UNLOCKING
CONSCIOUSNESS

BRIAN MIND FORUM

Appendix 010

Hebbian Hypothesis of Neuro Genesis.

The Formation of Memory in the Brain

How new neural links and structures are grown

Donald O Hebb, Professor of Psychology. McGill University**,** coined the expression "neurons that fire together, wire together". This is accepted as the most likely position. The electrochemical activity of existing neurons *firing together* automatically generates the energy to stimulate the growth of new structures. There are a number of theories describing the physical process of how that electrochemical stimulation is converted into physical form: of *how* the neurons *wire together*.
Electrochemical activity generates electromagnetic fields. Where adjacent neurons 'fire together' the resulting overlapping electromagnetic fields attract glia cells to form a temporary speculative 'bridge' generating a short-term memory. Every time these 'bridges are activated they are strengthened and in due course mature into long term memory. The electromagnetic fields of distant neurons 'firing together' attract roaming messenger molecules which attract glia cells to form bridges. Some glia cells exhibit synaptic attributes, so some, if not all 'glia bridges' may be strings of glia cells each connected together by synapses: in effect 'synaptic bridges'.

A review and analysis of Professor Donald O Hebb's Book '***The Organisation of the Brain'****, A neuropsychological Theory*. John Wiley, New York, 1966.

There is a lot more to Hebb's theories of neo-connectionism than just '*wire together, fire together*'. In particular his comprehensive analysis of 'cell assemblies'; the concepts of 'engrams', 'pathways' and 'gradients'; the 'phase sequence hypothesis' and the idea of the 'direction of thought'.

His suggestion that where two existing filaments nearly touch they form '*Synaptic Knobs*' (after Lorente de Nó) seems highly probable. It is interesting that synaptic knobs and '*neurobiotaxis*' no longer appear in recent literature.

However, Hebb admits synaptic knobs cannot explain new neuron growth particularly the trillion links that are grown by the mature brain described by Colin Blakemore. *"We grow millions of new neural links every second of our active lives"* [lots of references]. If synaptic knobs help link existing neurons that are very close together, what about longer links between neurons that are not near each other, and the creation of new neurons?

Question One. How do these trillions of new neuron links grow? What stimulates their growth? How does the 'firing together' cause the 'wiring' to take place? [The 'Trillion' problem]

Question Two. How does short term memory fit in to the picture? There is no time to grow new temporary synaptic knobs. [The 'Shopping List' problem.]

Question Three. How do the neural links grow to create complex 'cell assemblies' that enable us to learn to speak, swim, balance bicycles, drive cars? ['Motor Neuron' problem]

Question Four. How do we grow the axons (or dendrites) to link together long strings of standard words to recite a poem or actor's script: learning and using the multiplication tables is another example? ['Recitation' problem].

Question Five. How do cell assemblies link together? [Hierarchical links]

Question Six. If some short term memories are made of other than synaptic knobs how they develop into long term potentiation? [Long term memories]

Gerald Edelman has made great progress with his '*Remembered Present'* hypothesis – and sparked neural programming. He has not suggested the mechanism of this 'remembering'. Hebb mentions 'phase cycles' to sustain transient electrical activity. Recently dubbed the '*zeno effect'*.

Eric Kandel has shown conclusively that *Aplysia* grow new neural networks, but has not suggested a mechanism. In the literature there is no suggestion of synaptic knobs.

Francis Crick (and now Christof Koch) have suggested that a new type of neuron has evolved and site *Spindle Cells* as candidates.

Lots of people have taken up the 'cell assembly' concept and 'engrams', 'phase sequences' and hierarchies of assemblies. Arthur Koestler developed the concept of 'holons'. Herb Simon explored the 'architecture of complexity'. Other suggestions include 'mental subroutines' and 'chunking'. John Duncan suggests 'neural enclosures'. Arie de Geus and I suggested neural modules, or *neurules*. Similar concepts are Dawkins' 'memes' Terence Deacon's 'symbols', even, perhaps, Guy Claxton's 'minitheories'.

To a systems analyst they all look like 'software'. I think we are beginning to appreciate we are all missing a trick about programming and software. The history is that we invented programming and called it software. The reality is that programming is just one example of the Science of Software we have stumbled upon. Software is the science of building patterns of simple components to carry our complex functions. *[1] The whole is greater than the sum of the parts. It is ubiquitous. [Another example of software involves converting DNA to cells].

