19

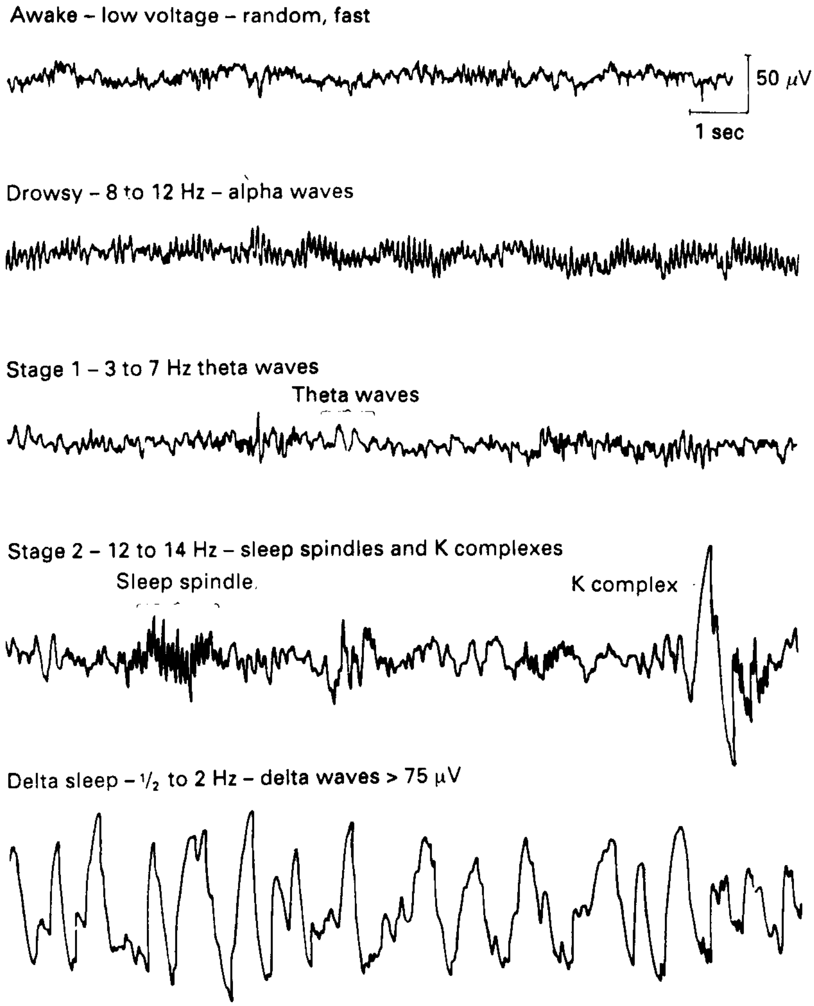
Sleep

- Sleep shows several stages; QUIET SLEEP (stages 1, 2, 3 & 4), shows large waves in the EEG, whereas ACTIVE SLEEP, associated with dreaming, shows an EEG pattern similar to that of waking.
- SLEEP DEPRIVATION, whether overall, or specifically of active or deep sleep, shows REBOUND, implying a specific function for each type of sleep.
- Comparative studies suggest that quiet sleep is associated with metabolic recuperation, whereas active sleep relates to the ecological niche occupied by the animal.
- Active sleep is associated with learning and memory.
- INSOMNIA is a common sleep problem and can be treated either with drugs or by psychological techniques such as RELAXATION THERAPY, STIMULUS CONTROL THERAPY or CONDITIONING.
- Nightmares and SLEEP APNOEA occur during active sleep, whereas NIGHT TERRORS, SOMNAMBULISM, BRUXISM and ENURESIS occur during stage 4 sleep.

Although one third of our lives is spent in sleep, and very many GP consultations concern sleep difficulties, we still do not know why we sleep, or what is its purpose.

Modern sleep research began when the EEG allowed a clear separation of the STAGES OF SLEEP. The fast, irregular, low voltage waking EEG (Fig. 19.1) suggests the summation of many independent electrical activities, which tend to cancel each other out. With relaxation, particularly if the eyes close, the ALPHA RHYTHM (9–13 Hz) appears. The slower BETA RHYTHM (4–8 Hz) appears during STAGE 1 SLEEP, midway in conscious level between sleep and waking. In STAGE 2, the first stage of true sleep, the EEG shows SLEEP SPINDLES, short bursts of 12–16 Hz activity, and K-COMPLEXES, large negative and then positive swings of voltage. STAGES 3 AND 4, together called DEEP SLEEP, show the slow DELTA WAVES (1–4 Hz) which Grey Walter called the 'billowing waves of sleep'. Stages 1 to 4 reflect progressively deeper sleep (meaning that it is more difficult to wake the sleeper).

