Chapter 2, Computational Neuroscience and You

Places our subject in a number of contexts

Brain metaphors

- cooler for blood (Aristoteles)
- telephone switchboard
- FM radio
- analog computer
- digital computer

We will try to formulate mathematical models of a (small part of a) brain, using digital computers. But that doesn't make the brain a digital computer and it doesn't make the digital computer a brain!

Chapter 2, Computational Neuroscience and You (cont')

The function and functioning of the brain:

competitor with the heart (well into the middle ages) for the site of thinking, feeling etc championed by Alcmaeon, 500 BC, Galenos second century AD and then a growing number.

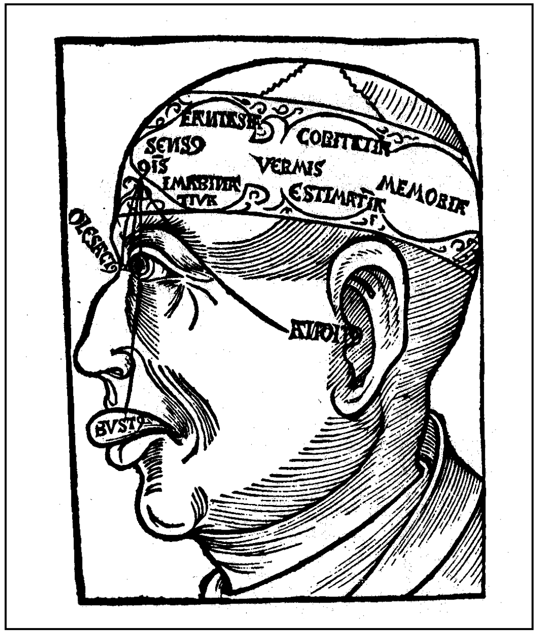
But poetically the heart still has the upper hand:

"I will remember you in my brain" – a correct but strange statement
"I will remember you in my heart" – an incorrect but normal statement

Chapter 2, Computational Neuroscience and You (cont')

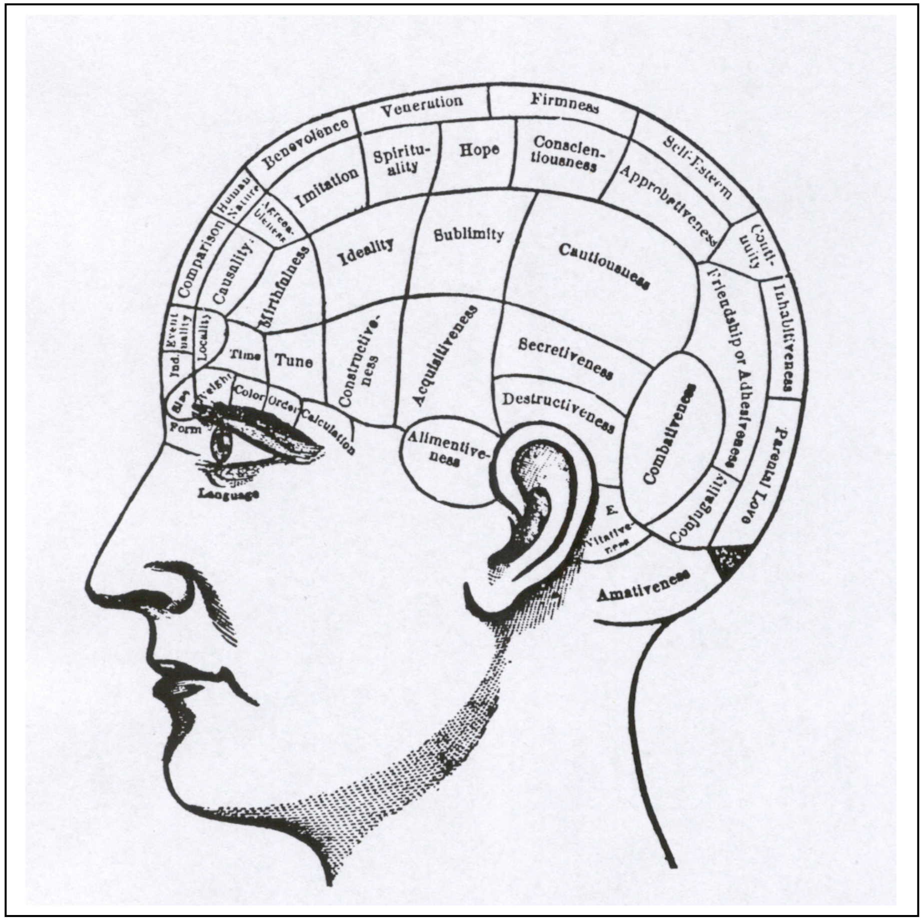
The function and functioning of the brain:

From Galenos and through the Middle Ages the brain was viewed as a hydraulic system with particular emphasis on the ventricles which were supposed to harbor the higher functions of imagination and common sense in the first ventricle, intellect in the second and specific memories in the third (no fourth ventricle was known)



