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EXPLORING THE BRAIN

Lecture 12

SLEEP AND DREAMS

by

PROFESSOR SUSAN A. GREENFIELD MA DPhil
Gresham Professor of Physic

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Gresham College, Barnard's Inn Hall, Holborn, London EC1N 2HH
Tel: 0171 831 0575 Fax: 0171 831 5208
e-mail: enquiries@gresham.ac.uk

GRESHAM LECTURE 12: Sleep and Dreams
Susan Greenfield
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We do not know if dinosaurs slept, but all birds and mammals for the last two hundred million years have displayed some type of sleep pattern. Sleep is a fundamental function of an elaborate brain. In contrast to sleep as we mammals know it, the 'rest' periods of insects is far less complex. Sleep can be determined by a range of signs: a slowing of body metabolism, relative immobility and of course, loss of consciousness (except in dreaming, with which we shall deal separately). There are four stages of non-dreaming sleep, distinguished by different patterns of electrical electricity recorded from the scalp using an EEG (electroencephalograph). When we fall asleep we descend very rapidly from the lightest Level 1 through these four stages, all of which have characteristic patterns of brainwaves generated from the scalp, down to the deepest level, Level 4. Throughout the night, we gradually surface and descend again, cycling through these four stages some four or five times.

As well as the four stages of sleep, through which we cycle several times a night, there is also another stage of sleep, which is totally different. It is in this stage of sleep that our eyes move rapidly, backwards and forwards, hence its name, Rapid Eye Movement or REM sleep: if people are awakened during REM sleep, they usually report that they have been dreaming. It is easy to imagine that the darting eye movements are a result of looking at images that move about in our dream world. REM sleep actually resembles normal waking in that the chemicals, mainly proteins that appear to be made during the night, cease to be manufactured when we dream. Indeed, if the living brain is imaged whilst a subject is asleep, then in terms of protein manufacture, the states of wakefulness and dreaming are indistinguishable. Moreover during this dreaming state of sleep, our EEG is just the same as when we are awake, unlike when we are asleep in dreamless sleep. However in normal sleep, when we are not dreaming, we might be tossing and turning, but in REM sleep our muscles become paralysed: this immobility is important because it stops us acting out our dreams. Imagine for example acting out a fall from a tenth storey apartment. REM sleep then is, paradoxically best viewed as a form of consciousness. It is often referred to as 'paradoxical' sleep.

Different animals display different amounts of REM, the dreaming sleep. Reptiles do not display it at all, whilst birds do occasionally, most usually as hatchlings. We humans share with birds this preponderance for the young of the species to generate REM sleep for more of the time. On the other hand, all mammals, at least according to their EEG, would seem capable of dreaming throughout their lives. In an average night's sleep of some seven and a half hours, we humans can spend a total of one and a half to two hours dreaming. The longest ever recorded single period of continuous REM sleep is about two hours. Given that REM sleep clearly occupies a significant portion of our sleeping time, it presumably has some value. So, why do we dream? There are several theories.

One theory is that since the brain is no longer tied down and restricted by the apparent reality of the messages coming from the outside world, it starts to, in a sense, free wheel. Its a little like the working day where our actions are frequently regulated by a definite timetable, imposed from the outside world: however, on a day off there need be no structure to activities, which can be capriciously selected and abandoned almost at random. On the other hand, there must be more to dreaming than the brain just playing around: there is evidence suggesting there is some definite benefit for the dreamer. If people are woken up when their EEG shows that they are in REM sleep, and thus probably dreaming, then they try and compensate the following night: the amount of REM sleep that they undergo increases. In one experiment, people were woken up every time their EEG registered REM sleep. They were woken up to ten times on the first night, but by the sixth night they were woken up as many as thirty three times as their brains tried time and again, in vain, to plunge into the dream world.

Another idea is that dreams enable us to come to terms with problems and consolidate whatever has happened during the day. Although in adults, it is easy to see that dreams may have come to serve this purpose, it seems unlikely that it is the prime purpose of dreams. The fetus at 26 weeks spend all its time in REM sleep, yet has no 'experiences' to consolidate or resolve. Dreaming time then declines gradually through childhood: this observation suggests that dreaming represents more a state of the functioning of an immature brain, where neuronal circuits are still very modest. Perhaps dreaming is the type of consciousness resulting from a less vigorous dialogue between brain regions, caused in turn by the fact that the connecting fibres are still becoming established.