After a period of stage 4 sleep, a further stage appears, which is very deep but has an EEG pattern similar to waking, except for the presence of SAWTOOTH WAVES. Since RAPID EYE-MOVEMENTS also occur, this



'ig. **19.1** Typical EEG records of the various stages of sleep. Reproduced with ermission of author and publishers from Hauri P (1982). *Current concepts: The Sleep Disorders*, 2nd edn, Michigan, Upjohn Company Press.

ıge is known as REM SLEEP, or PARADOXICAL SLEEP, because the waking G pattern is at odds with the depth of sleep; it is also known as TIVE SLEEP (AS) and DESYNCHRONIZED SLEEP (D), whereas stages 1 to 4 e known as SLOW-WAVE SLEEP (SWS), QUIET SLEEP (QS), and SYNCHRONIZED ΞEP (S). The sleep stages alternate during the night (Fig. 19.2), ırting by passing through stages 1, 2 and 3 to stage 4 during the st hour and then entering active sleep for about 15 minutes. The st of the night consists of 90 minute long cycles (an ULTRADIAN

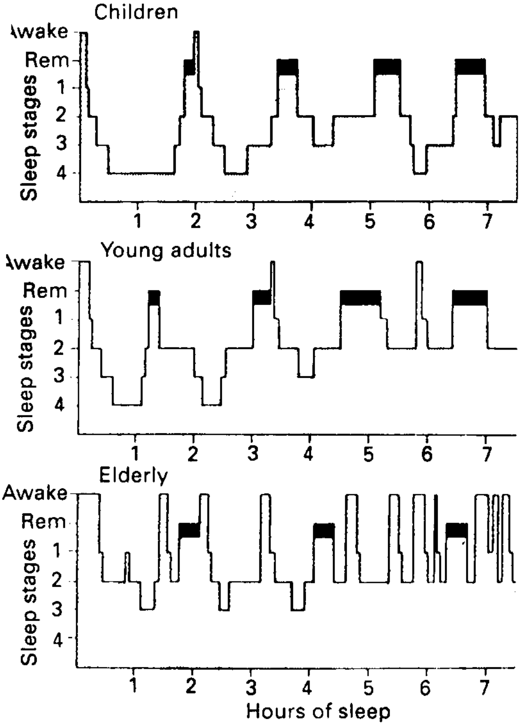


Fig. 19.2 A typical night's sleep in a young child, a young adult, and an elderly person, the ordinate showing the various EEG stages of sleep. Reproduced with permisson from Kales A (1968), Sleep and dreams, *Ann Intern Med*, **68**, 1078–1104

rhythm, faster than the day length), with active sleep increasing and deep sleep lessening through the night.

The sleep–wake cycle is a CIRCADIAN RHYTHM (returning once per day). Although many other biological processes are also circadian (e.g. body temperature falls in the small hours of the night as do serum cortisol levels), they are strictly independent of the sleep–wake cycle, occurring even if one stays awake all night (and perhaps explaining the nadir of performance and the increased weariness at about 4 a.m.). Some endocrine changes are however tightly linked to sleep, the best known being the surge of growth hormone in the first bout of stage 4 sleep (Fig. 19.3); its purpose is not yet known, although it is increased after physical exercise.

Active sleep is very different to quiet sleep. Most obvious are the eye-movements, which are mainly from side-to-side, and appear to be tracking a moving object; by contrast in quiet sleep the eyes gently roll upwards. Persons woken from active sleep report dreams about 80% of the time, compared with after 20% of wakenings from quiet sleep. Active sleep is also associated with flaccid skeletal musculature, erratic respiration and heart-beat, loss of temperature control, and genital engorgement, producing erection in men and clitoral engorgement in women. Quiet sleep shows greater muscle tone, steady respiration, and adequate temperature homeostasis.

