REITH LECTURES 1976: Mechanics of the Mind

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Lecture 2: Chang Tzu and the Butterfly

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Nathaniel Kleitman, a Russian émigré who settled in the United States in 1915, and Bruce Richardson, an American colleague, spent 32 days alone in the depths of Mammoth Cave, Kentucky, in 1938. Only the artificial lights in their underground home preserved the rhythmic cycles of the day. But the day by which Kleitman and Richardson lived was not the day of this earth. They forced themselves to join the routine of an unknown planet, one with a 28-hour day: 19 hours for waking and nine for sleep. Could their bodies tolerate this sudden space-flight to a world of different time?

Kieitman, a pioneer of the scientific study of sleep at the University of Chicago, had already developed methods of measuring continually the normal fluctuations of body temperature (hotter in the early afternoon, cooler in the early morning), and of recording the tossing and turning of restless sleep. He used the same techniques in Mammoth Cave to see whether his temperature cycle and sleep pattern, and those of Richardson, his companion, would stick to earth-time or switch to the clock of planet X.

To be brief, Kieitman stuck and Richardson switched. Kleitman was unable to adjust to the 28-hour day; his body temperature stubbornly followed the rhythm of the world outside the cave, and his sleep was inadequate and fitful, especially when, every six days, 'midnight' in the cave coincided with noon in the real Kentucky. Richardson, on the other hand, adapted well to his temperature cycle and his sleep pattern.

Similar experiments in underground bunkers in Germany, and in the continuous daylight of summer in the Arctic Circle, have proved that man has a clock in his brain—a clock set to the time cycle of his natural home. Like a real clock, the brain's clock can readily be shifted back and forth, but with some discomfort to its owner, as every jet traveller knows. Again, like a real clock, there is less scope for speeding it up or slowing it down: Bruce Richardson was one of the rare individuals who can tolerate a regular 28-hour day; most of us can only manage between 22 and 26.

Man is certainly not unique in having internal knowledge of the periodicity of time; even the simplest multicellular sea animals have their cycles of activity locked to the rotation of the earth on its axis. And the humble rat stirs from its daytime sleep at precisely the same time each evening: the rules of the solar system may be written in its genetic code. A rat kept in a room that is constantly dark or constantly illuminated will still obey a cycle of activity, but usually with a natural periodicity a little longer than 24 hours. It will not deviate from this inherent rhythm by more than a few minutes over several months; the timekeeper in a rat's brain is more accurate than most mechanical clocks.

In laboratories all over the world, the study of human sleep remains the most direct experimental approach to the question of consciousness. This nightly appointment with death is the most profound loss of consciousness that most of us are likely to experience throughout our lives. We shall spend more than 20 years of our lifetime asleep - unconscious, almost oblivious to the demands, the joys, the dangers of the world around us. The problem of human consciousness has stirred up fierce debate between the reductionists, who would banish the Cartesian soul from the machinery of the body, and the holists, who see consciousness as the most personal evidence for a universal law—that the whole is more than the sum of the parts. What is the poor scientist to do when confronted with the rumour of a phenomenon, which is all that consciousness is? His commitment to the 'postulate of objectivity', in the terminology of Jacques Monod, does not give the scientist methods to measure the private deliberation of the conscious mind.

How could a scientist deal with observations like these imaginary ones of Paul Jennings?

> When numbered pieces of toast and marmalade were dropped on various samples of carpet arranged in quality, from coir matting to the finest Kirman rugs, the marmalade- downwards incidence varied indirectly with the quality of the carpet—the Principle of the Graduated Hostility of Things.

'How can *things* be hostile?' the scientist must say. Faced with these improbable results, the physicist would surely conclude that some constituent in high- quality carpets exerts an attractive force, perhaps electrostatic or magnetic, on marmalade. The more cynical psychologist might suspect that the hostility was not in the toast itself, but in the subtle intentions of the person who dropped it.

Most scientists are embarrassed when they cannot explain events by the forces and laws that they already understand. Those who study the brain usually shuffle their feet uncomfortably, and quickly change the subject, when the discussion turns to that one brain function that we all know so intimately—consciousness itself.