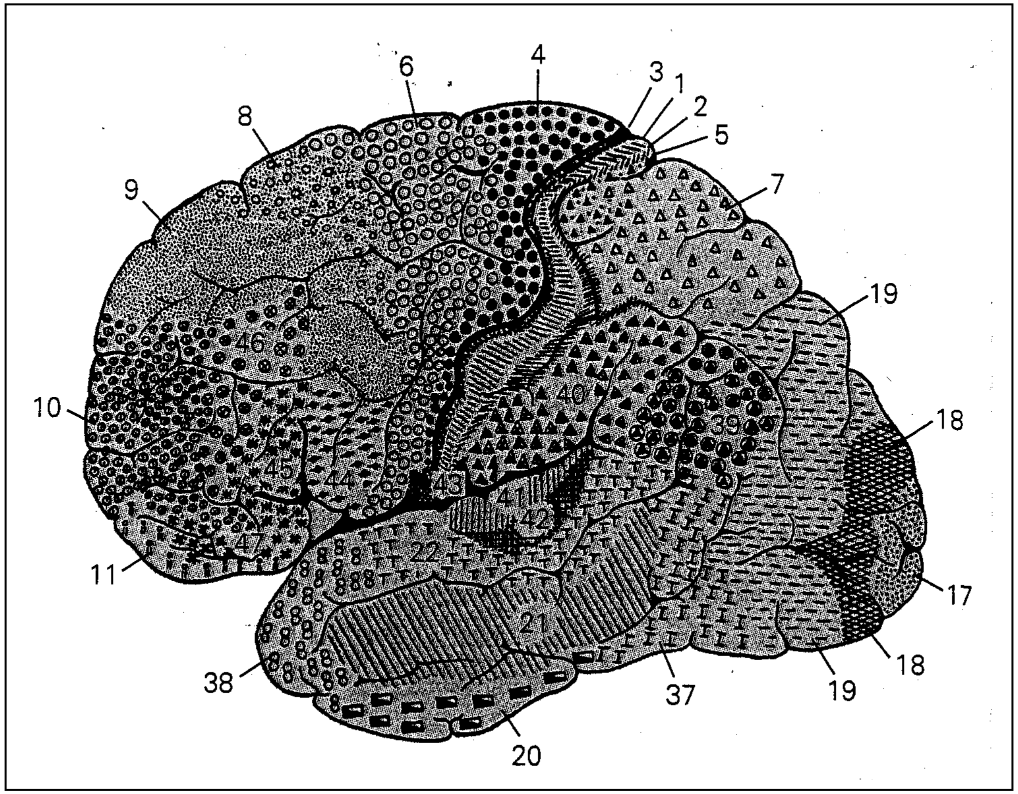
Chapter 2, Computational Neuroscience and You (cont')

A "refinement", no longer depending on the ventricles, was offered by the phrenologists of the nineteenth century:



Chapter 2, Computational Neuroscience and You (cont')

A fresh start, by Brodmann, at the turn to the nineteenth century:



Chapter 2, Computational Neuroscience and You (cont')

On models and explanations:

William of Occam (medieval philosopher): one should not increase, beyond what is necessary, the number of entities required to explain anything (principle known as Occam's razor)

Albert Einstein: make it as simple as possible but not simpler.

Lytton, page 12: Modeling is a tricky thing. To learn something about the thing being modelled, we need to reduce the model to the essentials. If we reduce it too far, however, we may miss a critical component that is responsible for interesting properties.

How simple is possible in modelling of neural systems?

This is a question of fundamental importance in computational neuroscience.

Furthermore it is unresolved.

Luck, intuition, common sense, all working on the raw material of knowledge waiting to be included into theoretical order, will contribute heavily at this stage of scientific development!

Chapter 2, Computational Neuroscience and You (cont')

Transistors as metaphor for neurons

page 14. Lytton makes a guarded comparison between the transistor (the basic component of the computer) and the neuron. The reader should be aware that neurons are magnitudes of order more complex structures than transistors.

I believe it is misleading to see the transistor as a metaphor for the neuron.

Chapter 2, Computational Neuroscience and You (cont')

Origins of computational neuroscience I

W.S. McCulloch and W.H.Pitts (1943), A logical calculus of the ideas imminent in nervous activity. *Bulletin of Mathematical Biophysics*, 5, 115-133.

The neuron was modelled as a simple threshold logic unit.
A number of such simple units could realize more complex logical expressions.
This was closer to a computer than to a brain and was known in computer science, in particular to John von Neumann, famous computer architect.

The paper by McCulloch and Pitts presented a simple device and mathematical proofs of the capacity of many such devices working together to perform more complicate tasks. This was quite an accomplishment but it has no following today.

Chapter 2, Computational Neuroscience and You (cont')

Origins of computational neuroscience II - how does learning come about?

William James (1892): When two elementary brain processes have been active together or in immediate succession, one of them on recurring, tends to propagate its excitement into the other.

Donald Hebb (1949): When an axon of cell A is near enough to excite a cell B and repeatedly takes part in firing it, some growth process or metabolic changes take place in one or both cells such that A's efficiency as one of the cells firing B, is increased.

"Hebb's law" is useful in computational neuroscience and it has been experimentally verified, long after it was postulated.

Chapter 2, Computational Neuroscience and You (cont')

The neural code(s) – still evading us (or at least me)

Millions of neurons emit spikes of voltages along their axons in a live brain.

Some activity is fairly transparent, e.g. retinotopic activity in Visual area 1 (Brodmann area 17).

But how is a face represented in fusiform gyrus?

Up a step or two from thalamic inputs of receptor signals, representation is abstract and not understood.

How do we solve the binding problem?

Chapter 2, **Computational Neuroscience and You** (cont’)

Mathematical models and computer simulations

We need mathematical models to run computer simulations. But we generally don’t aim to find “laws” neatly packaged in mathematical formulae.

Our models will consist of very many nonlinear elements and their joint behavior is difficult or impossible to condense into formulae. But some qualitative aspects can be established, primarily through computer simulations.