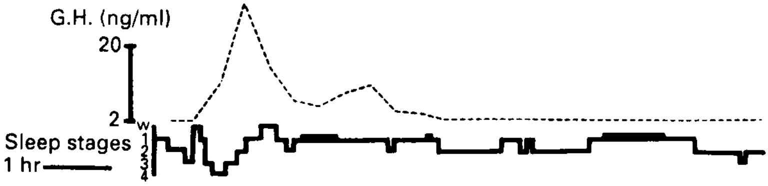


Fig. 19.3 The surge of growth hormone secretion in peripheral blood in relation to slow wave sleep in a young adult. Reproduced with permission from Mendelson W B, Gillin J C and Wyatt R J (1977), *Human sleep and its disorders*, New York, Plenum Press, 68.

Sleep can be manipulated pharmacologically and neurophysiologically. Stimulation of the mainly cholinergic ASCENDING RETICULAR ACTIVATING SYSTEM (ARAS) wakes a sleeping animal, and ARAS lesions induce continuing sleep, as probably occurred in the 1920s epidemic of the viral infection ENCEPHALITIS LETHARGICA. Lesions to the pontine noradrenergic LOCUS COERULEUS affect active sleep without altering quiet sleep, and lesions to the pontine serotoninergic RAPHE NUCLEUS result in permanent cortical desynchronization, and the absence of active *and* quiet sleep. Administration of serotonin, or its precursors, L-tryptophan and 5-hydroxytryptophan, produces increased sleep, and serotonin-depleting drugs such as para-chlorophenylamine, decrease sleep. Cholinergic agonists increase the proportion of active sleep, and shorten the ultradian AS-QS cycle, whereas antagonists have the opposite effect.

The amount and type of sleep varies within individuals, between individuals, and between species. Infants sleep more than adults, due entirely to an increase in active sleep (typically 9 or 10 hours a day at birth, compared with 2 hours in old age), while the proportion of quiet sleep remains much the same from birth to old age, at about 5 hours per night (see Fig. 19.2). Similarly differences between adults who are long, normal or short sleepers are also entirely due to differences in active sleep. Different mammalian species differ enormously both in the amount of active sleep and quiet sleep (Fig. 19.4).

Such differences in amount of sleep suggest they have different functions, and raise the whole question of sleep's purpose. That sleep is *necessary*, and acts as a drive-state, is shown by experimental *sleep deprivation*, in which individuals try harder and harder to sleep (and also suffer many perceptual and other symptoms), particularly after the second night of deprivation, when two or three-second long MICRO-SLEEPS start to interfere with other tasks. After deprivation there is also several days of increased sleep, a REBOUND PHENOMENON. If subjects are connected to an EEG then selective deprivation of active sleep is possible, by waking whenever active sleep starts; subjects are more agitated and impulsive the next day, but otherwise show few symp-

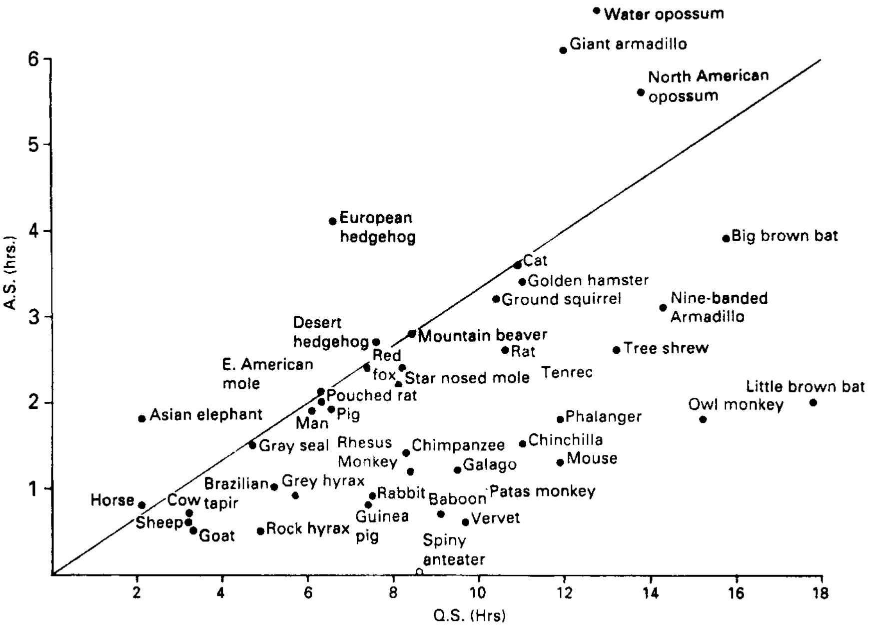


Fig. 19.4 Estimates of hours per day spent in quiet sleep (QS) and active sleep (AS) for a large number of mammalian species. Reproduced with permission from Meddis R (1979), in Oakley D A and Plotkin H C, *Brain, Behaviour and Evolution*, London, Methuen, 99–125.

toms, although the rebound after deprivation suggests a specific need for active sleep. Total quiet sleep deprivation is not technically possible, although *deep* sleep deprivation is possibly by sounding a buzzer whenever stage 3 or 4 sleep is entered; vague physical symptoms are reported, but with little distress, although again post-deprivation rebound occurs.

