THE MEANING OF LIFE
(in only five pages)

This is a short discourse exploring the origins of life and mind, and speculating about their future. It was written by Emeritus Professor William David (Bill) Williams, AO — a pioneer in, and contributor to, world knowledge of limnology, and an advocate for conservation of species, habitats and the environment.

HOW THIS ARTICLE CAME ABOUT

Bill Williams and I were talking over a coffee after a meeting of the board of Wetland Care Australia in September 2000. We were discussing what you can do on very long flights. Bill, as a world-renowned scientific adviser and speaker, was doing more travel than he really wanted. Then he suddenly said, with a grin that I didn't understand at the time, "Of course, one can always write something", and he pulled some stapled notes out of his briefcase and handed them to me. "I think this will interest you", he added. He had written almost all of it on a flight from Australia to Europe, and he had also completed it, as he states in his opening paragraph, on another such flight.

Bill refers to this discourse as a talk. I don't know whether he actually gave the talk during the remaining 16 months of his life; I have not been able to find any reference to it. By the time he wrote it he had been afflicted by acute myeloid leukaemia for some time but his deep intellectual restlessness continued unabated. "He could always find time to write, as he loved to do, but it usually was after dinner at home, when he could retreat to his den and work on into the early morning", as Keith Walker, his obituary writer, observed (*Australian Institute of Biology Newsletter*, ABN 71 266 532 502, vol. 4 no. 1, July 2002, p. 14).

"I've had a good life", Bill told Keith Walker a year later, "and if I have one professional regret it is that I did not speak out more strongly about the destruction of 'Spaceship Earth'".

This piece was yet another of Bill's efforts to put things into perspective.

— Clive Huggan, Canberra, November 2009

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W.D. Williams

A little while ago, I needed to see my doctor about high blood pressure. He gave me two pieces of paper and some advice. One piece of paper was a prescription for pills; the other was blank except for one word: NO. He asked me to pin it on my computer and refer to it whenever I was asked to chair a meeting, attend a conference, write a scientific paper. The advice he gave was that I take long walks and contemplate the meaning of life. This talk is a result of my contemplations. The paperwork was completed on the plane from Europe earlier this week.

Let me begin at the beginning. I mean almost the beginning: 15 billion years ago, the time of the Big Bang. You will note that I say 'almost the beginning'. By that, I mean 10^{-43} seconds after the very beginning, after so-called Planck time. Perhaps during Planck time the rules of the 'game' were formulated. Some 10.4 billion years after Plank time, part of the universe congealed to form the planet earth. The earth, therefore, is some 4.6 billion years of age. Whether other planets capable of supporting life also exist is an important question that I will partly explore later.

The early earth was unbelievably hot: it was an intensely radioactive molten lava fireball and remained so for almost 800 million years: some 3.8 billion years ago. This period of earth's history is aptly referred to as the Hadean eon. It was followed by the Archean eon (3.8–2.5 billion years ago), then the Proterozoic (2.5–0.58 billion years ago). During the Archean, the earth cooled, rocks formed, and early oceans developed. Also during this time, life arose, or at least self-replicating organic structures did. The first forms of life were simple and fossils some 3.5 billion years old have been recognized. Life probably arose before this time, perhaps about 0.5 billion years earlier.

The early atmosphere — that is, during the late Hadean — was dominated by carbon dioxide, formaldehyde and hydrogen cyanide, then later by carbon dioxide and nitrogen. Also present were ammonia, hydrogen sulphide and methane. At that time the atmosphere was superheated by volcanic and radioactive heat. Despite these conditions, there is evidence that life began a mere 600 million years after earth formed.

An important question at this point is: where did it arise? One answer is that it did not arise on earth but arrived here from space. This answer is not at all as implausible as it once would have seemed. First, a number of amino acids (the building blocks of organisms) has been identified in space (e.g. glycine, a common amino acid found in organisms, was identified from deep space in 1995). Second, in 1969 a meteorite was unearthed at Murchison, Western Australia, rich in carbonaceous matter and containing many amino acids. Nineteen of these occur in organisms; many more do not. Third, bacteria exposed in space by NASA on their 'long duration exposure facility' (LDEF) satellite for six years (1984–1990) were quite viable after recovery by the Columbus shuttle.

