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Understanding the Human Brain, Mind and Behaviour: A Major Aim of Biological Research

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The human brain is the most complex living structure on this planet and therefore the ultimate goal of biological research. There are no strong reasons for the belief that its structure and function will never be understood, or that its composition is something more than molecules and cells. When the physical basis of mind and behaviour is revealed, there will be far reaching effects for human society. The efficiency of education will be vastly improved, and the contributions of nature and nurture to the development of human personalities will become far more clear. The various problems in brain function in both young and old will be understood and effective treatments developed. The origins of crime and antisocial behaviour will be revealed, and even political decisions will in more and more cases be based on real information, rather than on guesswork and supposition. It does not seem to be widely realised that an understanding of brain function, mind and behaviour will be far more important for future human wellbeing, than various technological advances which are much more frequently discussed in the media or elsewhere.

Key Words: Brain, Mind, Memory, Neuroscience, Behaviour, Human genome, Molecular biology, Evolution

Introduction

In the history of biological research, scientists progressively focussed on components of decreasing size. First there were organisms and their taxonomy, then internal structures and organs. This was followed by the study of cells and tissues, and within cells there is the nucleus containing chromosomes. Genes were discovered, and later that they consist of DNA. The basic functions of DNA were unravelled: how it replicates, how it produces messenger RNA and codes for the sequences of amino acids in proteins. Also, how it interacts with histone proteins to form chromatin, and how it mutates and recombines. We now understand a great deal about enzymes and the proteins, about metabolism and its regulation, and how energy is generated. By understanding all these fundamental features of life, it has now been clearly demonstrated that life is no more than its chemical components, organised in such a way that order is generated from the intake of energy and maintained in that ordered state. There is no longer a place for vitalism, that is, for non-material entities in living systems.

With this solid basis of knowledge of life, scientists are now proceeding in the reverse order. Cells are becoming better understood: how they are organised and how they divide. How they interact with each other in tissues and organs. Much is known about the development of the fertilised egg to the embryo and adult, but a challenge for the twenty first century is to fully unravel the processes of this development. We will learn more about organ systems and how they interact with each other to produce the normal functional organism. Neurobiology has made great strides in the understanding of nerve impulses and their transmission. Every day new information is being obtained about the way the nervous system operates in various organisms, from the most simple to the most complex. Here we have a new hierarchy,

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because we will first understand the nervous system of simple animals, and then there will be progress in understanding more and more complex ones. Scientists will choose those experimental systems which are most amenable for further analysis and understanding. With this solid base of knowledge, the stage will be set for the final goal, namely, an understanding of the most complex biological object on this planet, which is without doubt the human brain.

There are those who will say that the human brain is beyond the reach of scientific investigation. Some believe that the brain has special properties, such as consciousness or free will, which are uniquely human and not explicable in terms of cells and molecules. Yet we know that the brain is the product of the zygote and the embryo, and that by interaction with the environment and learning, reaches the fully adult form which constitutes the personality of the individual. Others may agree that the brain itself is a physical organ, but argue that its very complexity is beyond the reach of science. Would they also say that an understanding of the nervous system of a worm, an insect, a fish, an amphibian or reptile is also beyond the reach of science? If they are not, then why not also an understanding of the brain of a mouse or other small mammal? If this understanding is attained, then we will already know a great deal about the human brain as well. For example, we would know about the neuronal basis of learning and memory, and the way information from the eyes and ears are processed, and much else. Also, the future analysis of the human genome in comparison to other mammals will reveal that uniquely human coding capacity that determines the development of the complexities of the human brain.

Again and again, forecasts about the limits to scientific investigation have proved to be wrong. It is only logical to believe that the continuing advances of science will eventually result in an understanding of the functioning of the human brain. It would be foolhardy to predict any time scale, but we can be sure that new insights will proceed step by step. Since the human brain is the most complicated structure in the living world, its understanding may well be the last important discovery, or set of discoveries, that will be made in the whole of biological research.

