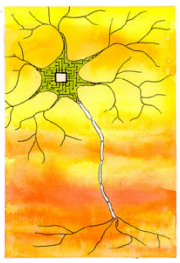
Computational Neuroscience

Lecture 1



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The human brain

- The most complex device on this planet
  - 10^{11} neurons
  - 10^{14} synapses
  - 100,000 miles of dendrites
- Puzzling question:
  - How does this complex device give rise to our mental abilities?
  - The question of the origin of mind fascinated philosophers since ancient times, but now we have data & tools to address it, as never before

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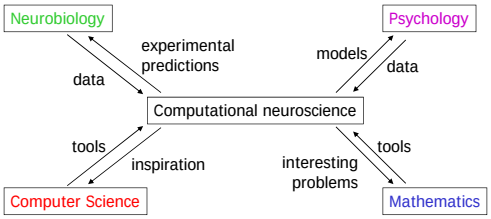
Computational neuroscience

- Builds mathematical models describing computations in the brain giving rise to our mental abilities



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Outline

- Organization
- Why build models of the brain?
- Current knowledge and open questions

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You and us

- Multidisciplinary students
  - Computer Science, Math, Physiology
  - Differences in syllabus & assignments
- Multidisciplinary lecturers
  - Dr. Roland Baddeley (CS->Physiology->Psychology)
    - 2 lectures
  - Dr. Rafal Bogacz (CS/Anat->Psychology/Math->CS)

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Unit codes

	COMS30127	COMSM2127	COMS35103
Group	3rd year Engineering	4th year and MSc Engineering	MRes in Systems Neuroscience
Credits	10	10	15
Practical sessions	No	No	Yes
Assignment weight	20%	20%	40%
Assignments	Simulations	Data analysis	Matlab & Data analysis

- Assignments available at the unit websites e.g.
  - www.cs.bris.ac.uk/Teaching/Resources/COMS30127

Syllabus

- Introductory topics (2 lectures) - Engineering Students only
  - Computational anatomy of the brain
  - Matlab & Differential Equations
- Models of single neurons (2 lectures)
- Visual system and coding (3 lectures)
- Learning & Memory (8 lectures)
- Decision making (3 lectures)

Background materials

- Slides available at the unit websites
- Some lectures based on:
  - Dayan P & Abbott LF (2001) Theoretical Neuroscience, MIT Press.
- Most lectures based on scientific papers
  - Lecture notes for some lectures
  - It is worth attending the lectures
  - It is worth taking notes

Exam

- Only issues discussed during lecture required
- Slides with info not required for the exam have F (for Fun) in the top right corner

Support

- Forum
  - Link in top right corner of unit website
  - Post your questions on the forum, and discuss
  - I will reply to questions during office hours
  - Do not send me e-mails
- Office
  - MVB 3.43

Why build models of the brain?

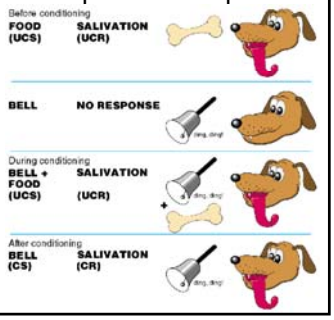
- They answer three types of questions about the brain (Dayan & Abbott, 2001)
  - Descriptive = What?
  - Mechanistic = How?
  - Interpretive = Why?
- They inspire new technologies
- You can learn transferrable skills

Descriptive = What?