There are three broad types of theory for sleep's purpose: that it is a PASSIVE OR RECUPERATIVE process; that it has a BIOLOGICAL or ETHOLOGICAL function; and that it has a PSYCHOLOGICAL function. These all overlap to some extent.

The oldest theories, which still have much support, are RECUPERATIVE THEORIES, which say that just as after physical activity a period of rest is needed to allow muscle metabolism to return to normal, so after nervous activity the brain also needs to recover. An immediate objection to the theory is that physiological recuperative processes do not take eight hours to occur; and neither does it say why sleep occurs at night, rather than immediately after 'neural exercise'. Partial supportive evidence comes from observations that mitotic rate and protein synthesis are highest during sleep, suggesting that cellular recovery may indeed be occurring, although these activities are linked to circadian rhythms rather than sleep rhythms.

PASSIVE THEORIES suggest that sleep occurs when there is nothing better to do, in particular if there is insufficient sensory input to keep the brain aroused. Two observations dispose of this theory. Firstly during SENSORY DEPRIVATION (in a darkened, silent room immersed in water at body temperature) people do not sleep continuously. Secondly, mid-pontine transection in the cat, just in front of the trigeminal nuclei, restricts sensory input to just that from the first two cranial nerves, and yet the brain shows *increased* amounts of waking.

The second group of theories, of a BIOLOGICAL OR ETHOLOGICAL FUNCTION, emphasize the behavioural aspects of sleep. It might be objected that *not doing* anything can hardly be called behaviour, but many important behaviours, such as HABITUATION to a recurring stimulus, or the 'freezing' of a frightened animal, precisely involve doing nothing and are biologically adaptive. Since in active sleep the cortex is apparently as active as during waking, then activity also need not be associated with actual movements.

ETHOLOGICAL THEORIES compare sleep in different species. For this a definition of sleep is necessary: 'a period of prolonged immobility, with raised response thresholds, taking place in a species-specific characteristic site and posture, at a particular phase of the circadian cycle (or in marine animals, the tidal cycle)'. On such a basis, all vertebrates, including fish, show sleep, and sleep can also be found in invertebrates, such as mollusc and insects, and this phylogenetic antiquity emphasizes the biological importance of sleep. Comparative studies (see Fig. 19.4) suggest large inter-species differences in the amount and type of sleep: a horse sleeps for three hours a day while an opossum sleeps nineteen hours each day. The amount of quiet sleep is inversely proportional to the size of an animal, so that a mouse has a lot of quiet sleep and an elephant has only a little. Since metabolic rate and cell turnover is greatest in small animals, this suggests that indeed some cellular recovery process is occurring during quiet sleep. In contrast active sleep is unrelated to body size, but instead relates to an animal's invulnerability to predation, either during the day, while finding food, or at night. One proposed evolutionary function of active sleep is to produce 'active immobility', which increases an organism's chance of survival during times, such as at night, when the risk of predation is greatest, and its best strategy is simply to hide, in a hole in the ground, or in a tree, and keep completely still.

Active and quiet sleep are clearly differentiated in all mammals and birds, but not in reptiles, amphibia and fish. Which is the evolutionary older form of sleep is not clear, since differences in brain structure between genera preclude any direct comparison of EEG wave-forms. Since active sleep is more complex, particularly in its relation to dreaming in man, it has been thought to be evolutionarily more recent, but that view has been challenged on the basis that since active sleep is associated with a loss of temperature regulation, converting the otherwise homoeothermic mammals to poikilotherms, akin to the cold-blooded fish, reptiles and amphibia, then it must be the older form of sleep. Comparative evidence shows that the speed of the AS-QS cycle is inversely proportional to body size (and hence to metabolic rate), elephants having a 124 minute cycle and mice a 12 minute cycle. Since larger animals have a greater thermal capacity they cool less quickly, and therefore can withstand poikilothermy for longer before cooling, and hence have longer bouts of active sleep.

