Chapter 19

Memory – What is Arranged and Where?

A person’s mental activities are entirely due to the behavior of nerve cells, glial cells, and the atoms, ions, and molecules that make them up and influence them.

Francis Crick 1994 [1]

How we ourselves acquire, store and transmit mental information – how our minds process (input, manipulate and output) information – would seem to be ultimate questions in bioinformatics. Having ‘solved’ the corresponding questions on genetic information in the 50s and 60s, Crick moved to brain research in 1976. One would have thought the two rules for his success in genetics would still apply: seek the simplest experimental system; find the store first and then work out how it fills and empties. For his experiments Crick had chosen the smallest known biological forms – the viruses that infect bacteria. And he went directly to the genetic store – DNA. When its structure was known, solutions to the acquisition problem (replication and mutation) and the transmission problem (transcription and translation) fell neatly into place. But neither rule was to be followed in his brain research.

The Organ Par Excellence

The DNA of bacterial viruses is like our own and is replicated and transcribed in similar fashion. So experiments with viruses could often be extrapolated directly to humans. But, although bacteria display aspects of learning and memory [2], there has long been doubt that data from bacteria or other organisms, simple or complex, can be extrapolated to the human brain. While in their famous 1858 Linnaean Society addresses Charles Darwin and Alfred Wallace agreed on the power of natural selection, Wallace came to draw a line at the human brain and favored explanations that pointed to ‘an unseen universe’ [3]. Likewise, the Oxford philologist Max Müller pointed to language as a unique human attribute that “is our rubicon and no brute will dare to cross it” [4]. For him language represented a difference, not in degree, but in kind. There was a sharp evolutionary discontinuity – in modern terms “the cognitive equivalent of the Big Bang” [5]. Wallace and Müller offered
explanations that we would today label as spiritual, religious or creationist. Thus, “the origins of *H. sapiens* acquires the status of mystery” [6].

Darwin considered that, *in all respects*, there was evolutionary continuity between man and animals [7]. In the first edition of *On the Origin of Species* he excluded from discussion the origins both of “life itself” and of “the primary mental powers.” While “it may be urged that, as man differs so greatly in his mental power from all other animals, there must be some error in this conclusion,” he held that “there is no fundamental difference between man and the higher mammals in their mental faculties.”

Crick adopted this view [1]. Yet, most of Nature’s evolutionary experiments, if successful, are copied. Birds have wings, but so do bats and insects. Fish have fins, but so do whales (mammals). However, our adaptation, the human brain, appears quantally different. Its evolution by natural selection accelerated to generate a profound discontinuity from antecedent organisms probably because of intra-species competition (human versus human), rather than because of inter-species competition. Other species did not (have not yet) get into the act.

Some argue that there are other examples of quantal evolutionary differences – the neck of the giraffe for instance; but even here there are intermediary forms. The gerenuks (“giraffe antelopes” in the Somali language) act like medium size giraffes by combining a long neck with bipedal browsing. Nevertheless, the neck is the organ *par excellence* of the giraffe, so if one is interested in the neck one should study it in giraffes, not in humans; likewise the brain is the organ *par excellence* of humans. Crick studied the brain in humans when feasible; otherwise, he studied their nearest monkey relatives.

### The Cupboard is Bare

We saw in Chapter 1 that Butler in the 1870s thought that mental and hereditary information would be stored in the same way [8]. Yet when Crick started to work on the brain in the 1970s there were still few clues as to the form long term memory might take. Crick could not go directly to a ‘memory molecule’ and try to work out its structure as he had done with DNA in the 1950s. Instead, he allowed himself to be diverted into neuroanatomy and neurophysiology, studying input and output from the memory store – fascinating subjects with a wealth of novel gee-whiz technologies – but not the store itself.

Since DNA is an excellent long term information store, Crick naturally conjectured that the brain might also store its information – at least, information relating to long-term memory – in this way [9]. So if the store were intracellular, brain cells would be expected to contain DNA in excess of that needed for their normal function. But human brain cells have the same quantity of DNA as other cells of the human body and, indeed, of cells of mam-