The other perhaps more plausible answer is that life arose on earth from the rich brew of organic chemicals in the primordial oceans. Early laboratory experiments pointed to the likelihood of this: in 1953, Urey and Miller tried to create what they thought at that time were the conditions under which life arose. They mixed boiling water with hydrogen, ammonia and methane (at that time thought to be the likely gases of the early atmosphere) and passed electric sparks through the mixture. The experiment produced several organic compounds, including two amino acids only produced in living organisms. Later, similar experiments produced fatty acids, also important in living organisms, and even some chemical compounds which form the building blocks of DNA. Unfortunately, the promise of these early experiments proved somewhat illusory since the early atmosphere is now believed to be different from that used in the experiments of Urey and Miller (it is believed to have been largely carbon dioxide and nitrogen, as indicated) and one much less chemically reactive. Another point is that the chemicals produced in the experiments were highly reactive and did not persist long. Whatever the conditions which produced life, the assumption is that when the right chemicals were present in the right quantities, the combination produced something unexpected: a living organism.

Let us assume, then, that life did arise on earth. The question which follows is: where? The leading contenders for the most likely habitats are oceanic hydrothermal vents and shoreline pools. Hydrothermal vents are cracks in the ocean floor through which hot gases and water are emitted. Present-day vents are inhabited by bacteria able to withstand the extreme conditions — and which form the basis of food chains in the vicinity. As for shoreline pools, the suggestion is that DNA formed in a marine chemical broth and was protected from breakdown by fatty bubbles which formed in the pools partly as a result of wetting and drying (tidal) cycles. The process led to a self-sustaining chemical system within a bubble, that is, a proto-cell. RNA, the precursor of DNA, formed first. The process began about 4 billion years ago and life persisted in this simple form for some 2 billion years. The organisms involved constitute the procaryotes, whose modern counterparts are the bacteria and blue-green 'algae'. All lack a defined cellular nucleus, and defined structures for processing energy (mitochondria) and fixing light energy (chloroplasts). Despite their simple structure it appears that they were agents of vast global impact: they changed the earth's atmosphere from one rich in carbon and poor in oxygen to the reverse.

One core feature of all life on earth is that DNA (deoxyribonucleic acid) forms the essential building block. Its structure, as is well known, was first elaborated by Watson and Crick in 1953. It comprises two strands arranged in a helical pattern linked by pairs of nucleotides of only four types: adenine, cytosine, thymine and guanine. Adenine pairs with thymine, cytosine with guanine, with pairs arranged as steps on a ladder. The total DNA molecule in humans consists of 3.2 billion pairs packaged in 23 pairs of chromosomes. One pair of chromosomes determines sex: males have an *x* and a *y* chromosome; females have two *x* chromosomes. Genes are simply small stretches of the DNA molecule containing on average about 1000 base pairs.

There is no need to remember these details. The important general point to remember is that the arrangement of the nucleotide pairs provides the basic information for the development of organisms and their subsequent structure and function. At the most basic level, living organisms can be regarded simply as carbon-based physical structures whose building and operating instructions are provided by a coded set of information in a large chemical molecule.

I need not elaborate the complex and convoluted path trodden during the evolution of humans. Two matters, however, need to be underscored:

- Higher forms of life (the earliest eucaryotes) first appeared about 1.4 billion years ago and probably arose as mutually supportive, symbiotic relationships between simpler organisms. The result was complex cells with nuclei, mitochondria (energy-producing structures), chloroplasts, and other cell inclusions. They had a profound effect on the earth's atmosphere; as noted, with procaryotes, they fundamentally changed its composition. Simple eucaryotes and procaryotes co-existed for the next 0.9 billion years. Then, about 0.58 billion years ago (580 million years ago), eucaryote cells themselves began to associate to form multi-cellular organisms. Again, the association probably arose as a mutually supportive activity. Thus, all higher animals and plants are essentially large colonies of 'individual' cells, each with defined roles.

- The driving force for this progression (that is, this evolution) has been natural selection, survival of the fittest. Only those organisms which, statistically at least, are better fitted to survive and pass on their genes (i.e., information systems) do so.

An important aside to be made here is that unless one invokes some supernatural entity (God?), *all* human attributes can be explained by evolution, including those considered to be essentially human such as sentience, the ability to have emotions and intelligence. One needs only to read Jared Diamond's book on the 'third chimpanzee' or those by Jane Goodall on the natural history of African primates to realise that so many so-called uniquely human attributes are shared with our close relatives (and theirs with their ancestors and so on).

