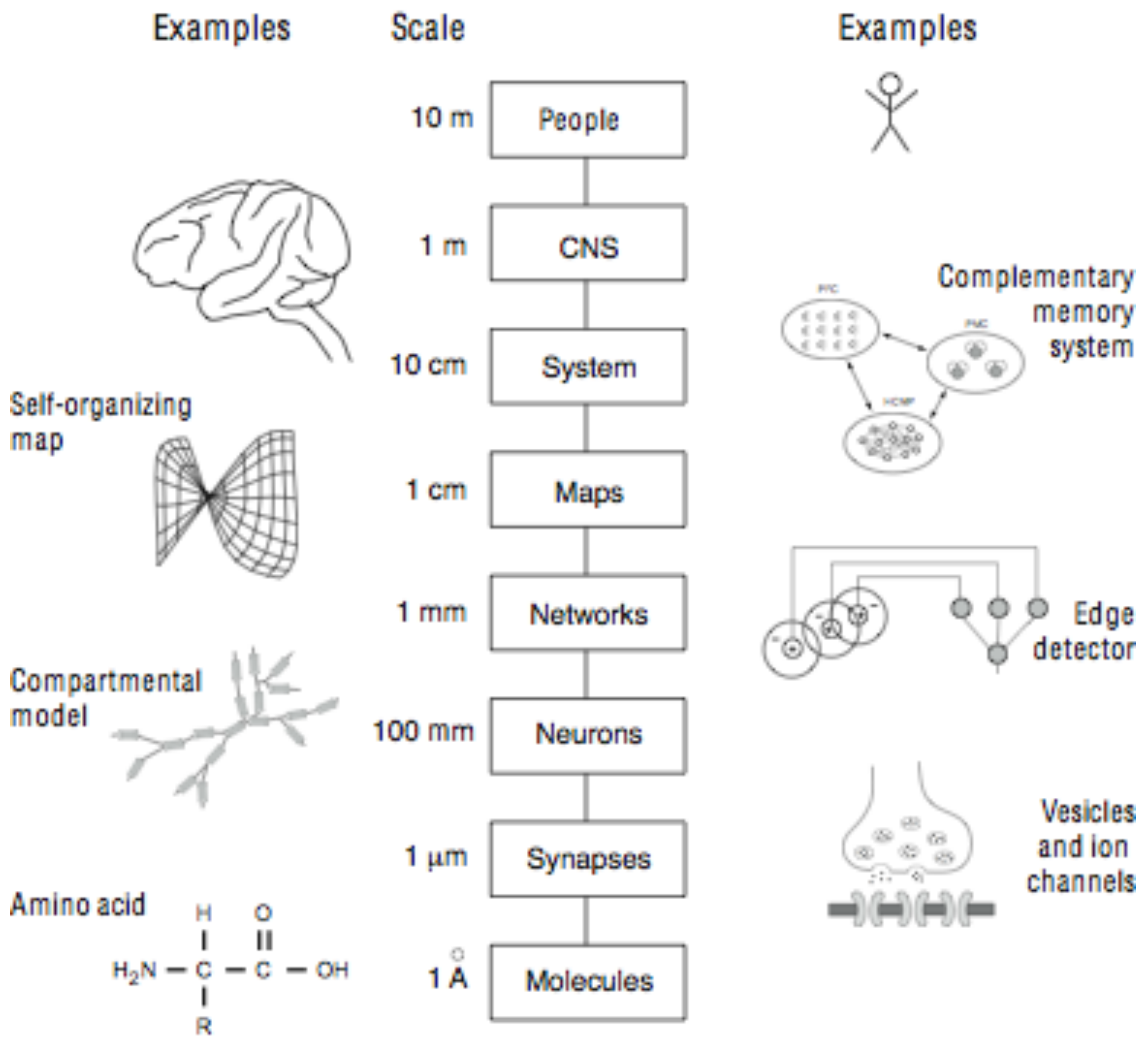
What is Computational Neuroscience?