If *things* cannot be hostile, how can the bits and pieces of molecular hardware that make up the brain have emotions and thoughts? The brain researcher of today is almost as impotent to evaluate consciousness as a computer is to judge beauty or put a price on a Rembrandt portrait. But it does not follow that beauty is more than the sum of a number of definable features, or that a Rembrandt is more than all its individual brush-strokes. The problem is to define all the brush-strokes of the brain before we reject an opinion like that of W. Somerset Maugham, who said:

> The highest activities of consciousness have their origins in physical occurrences of the brain just as the loveliest melodies are not too sublime to be expressed by notes.

There is no reason to believe that the scientific method will fail to account for the phenomenon of human consciousness, without invoking a new, transcendent principle. Indeed, some would say that there is no phenomenon to explain. In his remarkable book, *The Concept of Mind*, Gilbert Ryle attempted to show that the everyday use of linguistic terms associated with the concept of consciousness, like 'believing' and 'thinking', is based on a logically untenable model of the mind as a 'ghost in the machine '-an independent, invisible and secret agent, whose actions are intangible and cannot be revealed. Ryle rejected the doctrine that each of us is privy to an inner world of ghostly happenings, and gave an account of our lives as conscious beings in terms of observable actions and dispositions. Words like 'knowing' and 'believing' describe propensities to act in particular ways, under certain circumstances. If this kind of unmasking of consciousness destroys its special qualities, must we conclude that consciousness does not exist at all? To call 'knowing' a disposition to act may bring consciousness within the professional realm of brain research (and that is an important step), but it does not mean that there is nothing to explain. Ryle may have exorcised the ghost from the machine, but he has left a machine of much greater complexity.

Then is consciousness - as some reductionists insist - a mere epiphenomenon that results from the actions of an immensely complex, but wholly mechanical, brain? Such a view might imply that any complicated calculating machine would automatically be conscious. But few would claim that the world's combined telephone network, an undeniably enormous system of switches, has consciousness. Hostility, perhaps, but consciousness, surely not.

On the other hand, I am sure it is wrong to believe that no computing machine can ever be conscious. The first requirement of a conscious machine—though perhaps not a guarantee of consciousness—is motivation. The nervous system did not first evolve as a device for intellectual exercise and conscious reflection. It simply made animals better at achieving their biological goals of eating, drinking and reproducing themselves—things that do not interest most computers.

If evolution has given us internal awareness, it must presumably have had survival value. One advantage that consciousness provides us with is the ability to make predictions about the behaviour of other people, or even of other animals. It supplies a set of rules for relating emotional states to external events, which must surely be valuable in the complex social intercourse that governs the lives of people, no less than of chimpanzees or of the wild dogs of Africa.

When asked by the hostess at a rather boring party whether he was enjoying himself, Oscar Wilde is reputed to have replied that he certainly was, for there was no one else there to enjoy. And in his play, *An ideal Husband*, Wilde wrote: 'Other people are quite dreadful. The only possible society is oneself.' But in a society of one, consciousness might not be needed at all.

Nothing illustrates better the need for society in the creation of consciousness than a remarkable experiment of Ronald Meizack. He reared some dogs in total isolation, from infancy to maturity, so that they had no opportunity to learn the rules of social interaction. When he released the dogs and studied their behaviour, he discovered that they seemed to have little or no sense of pain, or at least nothing more than a brief reflex response to it.

And in his famous work on conditioned reflexes, Ivan Pavlov was even able to transform overt pain to apparent pleasure. In one experiment, instead of combining a ringing bell with morsels of food, to teach an animal to salivate to a neutral stimulus, Pavlov used a brief electrical shock to the dog's paw as the 'unconditioned' signal that food was about to appear. Now, at first, the dog reacted violently to each shock, and its appetite was decidedly reduced. But gradually, a surprising transformation took place. The electric shock no longer prompted any sign of pain. On the contrary, when the shock came, the dog salivated, wagged its tail, and turned expectantly to its food bowl.

Philosophers from Aristotle to Ludwig Wittgenstein, from René Descartes to Peter Singer (the author of a recent book, entitled *Animal Liberation*) have argued that the expressions of emotion and thought are the means by winch each human or animal communicates its consciousness. For Descartes, animals had no rational soul; they could not verbalise propositional thoughts in speech, and were therefore not conscious. But Singer reasons that feelings, principally those produced by pain, can be ascribed to others, including animals, by observing reliable behavioural signs that we recognise as similar to the responses we ourselves produce when we consciously experience pain. What, then, are we to make of the observations of Melzack and Pavlov, which seem to show that the emotional state of pain is not related in a simple way to a particular stimulus? Behaviour, the overt product of consciousness, is modified by social as well as personal experience.

