REM SLEEP, FUNCTION OF

Perhaps the greatest mystery in the field of sleep and wakefulness is the function of REM sleep. It seems obvious that REM sleep must have some vital function. Virtually all mammals have REM sleep. In human adults it occupies approximately 90 to 120 minutes of sleep time each night. The intense brain activity during this state is mirrored by intense mental activity experienced as dreams. It is difficult to believe that this physiological state does not have some vital survival role. There is no general agreement among sleep researchers about the function of REM sleep.

Theories of REM sleep function stem from several kinds of evidence. These include data from REM sleep deprivation *(see also* DEPRTWOION, SELECTIVE REM SLEEP), developmental studies, the distribution of REM sleep amounts in different species, the correlation (or lack of correlation) between REM sleep and intelligence, and the role of REM sleep inferred from physiologic studies of the brain.

The most direct approach to answering the question of REM sleep function is to deprive organisms of REM sleep and determine the nature of the ensuing deficit. Early studies in humans and animals found that such deprivation produces a selective increase in the amount of REM sleep when sleep is allowed after deprivation is terminated. This REM rebound indicates that a need for REM sleep exists and accumulates in its absence, analogous to our need for food or water. Early studies also suggested that psychiatric problems occurred during REM sleep deprivation, suggesting that perhaps processes accompanying the dreams of REM sleep facilitated the maintenance of sanity in waking. Further studies have shown that this initial report was not correct. While REM sleep-deprived individuals certainly become irritable, and the frequency of certain behaviors changes in REM sleep-deprived animals, grossly pathologic behavior does not occur after deprivation of normal individuals.

A number of studies have examined the possibility that REM sleep is essential for forming permanent memories, and several studies have reported that REM sleep deprivation produced greater effects on memory retention than deprivation of NREM sleep stages. There is also some evidence suggesting that the amount of REM sleep increases after intense learning experiences. On the other hand, many investigators have failed to find relations between REM sleep and learning. Thus, the effect appears to be a small one, if it exists at all. Others have hypothesized that REM sleep is required for "forgetting" certain types of information, but evidence for this hypothesis is lacking (see also MEMORY; LEARNING).

It is clear, at least in rats, that complete deprivation of REM sleep for periods of weeks results in death. This effect, however, is less marked than that of total sleep deprivation, and it is not clear that the effect of long-term REM sleep-deprivation procedures produce qualitatively different effects than does the deprivation of NREM sleep (see also DEPRIVATION, TOTAL PHYSIOLOGICAL). The cause of death after either kind of deprivation is not yet established, although this is an active area of study (Rechtschaffen et al., 1989).

A second kind of evidence bearing on REM sleep function is the distribution of REM sleep amounts across different species of animals (see PHYLOGENY). In this approach researchers try to correlate other characteristics of animals with the nature of their REM sleep and, in particular, with the amount of REM sleep. Because REM sleep is associated with the dreaming state in humans, it is often assumed that humans and other "intelligent" animals have more REM sleep than "lower" animals. This is clearly not the case. Human REM sleep percentages are neither uniquely high nor low. For example, opossums and ferrets are the current "REM sleep champions," having more than 6 hours of REM sleep each day and devoting more than 30 percent of their sleep time to REM sleep. Adult humans have about 1.9 hours of REM sleep each night, 24 percent of their sleep time. Animals with very low amounts of REM sleep include larger animals such as elephants and hippopotami. Elephants have 1.8 hours of REM sleep each day, indicating that the elephant's legendary memory does not require large amounts of REM sleep. As a group, birds have less REM sleep than mammals. It is unclear whether reptiles and other nonmammalian vertebrates have REM sleep. Only two mammals have been found to lack REM sleep. One is the ECHIDNA, or spiny anteater, a primitive egg-laying mammal found in Australia. The other is the bottle-nosed dolphin. Other aquatic mammals have REM sleep (see PHYLOGENY).

Phylogenetic evidence is at variance with the often expressed belief that REM sleep is related to higher intellectual function. Nevertheless, the variation in REM sleep amounts has been shown to relate to the security of the animals' sleep arrangements. Animals that are subject to predation and have unsafe sleeping places tend to have little REM sleep, whereas predator animals or animals with safe sleeping places have more REM sleep. Since REM sleep is in some sense a deeper stage of sleep, an abundance of REM sleep might be maladaptive for prey animals. This theory explains variations in REM sleep amounts in terms of the danger of the state, but does not really explain what function the state performs.