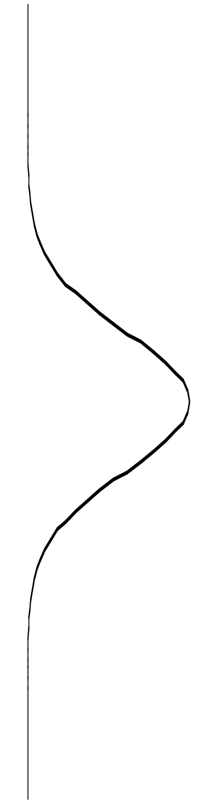
Computational Neuroscience is the theoretical study of the brain to uncover the principles and mechanisms that guide the development, organization, information processing and mental abilities of the nervous system.

Levels of organization in the nervous system



Levels of modeling

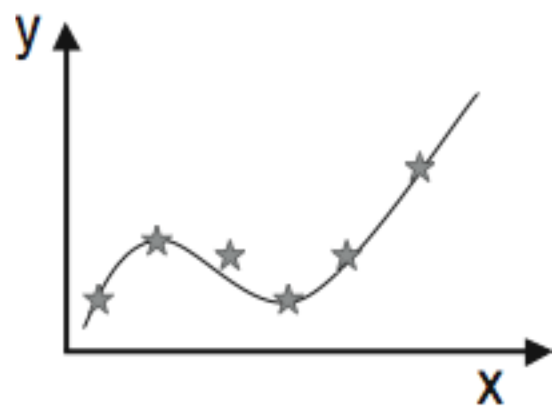
- Computational biochemisty and biophysics
- Compartmental Models
- Network functions
- System level-level organizations



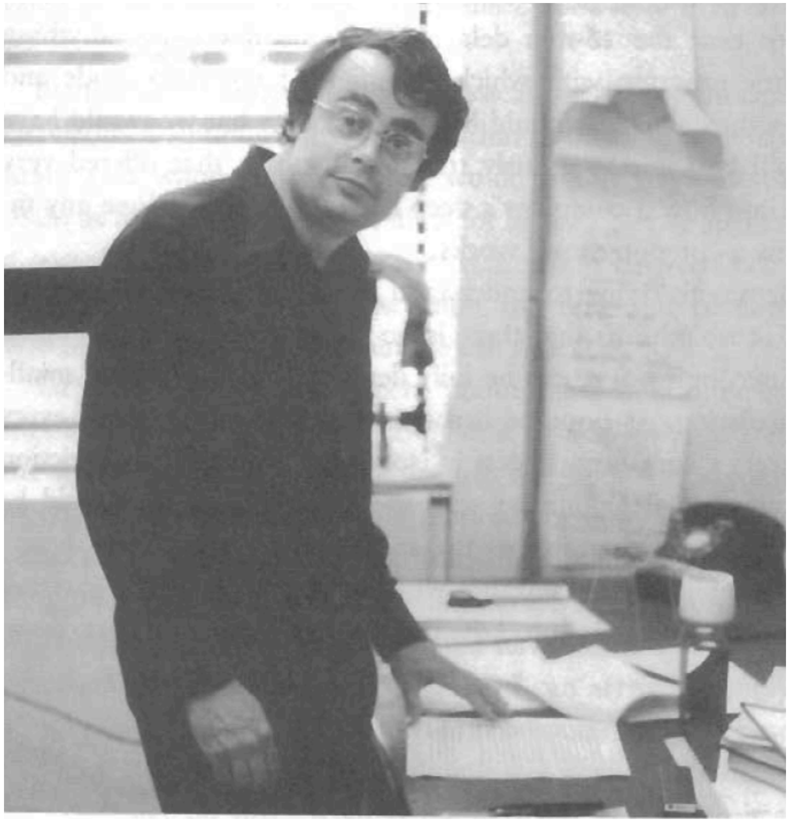
RI ←→ AI

Neural/sub-symbolic ←→ Cognitive/symbolic

What is a model?



Models are abstractions of real world systems or implementations of hypothesis to investigate particular questions about, or to demonstrate particular features of, a system or hypothesis.



David Marr (1945-1980)

1969: A theory of cerebellar cortex.

1970: A theory for cerebral neocortex

1971: Simple memory:
a theory for archicortex.

1982: Vision

"To phrase the matter in another way, an algorithm is likely to be understood more readily by understanding the nature of the problem being solved than by examining the mechanism (and the hardware) in which it is embodied."

