Welcome to CSE2330 Introduction to Computational Neuroscience

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Research interest: Modelling learning in autism with neural networks, i.e. applying concepts and techniques from computational neuroscience to gain insights into the mysteries of autism

Course literature:

W.W. Lytton: From Computer to Brain; *Foundations of Computational Neuroscience*, Springer, ISBN 0-387-95528-3
A text full of insights that doesn't rely heavily on mathematics.
The ideal introduction at an undergraduate level.

E.T. Rolls and A. Treves: *Neural Networks and Brain Function*, Oxford University Press, ISBN 0-19-8524 3 (pbk)
Covers a wide variety of neural network models and places them in proper central nervous system context but doesn't treat modelling of neurons at any detail.
A valuable complementary text.

P. Dayan and L.F. Abbott: *Theoretical Neuroscience Computational and Mathematical Modeling of Neural Systems*, The MIT Press, ISBN 0-262-04199-5
A comprehensive text which does rely heavily on mathematics.
The ideal introduction at a postgraduate level.

Additional suggestions for reading on particular topics will be given as the course proceeds.

Course outline, lectures

The lecture will largely follow the presentation in Lytton but some additional material will be covered.

Lytton divides his book into four sections which we will treat according to:

Perspectives (aiming at two lectures)
Computers (aiming at parts of one lecture)
Cybernetics (aiming at six lectures)
Brains (aiming at four lectures)

Unsupervised learning and reinforcement learning as well as attempts to model Alzheimer's disease and the autistic spectrum disorders will also be covered in lectures, aiming at four lectures.

Course outline, pracs

The practical exercises will be devoted to modelling neurons, neural networks and to applications of computational neuroscience to illustrate and gain understanding in particular of

edge enhancement in vision

associative memory and Alzheimer's disease

attempts to understand aspects of autism

What is a proper role for computational neuroscience?

From Lytton (page 36):

> Neuroanatomy is the study of form. Neurophysiology would like to be the study of function. Unfortunately, it only occasionally rises to this ideal. We are often so clueless as to what’s going on that neurophysiology becomes more a description of the dynamics than an explanation of its meaning or intent.

What is a proper role for computational neuroscience? (cont')

Computational neuroscience proposes to find meaning and intent in the form and dynamics of neural systems.

www.cybertime.net/~ajgood/addendum.html - 53k

If you think that’s boastful, consider the following:

Rosenblatt, inventor of the perceptron:

It is significant that the individual elements, or cells, of a [biological] nerve network have never been demonstrated to possess any specifically psychological functions, such as “memory”, “awareness”, or “intelligence”.

Such properties, therefore, presumably reside in the organization and functioning of the network as a whole, rather than in its elementary parts.

In order to understand how the brain works, it thus becomes necessary to investigate the consequences of combining simple neural elements in topological organizations analogous to that of the brain.

We are therefore interested in the general class of such networks, which includes the brain as a special class.

Some other possible views on computational neuroscience

Picasso

Salvador Dali

What is a theory good for?

Lots of facts are known from experiments.

A theory offers

- a way to relate these facts to each other (a “theoretical framework”)
- see some facts as consequences of other facts
- a way to predict the outcome from new experiments

A science assumes the existence of a theory.

A good theory is a very practical thing.

A good theory should be expressed in a “computer model”, to allow for “computer experiments”.

What facts about the central nervous system do we include in a theory?
(or maybe rather model)

Facts about

- the synapse

- the neuron
  - firing rules
  - plasticity rules

We should include facts about (i.e. model) the connectivity among neurons organized

In six horizontal layers (in cerebral cortex)