The issue of an intellectual role of REM sleep has also been addressed by comparisons among humans. While there is some evidence that REM sleep amount may be positively correlated with a person's weight, there is no good evidence that it is correlated with intelligence.

Another variable correlated with the variation in REM sleep percentage among groups of mammals is the maturity of animals at birth. Thus, the opossum with its large REM sleep quota is born in a very immature state, whereas grazing animals such as horses, which have relatively little REM sleep (0.6 hours per day), are born mature enough to begin functioning independently soon after birth. One theory to explain a correlation between REM sleep and level of maturity at birth is that REM sleep aids in the development of the nervous system.

This theory is further supported by the fact that the amount of REM sleep in all animals examined so far is maximum at birth and decreases to a lower "plateau in adulthood." In humans, for example, newborn infants spend more than 6 hours a day in REM sleep—more than 3 times the adult amount (see INFANCY, NORMAL SLEEP PATTERNS IN). For this reason, it has been hypothesized that REM sleep may stimulate the brain and thereby aid in its development. This theory does not, however, explain the function of REM sleep in the adult. Nevertheless, although direct evidence for or against this theory is not available, the developmental decrease in amount of REM sleep is so consistent across species that it seems likely that REM sleep does fulfill some as yet unspecified developmental role.

Investigations of neuronal activity during REM sleep have revealed intense activity within the brainstem. The behavioral expression of this activity is normally blocked by a system that prevents activity in motoneurons and thereby blocks movement. Scientists have hypothesized that this intense neuronal activity is a way in which connections are formed within the central nervous system. Such connections might allow animals to express genetically determined behavior patterns. For example, the complex motor patterns required for stalking prey, getting and storing food, or mating may be imprinted on the central nervous system by the motor sequences commanded during REM sleep. This theory is also difficult to test experimentally, because it would require extended periods of REM sleep deprivation, and again, it does not explain the need for extended periods of REM sleep in the adult.

REM and NREM periods normally alternate within the sleep period. Because brain neuronal activity is greatly reduced during NREM sleep, some have hypothesized that REM sleep's function is to stimulate the brain to allow it to recover from NREM sleep. This theory is consistent with the finding that we are much more alert when we awaken from REM sleep than when we awaken from NREM sleep, and the fact that some animals, such as cats, almost always wake up right after REM sleep. Nevertheless, this theory does not adequately explain the long duration of REM sleep (see ATONIA; CYCLES OF SLEEP ACROSS THE NIGHT).

Although much of the brain is intensely active during REM sleep, several populations of neurons greatly *decrease* their activity at this time. Neurons releasing the neurotransmitters serotonin, histamine, and norepinephrine are continuously active during waking, decrease their level of activity during NREM sleep, but are completely inactive during REM sleep (see CHEMISTRY OF SLEEP; REM SLEEP PHYSIOLOGY). Of these transmitters, the functional role of norepinephrine is best understood. This transmitter appears to increase the efficiency of signal processing throughout the nervous system by increasing the response of neurons to signals produced by other neurotransmitters, while reducing the level of background "noise." There is evidence that uninterrupted release of norepinephrine would cause a gradual degradation of this system by reducing the sensitivity of receptor systems for norepinephrine. It may be this loss of sensitivity that we experience as sleepiness. The interruption of norepinephrine release that occurs in REM sleep would prevent this degradation of receptor sensitivity. This pattern of state-related neuronal activity and inactivity, led Siegel and Rogawski (1988) to hypothesize that the maintenance of receptors for these systems of REM-off neurons is a principal function of REM sleep. There is some limited evidence to support this theory, based on recordings of neuronal activity during sleep deprivation. Related theories have hypothesized other neural recovery functions for REM sleep, including synthesis of various neurotransmitters. Further work needs to be done to monitor neuronal metabolism and structure and to establish the time course of any REM sleep effects.

In conclusion, we do not yet know the function of REM sleep. Several possibilities have been suggested and are under active investigation. One or more of these may prove to be correct. However, it may well be that the most critical functions of REM sleep have yet to be suggested.

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