At the beginning of the twenty first century, there is much discussion in the media and elsewhere about the future of human biology. We hear about bionic man, about replacing organs grown from stem cells, about artificial intelligence, and about altering genes to produce improved offspring. Yet, surprisingly, there is almost no discussion about an understanding of the human brain and its consequences for human society. I believe the consequences will be immense, and in the rest of this article I will attempt to explore them. It is most convenient to do so under successive headings.

Education

Humans have a unique ability to acquire and memorize knowledge. This is shown with particular clarity in the learning of language by young children. Although most children learn one language it is well known that they can acquire the ability to understand and speak more than one in a bilingual or multilingual environment. This highlights a major feature of learning ability, namely, that individuals have the potential to learn much more than they normally gain from their parents and their education. It is also illustrated by blind people being able to read braille, and deaf people learning to understand sign language and to lipread. It is not that these impaired individuals have special compensatory ability, because those with normal sight and hearing could also learn braille, sign language and lipreading, but they do not need to do so.

Methods of education are not at present changing very fast. Indeed, we would probably be on safe ground to say that well educated Greeks or Romans were as well informed, or possibly better informed, than the average educated individual today. The reason teaching methods may have stayed much the same for long periods of time is that we are using empirical methods that we know are reasonably effective. All this is done in the absence of any real knowledge about the way information is stored and assimilated in the human brain. When we come to understand in detail the way the brain processes and retains information, and how learning and memory actually operate, then we will be in a far stronger position to improve educational methods. It will, for the first time, enable children to achieve their full educational

potential. All parents want their children to achieve well at school or during higher education. When the process of learning is understood. They will attain more advanced goals, and society as a whole can only benefit. We can also expect that those with learning difficulties, such as children with dyslexia, will benefit from the future understanding of the cause or causes of their particular learning problem. We can also predict that children will be able to acquire expertise in chosen areas. For example, it is well known that children in musical families may develop the ability to play a musical instrument with a high degree of skill, or to compose music. In the future when much more is known about the development of creative skills, it will be possible for more and more individuals to reach their full potential in any discipline that is appropriate. Not least, it will also be possible to understand which children or adults have particular aptitudes that can be fully exploited through exposure to highly efficient educational procedures. This means that the present educational system, in which a class of children are taught in much the same way may well become outdated, because children are not all the same, and a teaching regime that suits one child may not suit another. Education will become much more plastic, so that individuals can be provided with what are the best opportunities for each of them.

Nature and Nurture

The debate about the relative importance of nature and nurture will continue for a long time. Fifty years ago it was fashionable to believe that environment was much more important than heredity in shaping human personality. Then with the advent of sociobiology, the pendulum swung the other way and genes were thought to be responsible for all manner of behavioural traits. It is established that specific genes may predispose individuals to particular diseases, such as Alzheimer's disease or certain cancers, and a large number of inherited metabolic defects have been known for a long time. It is quite another thing to believe that there are genes for aggressive behaviour or homosexuality, or other behavioural traits. It is in fact very well established that both an individuals genetic make up and the environment are necessary for the optimal development of an adult's personality and social behaviour. One way of thinking about this is to consider an area enclosed by two dimensions: one dimension comprises the inherited component and the other dimension the environment. The area enclosed is the outcome of that individual's development. It then becomes obvious that reducing one dimension, for example by an inherited defect, will result in a small enclosed area and therefore a disadvantaged individual. Similarly reducing the other dimension by failing to provide proper education, or bringing up a child in a poor home environment, will also have deleterious effects on an individual's personality and abilities.

From the human DNA sequence we can expect more and more genes to be identified which may have effects on particular human traits. Nevertheless, the way genes and the environment interact to mould the final characteristics of an individual, can only be fully understood when the functioning of the human brain and sense organs are understood. We will then know how information from the environment is processed and stored as memory. We will know how different experiences interact with each other in producing an individual's personality. We will know the way education can best be exploited, as discussed in the previous section. We will identify the genetic components that make the human brain unique amongst animals, for example, the genes necessary for the acquisition of language, the ability to use tools and the way in which reason and foresight arise in the developing individual. We will understand human emotions much better, and therefore human relationships. From this we will know a great deal about family and social behaviour. We will have new insights into the thought processes involved in creativity and the ability to solve problems. Armed with all this knowledge, it will be possible to optimise an individual's development so that he or she can achieve maximum benefit, in terms of educational achievement, creativity and social interactions.