In a Turing Machine there are only three instructions: add subtract, jump in certain conditions. Incredibly difficult. By the mid fifties this had been extended to eight or so basic functions again and again in ever more complex patterns and call it programming subroutines, then we design programs to build hierarchies of subroutines. To make programming easier we invented 'languages'. Each 'word' is a mini subroutine. [I helped design one in the 80's!].

The brain strings together neural networks, using the same basic networks again and again to build special purpose structures. The actor strings together basic words so that he can declaim them*[2]. The researcher strings together concepts speculatively to see if they generate a plausible solution. But how does '*the brain string together neural networks'*[Q4-5]*?*

You use the analogy of various rivers filling a lake till it overflows creating a new channel. This is very attractive way to link larger 'assemblies', but how are these *'new channels*' created?

Hebb, Lashley and co were writing before computing – or DNA- or *f*MRI scanners. Most of the discoveries about the manifold functions of Glia were in the 1980, and 90's [Andrew Koob, R Douglas Fields et al]. Faraday electromagnetic fields are a couple of centuries old, but I doubt if anyone in 1950 was aware of their ubiquity in the brain. Hebb uses the 'switchboard analogy' and 'field theory' p *xvii* *[1]

Put these discoveries together and we can suggest an hypothesis which answers ALL these questions. The '***glia bridge'*** hypothesis, which has the considerable advantage of an established precedent – in the womb the first neurons climb up glial scaffolding [best description I know is by Steven Rose *21st Century Brain* p72 et al. He cites lots of references].

Why does this matter?

You use a compelling analogy of an island of multiple octopuses. This works very well, but like all analogies it is only part of the story. It tends to give the impression of a closed system: no new octopus arms! You use 'passageways and tunnels (p67), links (p69), strung together, woven, connections (p70). Nouns & adjectives: one to many, many to one (p83) and 'grooves'. How very much more powerful the argument if one could refer to the process rather than rely on analogies.

There is one much more important objective in stimulating a major debate on these issues. The '*glia bridge'* hypothesis is completely open ended. There is every reason to believe the brain could grow *two* trillion 'Blakemore' links –even *three trillion*. It depends on no DNA based restrictions, or hereditary limitations or attributes [we are not limited by the number of octopuses - IQ - we are born with]. There is an ultimate limit on how fast we can run. There is no limit on how much we can learn.

Thus, this vigorously supports the argument that 'nurture' i.e the quality of education is by far the most dominant determinant of everyone's capacity to learn. If we could promote a cognitive neuroscientific 'discovery' that describes how the whole community is capable of unlimited benefit from a good education, then it would provide an excuse for the diehards and luddites to join the bandwagon!

Notes. *[2]. It is interesting that the entire panoply of computing is built out of only eight basic instructions. Each is used repeatedly many mega millions of times in every application. The brain has tens of thousands of basic words to play with! Some measure of the distance computing has to go to catch up!

Hebb gives a very good description of 'autopilot'. P107
Learning transfer 110
Stimulus of the moment 126: Edelman's remembered present. The Zeno effect.
Cumulative learning 109
Meaning 117 & 133
An extremely illuminating example of the importance of multi-media to learning.
Remembering 'left' and 'right'. 118. New names 127. Sensations 128-132.
Similarities of brain activity in womb to coma & sleep 122. Could be argued to support Crick's suggestion that some of our consciousness comes from specially evolved neurons, that start to develop in infancy.

In his description of memory Hebb lists. 'Input', 'Formation' of memory and 'Recall'. He does not mention 'Recognition'! This is an important oversight. He uses Lashley's concept of a 'memory trace'. Lashley famously spent a great deal of effort trying to locate the 'memory trace' of just one word. No one has ever found one. Thinking about the process of recognition helps a lot in understanding how the brain develops. We could call this **Question Seven** How does the brain recognise incoming information? [the Recognition problem]

*[1]. The Computer analogy. There seems to be mega confusion about this. The computer is a poor analogy for the brain. All a computer can do is process digital codes. We do all the rest. We design the codes and we interpret them.
A computer program lists the sequence in which the instructions are to be executed.
A biological 'program' grows physical structures (neurons?) that link networks in the sequence they are to be stimulated.
Computing's over riding contribution is to help us formulate the right questions. Telecoms has taught us a lot about information. There are so many problems to mapping information processing onto the brain, I am beginning to wonder if the brain processes information at all – at least in the IT sense. In some ways the brain only seems to process sensations! That would put the cat among the pigeons!

2018 // Book Final // Appendices NEW // 010 Hebbian Hypothesis 16 07 July