If true, this idea could have two very interesting implications: first, it suggests that when we are in REM sleep, the degree of communication between regions in our brain becomes far less. Secondly, it has been noted that the consciousness of schizophrenics is frequently very similar to the illogical but very real consciousness of our dreams. Hence it might be the case that a central problem in schizophrenia is a reversal to a reduced communication between regions of neurons, leading to a dream-like view of the world. Although the 'function' of dreaming then might end up being one of consolidation of our problems, it is more likely that dreaming arises as a result of certain states of brain activity that cannot process large amounts of sensory input either because we are asleep or because, as in infancy, the brain is underdeveloped, or because , as in schizophrenia, prevailing chemicals have modified the efficacy of large scale dialogues over large banks of brain cells. A further idea is that dreaming represents the lowest end of a continuum of consciousness, which in turn would be reflected in the number of brain cells recruited into a working assembly at any one moment. Since there were no powerful inputs from the senses, it could be the case that relatively fewer neurons were corralled together, resulting in a smaller degree of consciousness. If, however, dreaming is a further facet of consciousness, its 'cause', the means for its generation and indeed its function, can still only be at the most, extreme conjecture.

But what are the functions of ordinary sleep, when we are completely unconscious? This is an important question because sleep is a pretty risky business: in the Cro-Magnon world into which our species evolved 30,000 years ago, the sleeper is highly vulnerable to attack from passing predators. Sleep must therefore have some enormous benefit in order to debilitate us in this way for up to eight or so hours per night. It is now known that during sleep the brain makes proteins at a much faster rate than when we are awake. Proteins are large molecules that are essential for maintaining the structure and which underpin the function of all the cells of the body, including neurons. So sleep gives us a chance to stockpile the chemicals that seem to be vital for our brain to function properly. But functioning properly does not just mean that all the processes we are conscious of, such as learning and memory, but the unconscious process as well, such as those regulating temperature.

We normally only use a part of the energy derived from food and oxygen to be converted to heat immediately, to keep us warm. The remaining energy is stored for all the other vital functions of brain and body. However if people are allowed only three hours sleep a night, many of these functions start to decline within a week. If we are deprived of sleep, energy is not stored up so efficiently, but more is squandered immediately, dissipated as heat: hence anyone continuously and completely sleep deprived would eventually, literally, be burning themselves out. If rats do not sleep for long periods of time, they gradually need more and more food to restore their energy. Eventually such rats die, underweight and exhausted, despite their huge food intake. So sleep is vitally important.

Another intriguing feature of the brain and its arousal system is that usually, the brain 'knows' when to fall asleep. At least in a number of non-human animals there is one area of the brain that plays a very important part in sleep and waking, the pineal gland. The pineal gland lies right deep down at the centre of the brain: unlike most other brain structures which are duplicated either side of a mid-line, the pineal gland is right over this mid-line, straddling the middle of the brain.

For this reason the philosopher Rene Descartes, over three hundred years ago, thought that the pineal gland was actually the seat of the soul. Descartes argued that because, unlike other brain regions, there was no two pineal glands, and because we only have one soul, then the pineal gland must be the seat of the soul.

Nowadays however, we know that rather than playing such a rarefied role, the pineal gland is important in regulating sleep and wakefulness. Birds are stimulated directly by light through their skull: we know that even when the pineal gland is isolated from birds completely and put it in a dish, it is still sensitive to light. The pineal gland is not responsive when it is already light and becomes dark: however, when it is the other way around, if it is dark and suddenly becomes light, then the cockerel awakens. The pineal gland secretes the hormone melatonin. This is a substance which fluctuates in the brain according to time of day. When levels are high in the brain, sleep ensues: in fact when melatonin is injected into sparrows they subsequently fall asleep. Although such a simple sequence of events might seem at first glance to be of little relevance to us sophisticated humans, it is worth noting that in the US at least, melatonin is proving an increasingly popular way of overcoming jet lag. A tablet of melatonin, taken just before sleep in the new time zone, ensures that sleep occurs rapidly, and for a decent period of time.

In us humans however, the sleep wake cycle is normally controlled by a variety of factors. We can see just how important these outside clues are from experiments where people have been put in caves and left entirely to their own devices, free from all the demands as well as clues from the outside world.

One such, a former RAF officer David Lafferty, answered an appeal in 1966, placed in the Daily Telegraph, for a volunteer to live in isolation in a cave 350 feet underground for at least a hundred days. In return he received £100, plus a further £5 per day for each subsequent day spend underground. In fact he set a new record of endurance by remaining for one hundred and thirty days. At the end, doctors were surprised at Lafferty's good physical and mental health: however Lafferty himself was surprised when he heard how long he had been underground. Left to themselves, Lafferty's biorhythms had settled down to be longer than was actually the case, to some twenty five hours. He therefore had underestimated the time he had spent underground. In general this slight underestimate seems to happen when people are isolated; so clearly we do have a basic and rather regular internal clock, but we also need to fine-tune it by using external cues, so called 'zeitgebers' such as domestic clocks, from the outside world.

Sleep is one of the most basic and as yet still mysterious functions of our brains. It has probably evolved for several reasons, to conserve energy, stockpile chemicals, and to protect us from coming to harm in the dark. Dreaming is perhaps the most baffling phenomenon of all, but nonetheless may one day serve as a window on to the ultimate secret of the brain, the nature of consciousness itself.