UNLOCKING
CONSCIOUSNESS

BRIAN MIND FORUM

Appendix 014

Convergence of Cognitive Neuroscience, Biogenetics, Synthetic Biology and Computing

Give me a fulcrum and I will move the World

Circa 300 BC. Archimedes

Over the last century our knowledge of every branch of science has advanced at an ever increasing pace, yet now, at the beginning of the third millennium AD, we are on the cusp of, perhaps, the greatest expansion ever – and in almost every sphere of research. The invention and breakneck speed of the development of computers has played a major role in this endeavour by processing research material, and speeding up communications and disseminating information. Computing is transforming business, commerce, industry, finance and the basic fundamentals of both education and economics. However, increasingly, we are beginning to realise that this is only just a part of the potential contribution computing science can make.

Just as Galileo looked through his telescope, and Hooke through his microscope, computers are enabling us to see things we had not been able to see before. Biogeneticist, J Craig Venter says "The once distant domains of computer codes and those that program life are beginning to merge". Cognitive Science Philosopher, Daniel Dennett has included a chapter on 'programming' in his latest book on *'Intuition Pumps and Other Tools for Thinking*'. The Edinburgh physiologist, Jamie Davies comments on the valuable insights computing can offer his discipline. UCL is exploring the convergence of carbon and silicon based life forms. David Deutsch and Chiara Marletto, at Oxford are drawing attention to the similarities of human reasoning and gene replication to programming. Evolutionary biologist, Andreas Wagner describes the "deep unity between the material world of biology and the conceptual world of computation". He goes further, suggesting computers are also "the microscopes of the 21st century".

Computers supplement our Brains

While telescopes and microscopes supplemented our eyes and launched the scientific revolution, the invention of steam power and electricity drove the industrial revolution. This massive increase in the supply of energy supplemented our muscles. Now computers are beginning to supplement our brains, and the impact of the computing revolution will be orders of magnitude greater than all that has come before.

Now that we have half a century's experience of designing and programming computer systems we can begin to appreciate the contribution that our burgeoning knowledge can make. There are now two information processing systems in the universe that we know about. Throughout natural history, the brain has evolved as a means of organising all the organs of a life form to behave as one cooperative, coordinated whole. The brain does this by processing information from all its sensory and other organs. The new kids on the block are our electronic digital computers, which can do one thing and one thing only; just process information, and they only have three instructions with which to do this. However, the way computers have been designed teaches us a great deal about the way the systems of the brain achieve their almost miraculous tasks.

The Duality of the Brain.

The first and most significant contribution of computing is that it helps us understand the duality of the brain's neural systems that has puzzled humans from the birth of recorded history. The Egyptians used the word 'ka' to describe the 'vital essence' that observably departed from the body when people died. The Hindus and Buddhists thought this was a spirit or 'atman'. Descartes' dualism suggested that 'while the body, of which the brain is a part, works like a machine the mind is not material'. Given the problems that Galileo experienced, it is not surprising he choose to describe the mind as 'soul'. Sir Charles Sherrington opined that "the mind was invisible and intangible, and *per se* cannot even move a finger, let alone play the piano". By the late 1930's Edwin Schrödinger was sure that both the brain and mind must operate to the rules of physics.

None had the privilege of programming a computer!

Computers are exactly the dual systems that everyone sought.

Hardware & Software

The integrated circuits in a computer, mostly of semiconductors that we can see and touch are the Hardware, and we have coined the term Software for the patterns of ephemeral electronically coded instructions – the programs - that flow over these circuits. Without Software all computers are useless, they cannot even make the tea! Without Hardware, Software programs have nothing to operate upon.

The BRAIN is observably the physical hardware: the neuron networks, the family of glia cells, the glands, the neurotransmitters, the messenger molecules, and more. We can open a skull and see and touch them all.

The MIND (or spirit, soul, ka or atman if you prefer) is the mass of ephemeral patterns of electrochemical signals and electromagnetic fields flowing in waves across the brain all bathed in floods of hormones.

Without the Mind (neural Software) the Brain is dead. Without the Brain (neural Hardware) the Mind has nothing to operate upon. We could say to Sir Charles Sherrington that the Mind may, indeed, not be able to play the piano, but nor can the Brain play the piano either. Moving the fingers over the keyboard requires the coordinated activity of both!

We can now say with some confidence that both the Brain and the Mind are equally tangible and measurable, and both operate within the conventional rules of Physics.

Programming

The second great contribution of Computing is the concept of '*Programming'*: from the design of a system to all the coded functions of a complete software application. The crucial essence of software is that it enables a fixed piece of equipment, or hardware, to be used for an unlimited number of applications. We are all familiar with being able to use our laptop to write text one minute, check a spreadsheet the next, then compute some formula, or skype a friend. Same hardware, different programs.

Similarly, we have one set of neural networks that, for instance, manipulate the muscles of our lungs, vocal chords, mouth, lips and tongues. Across this single neural hardware system we can speak every word we know, sing, and play many musical instruments.

The instructions at the disposal of the computer programmer are remarkably modest. There are just three: add, subtract, and the ability to jump to another instructions in certain circumstance. Alan Turing outlined this 'software' system in his famous paper to the Royal Society in 1936, which he described as a processing 'machine'. In many ways the Mind, as opposed to the brain, can be seen as a Turing 'machine'.

We *invented* software programming and coding. In the process we have *discovered* the software of biogenetics, neuroscience and biology et al.

We are increasingly realising that this software, hardware dichotomy is common to many things. It is basic to the operation of the genes, how we learn from experience; and in other species, how bees operate as hives, fish swim in shoals and birds fly in flocks. There is increasing evidence that computing has enabled us to explore a whole new discipline: the science of software. For centuries we have really only known about the 'hardware'– what we could see and touch. We are now beginning to realise even in computing itself, but also in biogenetics, in biology and in psychology that the software actually plays the dominant role. Current computers are largely transistor based, but researchers are racing to build quantum, biological and light based processors using new materials recently discovered. They all depend on software, and the same basic software architecture will work on whatever hardware is invented.

Creativity and Evolution

Our knowledge of the hereditary transfer of physical information from one generation to the next via DNA is advancing by leaps and bounds. This 'Darwinian' evolution accounts for the growth of our physical structures - all our cells and organs including the brain: the *hardware* of our body. Computer science is helping us understand that there is a parallel process. We buy a new word processor software program and replace the previous version by uploading it to our lap top.

Learning a new language is a bit more difficult. The knowledge of the hereditary transfer of the information that flows over the brain: the *software,* is by learning and education. For instance, language is not inherited through our DNA. It is one of many skills that has to be learned by

each individual from their parents and peers. It is part of what can best be described as **cultural evolution**. Classical - Darwinian, or *hardware evolution* advances very gradually over many hundreds of generations. *Software evolution* can advance significantly within one single generation.

Understanding the logic of these systems

Advances in Biogenetics and our growing understanding of the plasticity of the brain in the context of software systems design is giving us a framework to develop a logical architecture for creativity. We are beginning to identify more than one stream of evolution and a logical explanation for each.

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