In man, too, cultural factors are extremely important in setting, not only the threshold, but also the context of pain. Acupuncture, itself an unpleasant procedure for most Westerners, has been practised for more than 2,000 years in China for the treatment of organic illness, and is, since the Cultural Revolution, quite often employed as the only form of anaesthetic in certain major surgical operations. Children in China are taught the classical theories, and even the techniques, of acupuncture from an early age. Some would argue that the undeniable success of acupuncture analgesia among the Chinese is simply due to a kind of cultural conditioning, like that of Pavlov's dogs.

Yet it is possible that acupuncture anaesthesia, and perhaps other cultural modifiers of pain, operate through a simple physiological principle. It has been known for many years that the pain-killing drug, morphine, and its derivatives act by attaching themselves to nerve cells in the brain— cells that somehow influence the threshold and sensation of pain. A naturally-occurring substance, named enkephalin, a tiny peptide molecule, has now been discovered in the brain; it acts just like morphine and reduces pain. In fact, it is presumably more accurate to say that morphine, the external agent, works just like enkephalin, the internal one. Enkephalin is a 'natural opiate', an analgesic drug that the brain itself can apparently synthesise to alleviate its own sensation of pain. Now, Chinese scientists have recently reported that the practice of acupuncture on a rabbit causes the production of a substance in its brain which, when injected into the brain of another rabbit, increases its tolerance of discomfort. This substance might well be enkephalin, secreted by nerve cells in the brain in response to the acupuncture needles.

Morphine and the related compound, heroin, are dangerously addictive drugs, and their unsupervised possession is illegal; yet we may all carry within our heads a 'natural opiate' that our brains use to regulate this most fundamental aspect of consciousness—the perception of pain.

For scientific, as well as philosophical, debate, it is important to distinguish the state of consciousness from the so-called ‘actions’ of the conscious mind, like choosing, whose existence as genuine operations Ryle and others would deny. It is this active aspect of consciousness that still gives scientists nightmares, philosophers headaches, and theologians eternal joy. The question of choice is often the subject of acrimonious debate between reductionists and theists; so it is curious to hear arguments from both sides of the fence that the actions of man are entirely predetermined, either by the totally predictable and mechanical operations of the connections in his brain, or by the predestination written for us all in the diary of an equally mechanical god. This attitude, whatever the motivation behind it, is an insult, either to the subtlety of the brain or to the mentality of God.

I see no reason why the alternative concept—choice of action—should necessarily be the exclusive property of those who believe in a permissive and forgiving deity. Some degree of flexibility of operation is the hallmark of an advanced machine. It is the serendipity of free will that makes it valuable.

Anyone who has tried to train an animal in a laboratory—or a child at home—knows that learning is never automatic, nor totally predictable. it is a source of frustration to the behavioural psychologist that, however well he trains a rat to run a maze, however easy the problem, the rat will never go in the correct direction in every single test. Now and then, he exercises his ratty free will and takes the alley with no cheese at the end. But the choice that the psychologist calls incorrect is, for the rat, a potentially valuable paradigm of action - the chance to discover, by chance, the unexpected. By this analogy, I do not mean to suggest that rats have conscious free will like man, nor to say that man is just a jumped-up rat, but it does illustrate that the existence of choice is not necessarily incompatible with a mechanical view of the mind. Just as one value of consciousness is to explain the actions and emotions of others, the element of free will in conscious thought is an internal explanation for the flexibility of our *own* behaviour.

The final aspect of conscious experience, its level or state, is the one that can most readily be judged by objective observation; it can most clearly be ascribed to animals, and hence is most accessible to the scientific method. And that is why so much effort has been spent in the study of sleep.