Marr, 1982

Levels of abstraction: Marr's approach

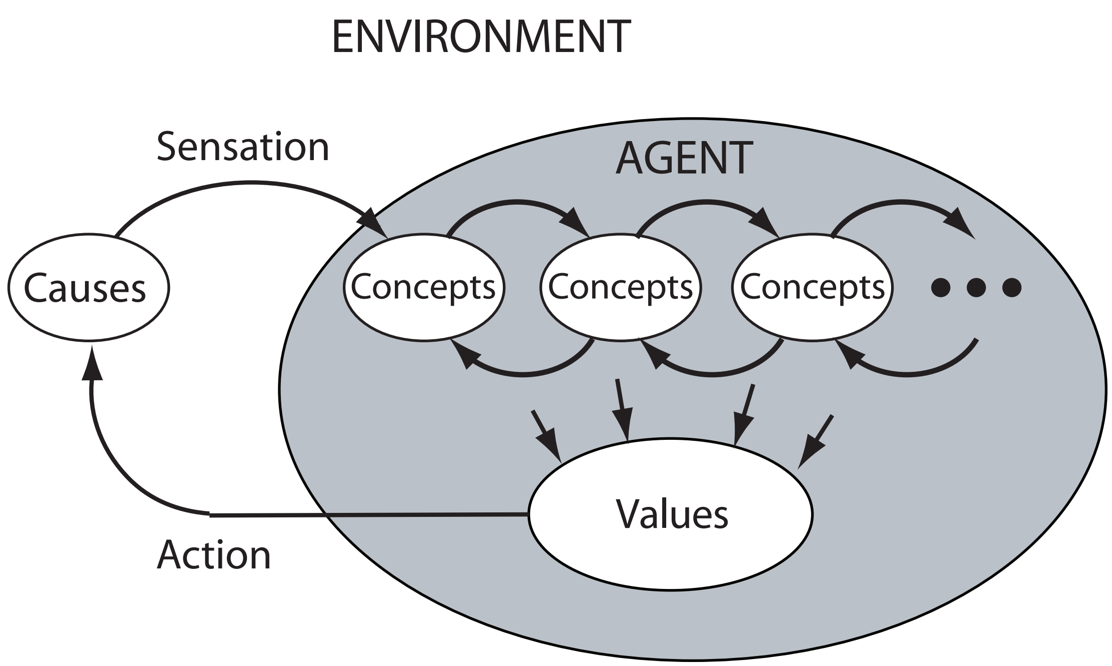
1. Computational theory: What is the goal of the computation, why is it appropriate, and what is the logic of the strategy by which it can be carried out?

2. Representation and algorithm: How can this computational theory be implemented? In particular, what is the representation for the input and output, and what is the algorithm for the transformation?

3. Hardware implementation: How can the representation and algorithm be realized physically?

A computational theory of the brain:
The Anticipating Brain

The brain is an anticipating memory system. It learns to represent the world, or more specifically, expectations of the world, which can be used to generate goal directed behavior.



Recent exciting development

- Deep networks
- Deep RL
- Neural Turing Machines

Outline of chapters

Basic neurons

Chapter 2: Membrane potentials and spikes
Chapter 3: Simplified neurons and population nodes
Chapter 4: Synaptic plasticity

Basic networks

Chapter 5: Random networks
Chapter 6: Feedforward network
Chapter 7: Competitive networks
Chapter 8: Point attractor networks

System-level models

Chapter 9: Modular models
Chapter 10: Hierarchical models

Course Format

This is a highly interactive advanced introductory course

- No lectures, only give directions and discuss questions
- No assignments, only projects that require active research
- Presentation of classic paper
- Research project or final depending on your progress

Projects (assignments) are research questions; they might not have simple answers and usual require further discussions. Hence, it is usually not possible to start the night before the deadline; designed for prepared, in-class work!!!!

If you don't ask I assume you know everything and that we can move on.

We need some mathematical concepts, including ODEs and probability. You need to refresh these concepts if necessary.

Further readings

Patricia S. Churchland and Terrence J. Sejnowski 1992,
The computational Brain, MIT Press

Peter Dayan and Laurence F. Abbott 2001,
Theoretical Neuroscience, MIT Press

Jeff Hawkins with Sandra Blakeslee 2004,
On Intelligence, Henry Holt and Company

Norman Doidge 2007,
The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science, James H. Silberman Books

Paul W. Glimcher 2003,
Decisions, Uncertainty, and the Brain: The Science of Neuroeconomics, Bradford Books