How can 'mind' be fitted into this scenario? Can 'consciousness', including the knowledge that life may have no meaning and with death cease, be explained by evolution and have a physico-chemical basis? Opinions are divided. Early opinions thought not: views were that there is something fundamentally different about human life and the mind which separates them from the physical world: in the famous phrase of Descartes: *cogito, ergo sum* (I think, therefore I am). Even many late opinions think not. Roger Penrose (*The Emperor's New Clothes* and *Shadows of the Mind*) clearly thinks not. His argument is that certain aspects of consciousness are uncomputable: to make sense of mind and consciousness, physics needs to be rewritten. Other opinions differ. Alan Turing, the 'father' of modern computers, and many more recent computer scientists, simply viewed and view the mind as no more than the expressions of a complex computer. Turing regarded the human mind as an advanced computer (the brain) which manipulated symbols [note his groundbreaking paper of 1937: on computable numbers and the Entscheidungsproblem]. The general view held by those who think that the mind can be explained in physical terms, albeit complex ones, is that mind is a reflection of the brain in action.

Notwithstanding earlier and some recent views on what constitutes the mind, most modern scientists now agree that the 'mind' is essentially the brain at work and that earlier views about the dualism or separation of mind and body are unsupportable. Research in this area — how the brain works — is certainly at the cutting edge and attracts intense interest. It is best described as cognitive neuroscience and is an alliance between neurologists, cognitive psychologists, and empirical philosophers (so-called neurophilosophers). Before 1970, it was left largely to the philosophers; now it is at the junction of biology and psychology. Many books have been published in the last few years which explore the subject — including an important one by David Chalmers who will be known to some here (*The Conscious Mind*, 1996). A recent comprehensive summary has been given by E.O. Wilson (*Consilience*, 1998). Two matters need to be dealt with: the physical structure and functioning of the brain; and how brain functioning translates to thought, sentience and intelligence (i.e., mind).

Physical structure of the brain and brain function. Although many details await completion, the main anatomical features of the brain and the nature of their essential functions are now known. In summary: the average size of the brain is about that of a grapefruit, weighs on average 3 pounds (Einstein's was 2.75 pounds), has a consistency of a firm custard, and is covered by a wrinkled outer surface. In gross structure, it consists of a hindbrain, midbrain and forebrain, the latter massively enlarged and including the cerebral cortex which covers most of the brain. It is of course the microscopic structure of the brain that conveys its properties. Within the brain are about 100 billion nerve cells, each a few millionths of a metre wide and connected to other nerve cells by hundreds or thousands of endings. This structure is the most complex known in the universe — at least, that is, to itself! The brain evolved to its present structure over a period of only 3 million years, but after the appearance of Homo sapiens a mere 200,000 years ago its size increased fourfold, with most growth in the neocortex (forebrain). Its development can be regarded as the fourth major event defining life on earth. The first was the appearance of simple life (the procaryotes); the second, the appearance of eucaryotes; the third, the development of multicellular organisms; and the fourth, the evolution of the brain. In gross function, the hindbrain controls breathing, heartbeat and bodily coordination, and the midbrain, sleep and arousal (and partly also auditory and some other reflexes). The forebrain is the master traffic control complex and regulates emotional responses and integrates and transfers sensory information. It is the forebrain that is the primary seat of consciousness and which stores and collates information from the senses, directs voluntary motor activity and integrates speech and motivation. Imaging by neurosurgeons (positron emission tomography) has allowed the determination of particular sites in the cortex which are largely responsible for certain functions, but no particular site in the forebrain represents the location of conscious experience.

Mind. Whilst the fundamental properties of the structures forming the mind — that is, neurons, neurotransmitters and hormones — are reasonably well known, the holistic, emergent properties of the neural circuits and of cognition, i.e. the way the circuits process information to create perception and knowledge, are not. Wilson (1998), as a tentative summary of present consensus, says that at the most basic level 'mind' is a coded representation of sensory perceptions and the memory and imagination of sensory perceptions. The information involved is probably sorted and retrieved by coding for direction and magnitude. 'Consciousness' itself is the parallel processing of vast numbers of coding networks which give rise to a variety of scenarios (virtual reality) comprising dense and finely differentiated patterns in the circuits of the brain. Nothing monitors this activity; it just is. Thus, consciousness is the virtual world formed from the scenarios, the massively complex aggregation of all participating circuits. The neural circuits themselves are parallel relays which successively integrate and link more and more coded information. As the biologist S.J. Singer put it: "I link, therefore I am"! With regard to what meaning involves, Wilson suggests that it is the linkage between neural networks created by spreading excitation that enlarges imagery and engages emotion. And *emotion*? Two sorts have been distinguished: primary (instinctive, inborn) and secondary (that arising from the personalized events of a human life). Secondary emotion appears to be expressed in the same channels already used by primary emotions. Free will is an illusion!

