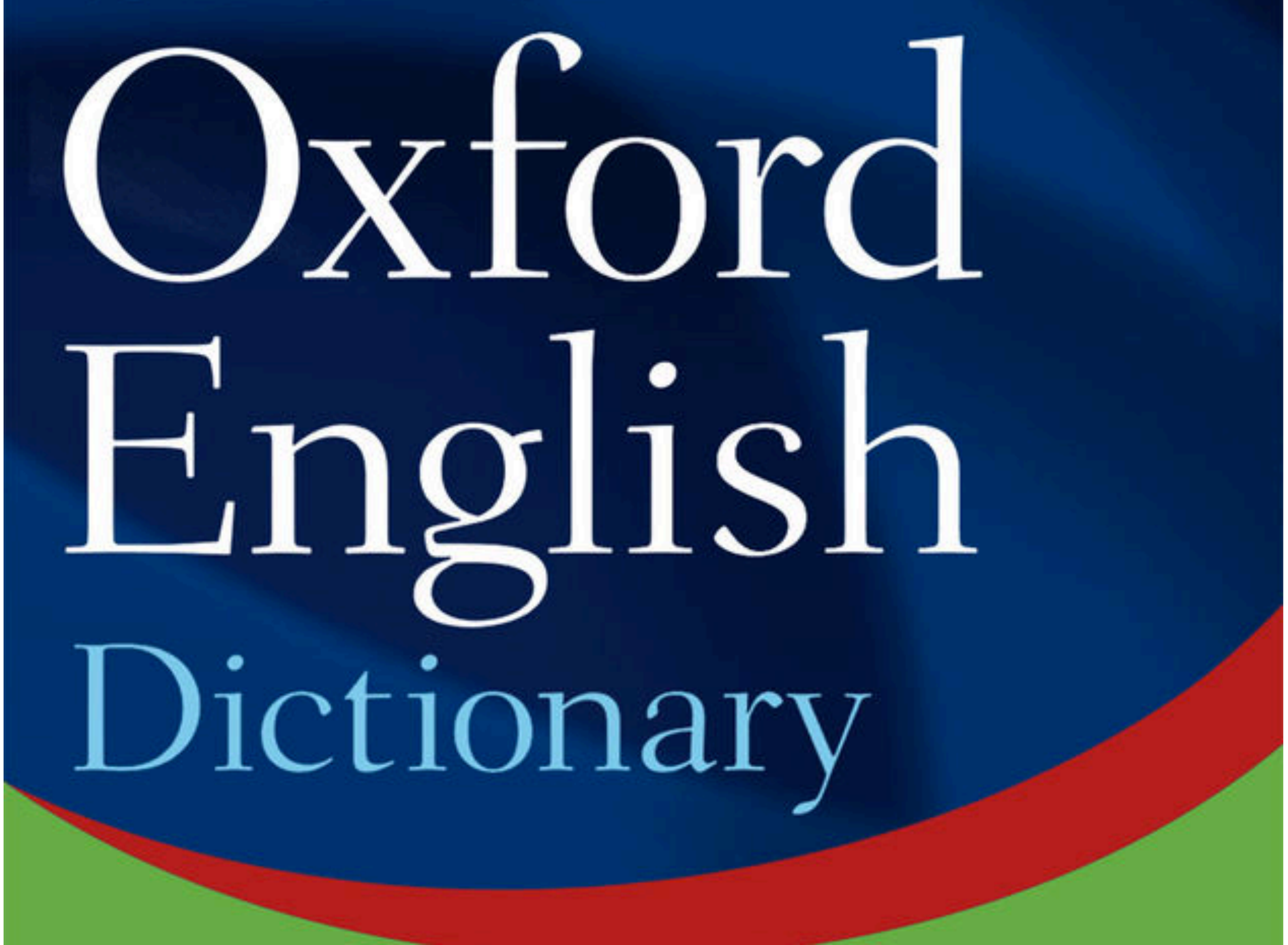
- Basic understanding of why brains exist.
- Appreciate the similarities and differences between brains and computers.
- Be able to articulate what computational neuroscience is.

What are brains for?

- To enjoy art and music, to love,… to have consciousness?
- But other species have brains: mice (10^7 neurons), flies (10^5 neurons), nematode worms (302 neurons) — as opposed to humans' 10^{11} neurons.
- General principles underlying brain function must account for these animals too.
- "The brain's purposes reduce to regulating the internal millieu and helping the organism survive and reproduce."
  - Sterling & Laughlin (Principles of Neural Design, 2015)
- These challenges necessitate that brains have mechanisms for:
  - Sensing
  - Memory
  - Decision making
  - Motor control

Brains vs Computers

Is the brain a computer?


Oxford
English
Dictionary

computer (noun)

An electronic device which is capable of receiving information (data) in a particular form and of performing a sequence of operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals.

brain

~~**computer**~~ (noun)

electrochemical

An ~~electronic~~ device which is capable of receiving information (data) ~~in a particular form~~ and of performing a sequence of operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals.

from sensors

mix of genetic and learned

control

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

Where did computational neuroscience come from?

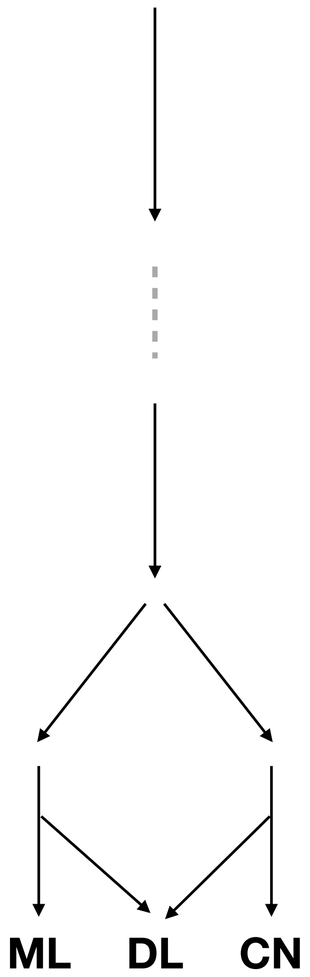
1940s-60s: cybernetics, cognitive science, artificial intelligence.
Wiener, McCulloch, Rosenblueth, Turing, von Neumann, Minsky.

1970s-early 1980s: “AI winter”

1980s: artificial neural networks, parallel distributed processing, connectionism.
McClelland, Rumelhardt, Hinton, Sejnowski

1990s-2000s: "machine learning” splits from computational neuroscience (and statistics).

2010s: ANNs resurge, rebranded as “deep learning”. Remerging with parts of computational neuroscience.



What is computational neuroscience?

- A computational view of brain function.
  Assumes the brain is an information processing machine.

- Computational methodology.
  Uses computational and mathematical methods (as opposed to doing laboratory experiments).

- In practise it encompasses both:
  1. statistical analysis of neuroscience data.
  2. computational modelling (simulations) of the brain.

Test yourself questions

- Name the three key evolutionary challenges that organisms face, which brains help tackle.
- Name two differences between human-made computers and brains.

Summary

- Brains evolved to help animals self-regulate, and to enable their survival and reproduction.
- *Brains are computers*. But their hardware and operational principles are very different to human-made computers.
- Computational neuroscience is a research field that tries to understand how the brain works from a computational point of view, using computational and mathematical methods.