- Compactly summarize large amount of experimental data in equations or algorithm
- Example
  - Large amount of experimental data describing the changes in electrical potential inside a neuron
  - Have been summarized in a few equations by Hodgkin & Huxley (1952)
    - Given neuron's parameters & potential
    - Equations predict future potential
  - This gave them:

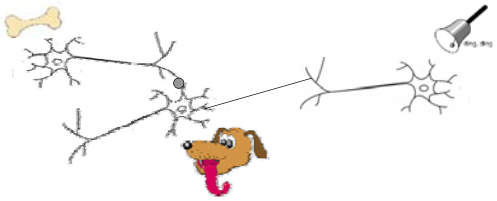
Mechanistic = How? (1)

- Show how neural circuits perform complex functions
- Example
  - Pavlov's conditioning



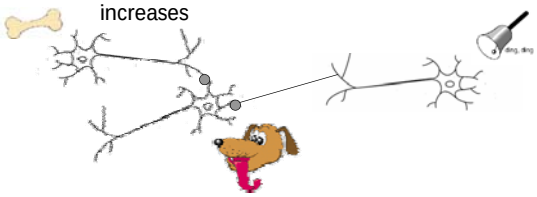
Mechanistic = How? (2)

- How changes in neural circuits may underlie Pavlov's conditioning?
- Hypothetical circuit



Mechanistic = How? (3)

- Hebb rule (1949):
  - If two neurons are active at the same time, the weight of synaptic connections between them increases



Interpretive = Why?

- Many computations in the brain performed in optimal or nearly optimal way
- Understanding what the optimal algorithms are and how they can be implemented biologically can help to explain why the brain is designed the way it is
- Example
  - WHY do certain parts of the brain include particular pathways?

Inspiring new technologies

- Often technologies are inspired by nature
  - E.g.: airplanes have wings
- But details of the solutions need not to be
  - E.g.: propeller works better than flapping wings
- Similar story with Artificial Intelligence
  - Neural Networks inspired Machine Learning (1984)
  - But current learning algorithms are not biologically plausible (e.g. support vector machines)
  - There are still open problems in need of inspiration
    - E.g. language, autonomy, etc.

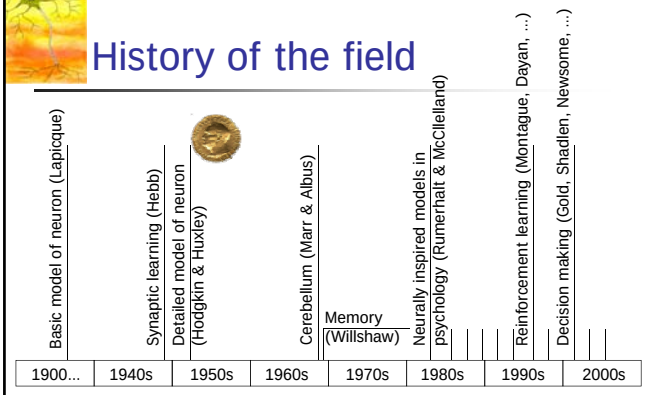
Transferable skills

- Some skills you will gain during this course may be useful in other areas:
  - Simulation of dynamical systems
    - Translating description of the system into a computer program
  - Data analysis in Matlab

Focus of this unit

- This unit focuses on modelling the computations in the brain
- It does not focus on neurally inspired algorithms that can be directly applied to real world problems
  - Those are covered in different units, e.g.:
    - Introduction to Machine Learning
    - Pattern Analysis and Statistical Learning

History of the field

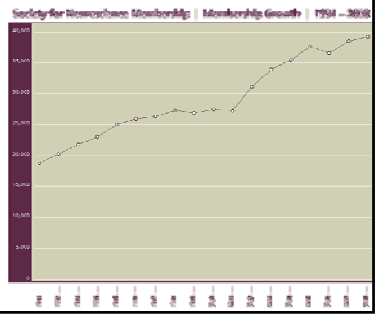


Currently open questions

- Details of:
  - Vision
  - Memory
  - Reinforcement learning
  - Decision making
  - ...
- Almost unknown areas:
  - Language
  - Reasoning
  - Consciousness

Size of the field

- Society for neuroscience
  - www.sfn.org
- Most research experimental
- Now: enough data to build precise theory



Bristol Neuroscience

- http://www.bris.ac.uk/neuroscience/
- Around 500 researchers
- A few research seminars per day
- Significant discoveries, e.g.
  - Main synaptic mechanism of Hebbian learning

Bristol Student Society for NEUROSCIENCE