Mental Illness

The relative influences of nature and nurture on mental illness will also be unravelled. For instance, the importance of genetic and environmental influences on schizophrenia, which is a present largely a matter for debate, will become clear. As a

result much better treatments will be devised. The same applies to epilepsy and childhood autism. It is now known that some cases of Alzheimer's disease are familial, but the majority are not. The course of the disease has already been studied by modern molecular methods, but the underlying cause or causes of the pathological brain changes are not understood. With an understanding of the normal brain, it will become far easier to comprehend the ways in which it can become defective. Moreover, much earlier diagnosis of dementia will become possible, and this will make it possible to devise ways and means of delaying the onset of the disease, or of preventing it altogether. The incidence of Alzheimer's disease and other dementias rise steeply with age, and there are at present different opinions about whether dementias are disease entities, or whether they are the result of the senescence of brain tissue. A much better understanding of aging itself, as well as the brain, should provide the answers to what at present are contentious issues. We will also know whether or not an active, creative brain can retard the development of dementia. So far, the evidence that this may be so seems to be largely anecdotal.

The study of the mind is in the province of psychology and psychiatry. These disciplines have received enormous attention from the end of the nineteenth century, and there is little point in trying to review the information that has accumulated. It can be fairly be said that psychology is not a single discipline, as other sciences are. Since the advent of Freudian psychoanalysis, various schools have followed with variable success in treating patients by his or related methods. At the end of the twentieth century, a large variety of drugs have become available for treating mental illness. Some have defined targets, such the seratonin re-uptake inhibitors (SRIs), which can effectively relieve depression. Others may have no known molecular or cellular target. They are found to be effective by empirical observation. Once one is found, then chemically related derivatives can also be tested in clinical trials. Psychiatry has benefited greatly from innumerable drugs, but it remains, with psychology, an inexact science simply because we are so ignorant of the human mind and brain, and the roots of human behaviour.All this will change when the function of the brain is understood.

Free Will

Free will and determinism are not fashionable topics for discussion, partly because they are thought to be in the realm of philosophy, and philosophers are apt to confuse the issue by debating, for example, whether feeling free is the same as having free will. I discuss the topic in a neurological context, and I think this makes it easier to come to meaningful conclusions. Let us consider an apparently free movement: an individual is asked to move either his left arm or his right arm. He feels perfectly free to choose either, let us say it is the left. How is that action accomplished? A signal comes along nerves from the brain and is transmitted to the left arm muscles, and there is no signal to the right arm. The signal from the brain arises in brain neurones, and it involves both chemical and electrical energy. It is not spontaneously created, because that would contravene a fundamental scientific principle. This means that the neurones responsible for sending the signal were themselves stimulated from some other cell or cells, but the individual was unaware of this event, which has in fact determined the choice the individual made. There way well be a "decision making" centre in the brain (Crick 1994). The decision I mentioned is trivial, but as we all know some decisions are difficult to make. They may take into account all manner of external factors and prior events, as well as consideration of the consequences of any decision.

It is sometimes said that only humans have free will, because all animals only have behaviour which is determined. Yet animals with awareness of their surrounding also make choices: to move right, or to move left. A cat or a dog on the prowl is continually making decisions about what it will do next. Yet it may also have conditioned or deterministic behaviour. When hungry, it will respond to a bell, if it knows that food is then provided. There appears to be no basis for believing that humans have some unique higher function of the mind which provides them with freedom of action, and that animals do not have that higher function.