The mysterious nature of sleep, and the dreams that it harbours, must always have occupied the thoughts of men. In the egg- shaped universe of Greek mythology, Night, the shell of the egg, gave birth to Hypnos, god of sleep, whose son was Morpheus, god of dreams, master of the fantasy land that lay close to the realm of the dead. There was widespread belief in the ancient world that sleep was a time of communication with the gods, a time when the spirit left the body to wander alone; and its experiences were the dreams of the night. The ancient Chinese would never rouse a sleeper hastily, in case his spirit did not have time to re-enter his body. The view that we lose our personality in sleep is still prevalent. Even the law seems to accept that sometimes a man is not responsible for his actions while asleep; courts in both the United States and Great Britain have acquitted people of murder when the act was committed during sleep.

It is probably the apparent futility of sleep, the wasted time, the biological danger of it, that leads us to cherish dreams, the sole conscious product of sleep. The interpreters of dreams, from the second-century soothsayer, Artemidorus of Ephesus, to Sigmund Freud, have capitalised on our fascination with these products of the unbridled mind. But the similarity between the untrustworthy image of the dream and waking experience has posed enormous problems for the philosopher. The Chinese Taoist, Chang Tsu, in the third century BC, was one of the first to express his fears. He wrote of himself:

> Once upon a time, I, Chang Tsu, dreamed I was a butterfly flying happily here and there suddenly, I woke up and I was indeed Chan, Tsu. Did Chang Tsu dream he was a butterfly, or did the butterfly dream he was Chang Tsu?

In most religions, dreams are incidents of mystical insight, of communion with the gods and of divine revelation. The irrational view that dreams are veiled predictions of future events was, and still is, widely held. The analytical psychologist, Erich Fromm, has tried to justify this belief by arguing that, if dreams are, as Freud suggested, the disguised fulfilment of unconscious wishes, then they might be expected to portray episodes that will be unwittingly sought out in real life. Aristotle, 2,000 years ago, took a more jaundiced view, saying that, since dreams come in such abundance and such variety, some of them will inevitably resemble future events, just by chance—perhaps the first example of a statistical argument in the behavioural sciences.

However, it was a belief in the power of premonition, and even the existence of telepathic communication, that led to the single most important technical advance in the study of sleep: the measurement of the human electroencephalogram. Towards the end of the last century, a young German, Hans Berger, who was serving in the army, slipped from his horse as it stumbled down an embankment, and he narrowly escaped serious injury. That evening, he was astonished to receive a telegram from his father asking if he was well, because his sister had had a feeling that he was in danger.

This event led Berger to change his studies from astronomy to psychiatry, at the University of Jena, where he received his doctorate in 1897, just at the time that Sigmund Freud was writing *The Interpretation of Dreams*, in Vienna. Berger was obsessed with the relationship between material events in the brain and mental phenomena, in which he included telepathy.

A long tradition of experiments, started by John Walsh in England and Luigi Galyam in Italy, had established that signals are carried along nerves to muscles, in the form of brief electrical pulses. It was known that the brain is packed with nerve cells and fibres, and electrical activity had already been detected in the brains of animals. Berger hoped to prove that electrical responses in the brains of men are correlated with consciousness, and might even be the physical medium by which thoughts could be telepathically transmitted. In 1924, he managed to record a signal with metal electrodes stuck to the head of his young son, Klaus.

But what strange signals they were! Whenever Klaus was relaxed and inattentive, Berger picked up a feeble but definite ripple of electrical potential, with a regular frequency of about ten cycles each second: he called it the 'alpha rhythm'. Much more exciting, Berger later found that these electrical waves of the brain certainly were influenced by conscious experience. He wrote:

> In many experimental subjects, opening of the eyes . . . caused an immediate change in the electroencephalogram and . . . during mental tasks—for example, when solving a problem of arithmetic—the mere naming of the task sometimes caused the same change.

However, it was something of a disappointment to Hans Berger that this change that occurred in the electroencephalogram when a person became more alert was not an increase in the amplitude of his alpha rhythm, but its virtual disappearance. The electroencephalogram became 'desynchronised', and decomposed into a torrent of tiny, high-frequency waves. But at least Berger had shown that the human brain, no less than that of an animal, is electrically active, and that alterations in mood, attention and the state of consciousness are accompanied by (some would say caused by) modulations of the electrical rhythm.