in millions of vertical minicolumns perpendicular to the six layers

in macrocolumns comprised of a number of minicolumns

in larger structures in the neocortex

in other structures in, e.g. cerebellum

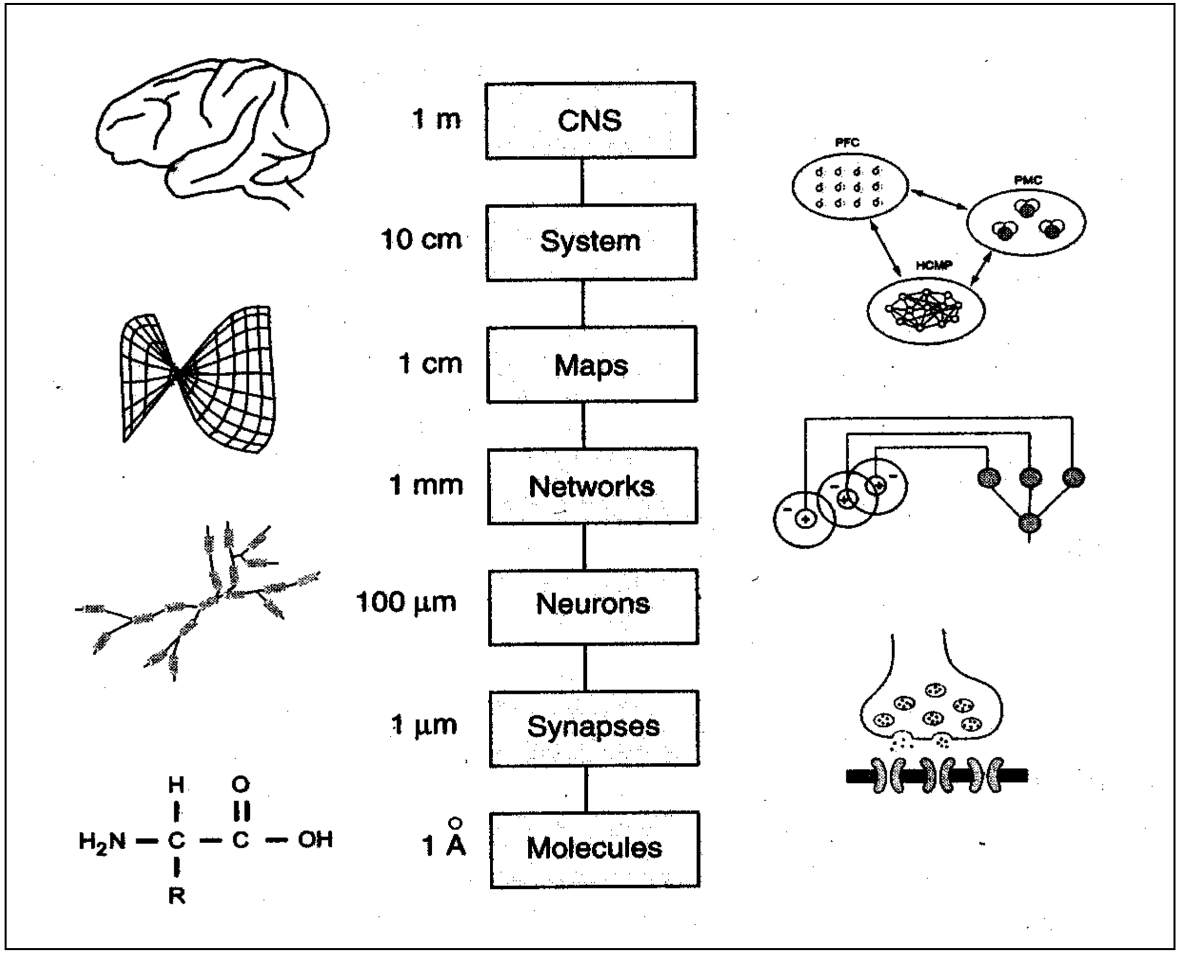
but we do a poor job of it … a good opportunity for fundamental research !

Arranging the nervous system in a hierarchy of study according to Lytton:

ions
transmitters and receptors
spines, dendrites and synapses
neurons
networks
systems
behavior or thought

Levels of organization according to Trappenberg

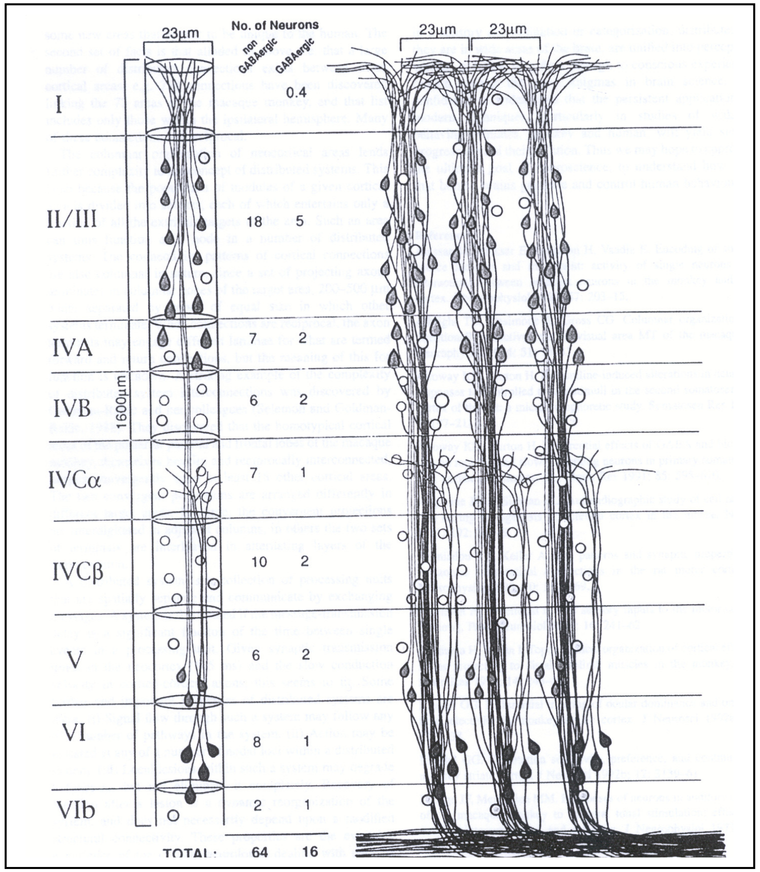
(in T.P.Trappenberg, Fundamentals of Computational Neuroscience, Oxford University Press)



But, amazingly, we know that Vernon Mountcastle was right in 1957:

"Whatever the level in the processing hierarchy, and the particular task there is a common architecture: the neural columns (mini- and macrocolumns)"

Only rarely is this knowledge incorporated into models!



From Mountcastle: "The columnar organization of the neocortex", Brain 1997, pp. 701-722

Chapter 1, Introduction, in Lytton

This chapter is

- written in a good mood (immediately obvious)
- full of insights (will hopefully gradually become clear)
- encourages you to believe this is the stuff for the future
- better read by the student than told by the lecturer

Therefore: please read and enjoy until next lecture!