There is also the misconception that if free will does not exist, then the world we live in becomes deterministic and predictable. Chaos theory makes is clear that outcomes may never be predictable. One can forecast the weather, but never with complete certainty, simply because there are so

many interacting influences, that it is very hard, or impossible, to take account of all of them. A simpler example is spinning a coin: all we can conclude is that it will land tails up or heads up. Nevertheless, if we were able to measure the spin imparted, the distance the coin moves, the air resistance, the way the coins hits the ground, and so on, we probably could, at least in principle, determine the outcome.

The relationship of freedom of action and free will to human activities becomes important when judgments are made about human actions in particular contexts. For example, the response of society as a whole to an individual within it that is exhibiting anti-social behaviour. This will become apparent in later sections.

Consciousness

As well as free will, it is often said that human consciousness is unique among animals, and people also often refer to the mystery of consciousness. Although we cannot experience the consciousness animals may or may not have, we can certainly observe their behaviour in the physical world. The senses of many animals are very highly developed, and we can see that they respond in very specific ways to environmental cues or stimuli. Indeed, it would be fair to say that the highly developed sense of smell in a dog makes it much more conscious of the olfactory world around it than humans, who in this example are largely unconscious of this particular world. Of course animals are not conscious of their place in the world, or that they will die, and they probably have very limited imagination. Humans' greater awareness of the world in which they live, comes in large part from language and communication. Young children would not be aware of the fact that they will one day die if they were not told that this would be the case. They then become conscious of their limited life-span.

Consciousness may be a mystery simply because we do know enough about its basis. After all, it was not that long ago that life itself was regarded as a mystery. Now we know there are genes and how they function and replicate. The mystery of human life resides in the human genome, the sequence of which is now known, and also in the rest of the zygote. There may be some surprises in store, but we can be sure the whole zygote is composed of molecules, and their properties will be unravelled. So it is with the human brain. Our huge ignorance will be gradually reduced, and finally we will understand the brain's power to reason, to think, to grasp abstract concepts, to experience emotion, pleasure and plain. We will develop important insights into our pleasurable responses to various art forms, and the judgment of the quality of music, visual arts and literature will become more objective and realistic. We will understand the function of sleep, and why we have vivid dreams. As well as all this, we will be able to define what consciousness really is, and at that point we will understand it.

Anti-social Behaviour and Crime

It is thought that the evolution of altruistic behaviour in man depended on kin-selection, whereby it became advantageous to cooperate with and help individuals who were genetically related. As communities got larger, kin selection tended to be replaced by social behaviour which benefited the whole group. It was advantageous to cooperate in obtaining food, or defending the group against common enemies or dangers. A moral code must have been extremely ancient, easily predating any religions that exist today. Within any such society, there are always individuals who deviate from the accepted behaviour and instead act out of self-interest. Such individuals can expect to be punished by the rest of the community, but this raises a very fundamental issue. If it is believed that the individual has a free choice between good and evil, then the punishment is retribution. If, however, the individual could not help himself, such as a father stealing food to feed his starving child, then retribution seems less appropriate. In this instance, punishment is regarded more as a deterrent to inhibit others from doing the same thing. In modern day society the punishment for a crime is usually regarded both as retribution and as a deterrent.

Unfortunately, this can introduce a great deal of confusion in the public at large, although they are for the most part unaware of it. Almost all religions state as an act of faith that humans have a God-given free will that enables them to choose between good and evil. If they choose evil they have sinned, and depending on the severity of their act, they should be punished accordingly. In this context, most people

regard the punishment as retribution. Now let us accept that there is no free will, and humans do not have any God-given ability to choose between good and evil. They may commit a crime through anger or hate, through hunger, through lust or through greed. In each case there is a cause; some emotion or characteristic of an individual has lead them into anti-social behaviour. In this case the punishment will be to deter others from doing the same thing. The distinction between retribution and deterrence is commonly blurred, and I think this is demonstrated by the ambivalence shown by most people. For example, if a young child has been abused sexually, and grows up to have emotional problems, including perhaps its own sexual problems, then a committed crime is usually attributed to the child's dis-advantaged upbringing. In contrast, when someone is murdered, the close relatives invariably demand the maximum sentence - clearly retribution - and appear to get satisfaction if this is imposed.