Any consideration of brain function and mind naturally leads to the question of whether it is possible to create a structure with an artificial intelligence (AI). Like opinions on the physical basis of the mind, opinions are divided on this possibility. Penrose and others think not. Turing and many modern computer scientists think it is possible. Wilson sits on the fence: he says that in principle it is possible but that it would be very difficult and is certainly not possible in the near future. The general point made by those who think it is possible is that DNA (contained in genes) is essentially no more than a means of communicating information (a set of rules to allow the development of a physical structure using carbon as the base element — since this is chemically reactive and could provide a suitable vehicle for evolution to act upon). Since vast amounts of information are already being communicated using silicon, at ever increasing speeds, complexity and miniaturization, it is only a matter of time before the point is reached when linkages between silicon-based information centres develop to a point that represents intelligence, i.e. develop a mind.

There is insufficient time to elaborate on the many different approaches involved in exploring AI. Let me simply say that computer scientists have already produced programs (some unpredictable in action!) which replicate, adapt and 'evolve'. Many of these are based on the premise (first enunciated by von Neumann) that life is a *process, not a property*. The mathematicians have contributed to the essential rules and I mention cellular automata — arrays of cells on a giant draughtboard instructed so as to evolve, adapt and replicate. The Game of Life (or God Game) elaborated by John Conway is a mathematical simulation of key properties said to define life — replication, adaptation and evolution. It was first run on graph paper and used counters; now it runs on computers. Other forms of computer programs that replicate, adapt and evolve are widely produced, some in order to maintain the complex telecommunication systems that now bind the earth. Others run robots. A relatively simple account of the many forms of virtual organisms now in existence has been given recently by Ward [*Virtual Organisms: The Startling World of Artificial Life*].

Penultimately, let me briefly and somewhat speculatively look into the future. Part of that future is pretty clear: at exponential rates, our technology based on the silicon chip and its computational abilities will expand to include every aspect of modern life from medicine to astronomy. Already, many features of modern life are 'controlled' by computers: banking, transport, communications, satellites, surveillance, education. Many authors have argued [see Kurzweil: *The Age of the Spiritual Machine*, 1999] that it is only a matter of time before human (carbon-based) and machine (silicon-based) intelligence merge. Whether this will favour carbon or silicon remains to be determined! When this happens, death and literature will be meaningless concepts, of course. Perhaps we should already be considering whether it has been wise to cede so much control of our lives to silicon. Certainly, one issue usually omitted from such considerations is that of unpredictability. On this matter, I note that issues of unpredictability are generally ignored by physical scientists, but are nevertheless extremely important [consider, for example, the absolutely vital feature of water which enabled carbon-based life to evolve in the first place: the fact that it is most dense at 4 degrees Celsius — a fact absolutely unpredictable from everything we know about its constituent elements, hydrogen and oxygen]. Ernst Mayr, an evolutionary biologist, has written at length on this matter. What unpredictable events lie ahead for complex silicon-based structures now that silicon has been released from its chemically unreactive state and its evolution enabled?

And finally, what of life elsewhere in the universe? Before Copernicus, the earth was the centre of the universe. We now know that this is very far from the truth. The earth is a small celestial object circling a star (the sun) that is one of 100 billion stars in our galaxy, which itself is one of 100 billion galaxies in the universe. It is widely assumed that life, even intelligent life, is not unique to earth, though this assumption has yet to be proved (but we are trying). Remember that I noted that amino acids have been identified in space and that it is not implausible that life on earth came from space in the first place. There is a reasonable chance that life elsewhere will be more intelligent than we are, given that intelligent life took only 4 billion years to evolve on earth and that the universe is about four times as old. Whether it and we can ever communicate is questionable. However, since 'life' is essentially coded information in physical form, and since information can be transmitted at the speed of light, it is not completely impossible. There is even the possibility that it could be transmitted at speeds even greater than that of light: a recent report in Nature records that scientists at Princeton have been able to boost a pulse of light to a speed 300 times that of light in a vacuum. A search is already under way for extra-terrestrial life by examination of signals from space. Perhaps we have already been infected?

Thank you, fellow carbon-based life-forms, for listening to me. I hope that I have not completely destroyed all your illusions of your importance and uniqueness. Indeed, I hope that you will now realize what an almost unimaginably complex, if not unique, machine you are. My intention has been to explore the meaning of life, not demean it.

Some further reading

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About Bill

Obituary of W.D. Williams in *Australian Institute of Biology Newsletter*, ABN 71 266 532 502, vol. 4 no. 1, July 2002, p. 14: **http://www.aibiol.org.au/news/Newsletter July 2002.pdf**