During the delicious drowsiness that heralds sleep, the alpha rhythm dominates; as sleep deepens, the waves become longer and slower in frequency. This mindless rhythm is, in a sense, the natural state of the brain; it is the pattern adopted when sensory stimulation is attenuated and vigilance is low. Indeed, some classical experiments between 1930 and 1950 suggested that sleep is essentially a passive affair. A large, untidy tangle of nerve cells and fibres, called the 'reticular formation', in the stem of the brain, was implicated in the maintenance of consciousness. Like a great computer without a power supply, the cerebral cortex without the reticular formation below it is only a potentially powerful machine. Damage to the reticular formation can produce a prolonged state of coma and unconsciousness, and brief electrical stimulation of it in animals will rudely awaken them from sleep, and abolish the lazy rhythms from their electroencephalogram.

Now, many sensory nerve fibres, bringing information into the brain from the sense organs have branches that terminate in the reticular formation, in addition to their main trunk-lines that run up towards the cerebral cortex. Any incoming signal is thought to have two effects: first, to inform a particular part of the cortex about the nature of the new event; and second, to ac4ivate the connections between the reticular formation and the whole cortex, hence desynchronising its waves.

But the relentless daily demand for sleep, the internal clock that would not let Nathaniel Kleitman adopt the schedule of a different world, and the infinite torment of struggling to resist the embraces of Hypnos, all demonstrate that sleeping and waking are not passive reflections of sensory input. Indeed, regular, gentle, electrical stimulation in many parts of the brain, including the lowest parts of the reticular formation itself, can throw the cortical electroencephalogram of an alert cat into rhythmic waves, and the cat will instantly settle down and drift into completely normal sleep.

More than 60 years ago, two Frenchmen, Legendre and Pieron, claimed that a chemical substance builds up in the brain of a tired animal, and that if the fluid from the ventricles is transfused into those of another animal, the latter will fall asleep. This unlikely story has now been all but proved by John Pappenheimer and his colleagues at Harvard Medical School. A substance, called ‘factor S’ by Pappenheimer, isolated from the cerebral fluid of sleepy goats, will greatly enhance the sleep of rats or rabbits into whose brain it is transfused. It seems likely that factor ‘S’ is, like enkephalin, a small peptide molecule, which gradually builds up during the waking period, and possibly acts on the brainstem regions that trigger the start of sleep.

Finally, measurement of the electroencephalogram has thrown light on the mystery of dreams themselves. In 1952, two students in Kleitman’s laboratory, Eugene Aserinsky and William Dement, discovered that, at roughly 90-minute intervals throughout the night, extraordinary things happened on the recording machine attached to their sleeping volunteers. The electroencephalogram suddenly reverted to the drowsy mode, as if the sleeper were about to wake up: his breathing became irregular, his heart-rate increased, his fingers twitched and, if the volunteer was male, his penis sprang to attention. Most striking of all, his eyes beneath their lids darted about crazily. These episodes are therefore called ‘rapid-eye-movement sleep’ or ‘paradoxical sleep’ because the sleeper is actually much harder to awaken, despite the alert state of his brain. Dement went on to find that, if someone is woken in this stage of sleep, he is almost certain to say that he has just had a vivid dream.

Now, experiments with animals point to another area in the brainstem reticular formation as the site if initiation of paradoxical sleep. This region may activate the cerebral cortex and trigger the spurious mental events of dreams. The level of consciousness is then regulated by a primitive part of the brain, not by the intellectual machinery of the cerebral cortex. This raises ethical and legal dilemmas of the most serious kind. The rapid advances in heart transplantation surgery a few years ago played a part in changing the public and legal attitude to dying. The present medical definition of death accepts the fact that a man, as an independent mind, can outlive his own heart. As in the recent case of Karen Quinlan in the United States, death is now equated with irreparable damage to the brainstem, even when the higher centres of the cerebral cortex are quite intact. Without the vital power that drives it, the mind may be suspended forever in sleep. But it would be short-sighted to think that this interpretation is less expedient and more absolute than one based on the function of the heart. Even our definition of life itself is determined by the prevailing level of medical expertise and current scientific opinion. The experimental study of sleep is important, because a full understanding of the control of consciousness may give us more objective criteria for the definition of death.

In my next lecture, I move on to the cerebral cortex itself, and to the perceptions that we trust as valid descriptions of the outside world.