This may all seem rather far removed from an understanding of the human brain, but it is not, provided one discards the belief in freedom to choose between good and evil. With a full understanding of the mind and behaviour, the origins of anti-social behaviour will become much clearer. In some cases there may be a genetic predisposition, perhaps triggered by an environmental event. In others the cause may be entirely environmental, such as a maladjusted upbringing. When causes are understood and explained, society will at least be in a better position to be tolerant, although human nature being what it is, individuals will still receive blame for evil or criminal behaviour. The more important point is that when causes are understood, then one will know how they should be eliminated. So everyone will benefit: there will be less anti-social behaviour and less crime. The same applies to addiction to drugs. When the nature of addiction is unravelled in detail, then it will become possible to devise treatments or regimes which will effectively eliminate the addiction, provided of course that the affected individual wishes that to happen. All the information about peoples' behaviour under different circumstances and with different genetic backgrounds will make anti-social behaviour much more like a physical illness today. The illness can either be prevented, for example by immunization, or treated. In the future the aberrant behaviour will also be preventable, or prevented from recurring.

Political Issues

In politics, opinions are polarised, in the sense that one party is convinced it is right and the opposing party is wrong, and *vice versa*. Although there are reports and investigating committees, it is not usual for a politician to carefully weigh up the evidence for a particular course of action. Most commonly, they assert their policy with full confidence. Traditionally, political parties of the right and left strongly differ in their attitude to individual members of the community. The right supports free enterprise and competition, so that society becomes stratified, with the hard working and gifted rising to the top, whilst those with the reverse characteristics become the least affluent. In contrast, left wing parties believe strongly in equality of opportunity and egalitarianism. They believe that right wing politicians favour privilege and benefit those individuals who are brought up in affluent circumstances, and that individuals in disadvantaged situations have fewer opportunities. It is evident that these differences relate to the relative importance of nature and nurture, as was discussed previously. They will therefore ultimately become scientific issues which impinge upon or become part of political viewpoints.

At present, different political parties may have different attitudes to education or to health or to crime, law and order. Yet as we have seen these are areas where an understanding of the human mind and brain will contribute increasing amounts of exact knowledge. There will therefore be much less place for dogmatic assertions about this or that, because the answers will already be available. The upshot will be that political issues, at least in many areas, will tend to become less and less important. No doubt there will always be fiscal and economic policies to debate, but one of the major activities of governments, namely, the making of laws, will be based more and more on the knowledge of people, and how they interrelate to one another. It will become far clearer how societies should be organised for the maximum benefit of its members. This can be illustrated with just two examples. In cities, people can live in individual houses with small gardens, in high rise apartment buildings, or

in apartments in buildings of two or three stories set in grounds with extensive leisure facilities, children's playgrounds, and so on. The study of human behaviour and development in these three settings would surely indicate which are the most beneficial for the majority of normal individuals. How could this not influence politicians who are responsible for urban planning and design in the future? Also, governments and the electorate are always greatly concerned about crime and how best to combat it, and this is often a political issue. As we have seen, a better understanding of the origins anti-social behaviour and crime will make it much easier to devise non-controversial (and therefore non-political) measures to prevent its occurrence.

The Acceptance of Scientific Information

There is not much doubt that humans avidly accept technological developments that improve in one way or another their life-styles. The situation is different for advances in science. With regard to a much better understanding of learning and memory, and therefore great improvement in the efficiency of education, there is little doubt that parents would welcome new teaching regimes for their children. Also, the majority of people accept the end results of biomedical research, although there will always be some who opt for alternative or holistic medicine. It is hard to imagine individuals who would not welcome advances in the prevention or successful treatment of dementias, or other serious mental illnesses.

It is the study of life itself which encounters the most difficulty in communicating the major findings. The evidence for evolution by natural selection is now overwhelming, yet many people reject it, and may not want to know what the evidence is. Others accept that the world is ancient and that evolution occurred, but seem to believe that it must in some way be driven by the design or plan of a higher being. Then there is the compelling evidence that life itself is based on the laws of physics and chemistry, and that all organisms use macromolecules and innumerable metabolites. to create ordered systems capable of reproduction. In the fertilised egg and embryo there is no room for vitalism. Molecular biology and the unravelling of the nature of life itself makes it evident that there is no soul, nor afterlife. Yet people continue to believe in spirituality and that they will somehow survive after death. They believe in religious dogmas and the efficacy of prayer. Many do not even understand that there is conflict between science and religion, but think instead that in some way they complement each other. From what we see around the world, it seems unlikely that religious attitudes will change, whatever science discovers.

This might at first sight seem to be a matter for grave concern, but when one realises that most people are interested in practicalities arising out of science, then it becomes much less important that they should understand what scientists are actually discovering. The elucidation of brain function, and all that follows from that, does not mean that those who are not experts will be able to understand all the intricacies, any more than people can understand the intricacies of electronics, or the internet. What is important is that the discoveries will be made and a solid body of knowledge will be established. Obviously, this will proceed step by step, as will its assimilation and interpretation. The consequences for society will be profound, as I have attempted to argue here. All individuals will be affected in many beneficial ways, just as they benefit from biomedical research or electronics today.

Prior Discussions

The text so far contains only one reference, simply because the topics discussed lie largely in the future, so no documentation is available. However, I cite here a few publications which are very pertinent to the evolving study of human mind and behaviour. Charles Darwin may have been the first to realise that human and animal behaviour can be subjected to scientific methods. His book "The Expression of the Emotions in Man and Animals" (1872) was a pioneering study which looked forward to the future. Then in the twentieth century, Konrad Lorenz and Nikko Tinbergen were largely instrumental in founding ethology, the scientific analysis of animal behaviour. It was characterised by careful observation and deduction rather than by experiment, and therefore its methods can be applied to man. To some extent this has been done, but there is probably a great deal more to be learned by appropriate methodologies. These may come

into their own as neurobiology as a whole advances. In 1966, Francis Crick delivered three lectures which were published under the title "Of Molecules and Men." In this he explains why molecular biology has made vitalism superfluous to our understanding of the living world. He writes "Exact knowledge is the enemy of vitalism," and in a telling passage (page 94-95) he foresees the extreme importance of understanding the brain: "Now there are some questions that affect us far more personally than others, and among these the working of the brain certainly ranks high. It can be confidently stated that our present knowledge of the brain is so primitive - approximately at the stage of the four humours in medicine or of bleeding in therapy (what is psychoanalysis but mental bleeding?) - that when we have fuller knowledge our whole picture of ourselves is bound to change radically. Much that is now culturally acceptable will then seem to be nonsense. People with training in the arts still feel that in spite of the alterations made in their lives by technology - by the internal combustion engine, by penicillin, by the Bomb - modern science has little to do with what concerns them most deeply. As far as today's science is concerned this is partly true, but tomorrow's science is going to knock their culture right out from under them."

Later on, Crick took up the study of the human brain, and reviewed our current understanding in a book "The Astonishing Hypothesis" (1994). In this he discusses consciousness, sensory perception, and much else. The astonishing hypothesis itself is that the brain consists only of cells, and the cells consist only of molecules. He does not enlarge on the passage above, and he tells me that so far as he is aware others have not done so either (F.H.C.Crick, personal communication). That actually is not quite correct because I wrote a short book "The Science of Human Progress" (1981) which covers similar ground to this article, and I also included similar material in a novel "Slaves and Saviours" (2000). Crick (1999) also wrote a recent review in which he predicts that there will in the future be more interaction between molecular biology and neuroscience. Other discussions and reviews are pertinent (e.g., Kandel & Pittinger 1999, Zecki 1999, Bateson 2001 and Gierer 2002). In 1970 Jacques Monod brought molecular biology to the attention of non-scientists in his book "Chance and Necessity." This built bridges between modern biology and philosophy, and became an influential best-seller. It did not anticipate, however, the consequences of a continuing advance of neurobiology and an understanding of mind, behaviour and brain function.

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