Psychological theories of sleep can be broadly divided into two categories, COGNITIVE THEORIES and PSYCHOANALYTIC THEORIES.

Cognitive theories of sleep derive, like much modern psychological theorizing, from the metaphor of the brain as a computer. Large computer systems with many users accessing many different files from disk and tape commonly used to have a 'down period' during the night when although users could not use the system it was nonetheless very active, carrying out 'housekeeping' functions, such as eliminating unwanted files, checking on users' accounts, cross-referencing between files, etc. By an almost exact analogy, it is suggested that sleep is the time for the brain to carry out housekeeping activities, checking over the day's events and filing memories, cross-referencing events against memories of previous events, etc. On this model, dreaming is explained away as a mere EPIPHENOMENON of cognitive reorganization; an unintended side-effect without functional significance, happening, by accident, to impinge upon consciousness. The theory supposes that cognitive reorganization is occurring during active sleep, since cerebral activity is diminished during quiet sleep. The theory is supported by experimental evidence: rats kept in a boring environment have reduced active sleep (but unchanged amounts of quiet sleep), presumably due to less cognitive organization being needed; LATENT LEARNING (see Chapter 3) in which a rat learns by wandering freely around a novel maze in which it will later be tested, is impaired if active sleep is selectively deprived; and in man long and short sleepers differ primarily in the amount of active sleep, and short-sleepers have been called PRE-PROGRAMMERS, while long-sleepers have been called RE-PROGRAMMERS, the former treating the next day much the same day as the previous one, while the latter analyse and reorganize the previous day's experiences in preparation for the next day. In man, experiments also suggest that sleep deprivation can impair the laying down of permanent memories, and that information learnt late in the day is learnt better, because it is closer in time to sleep and hence to cognitive reorganization and reprocessing.

The greatest psychological theory of sleep must surely be Freud's PSYCHOANALYTIC THEORY (see Chapter 11). However in his theory Freud does not say *why* we sleep. His biological training convinced him that sleep was biologically important, although he did not know why. The

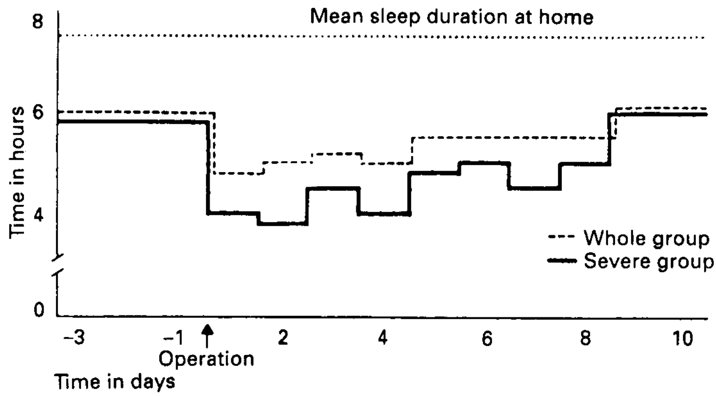


Fig. 19.5 Average duration of sleep in 93 hospitalized patients who were having either major or minor surgery, in comparison with normal average sleep duration when at home. Reproduced with permission from Murphy F, Bentley S, Ellis B W and Dudley H (1977), Sleep deprivation in patients undergoing operation: a factor in the stress of surgery. *Br Med J*, **2**, 1521–2.

role of dreams was to preserve that important sleep: '. . . the dream is an attempt to put aside the disturbance of sleep by means of a wish fulfilment. The dream is the Guardian of Sleep'. To Freud therefore dreams are not just an epiphenomenon, but neither are they the principal purpose of sleep.

Many patients have sleep problems, 30–40% of the population in surveys reporting problems with sleeping, and about 10% of the population at any one time taking tablets to help them sleep. The commonest problem is INSOMNIA, an inability to get to sleep, often coupled with waking during the night or in the early morning. Sometimes it is secondary to problems such as anxiety or depression (see Chapters 28 & 29), or to side-effects of prescribed drugs (such as rebound effects after using minor tranquillizers), or self-prescribed drugs, typically of caffeine in tea, coffee or cola drinks taken during the evening. Insomnia itself causes tiredness and irritability, and then anxiety and depression, which exacerbate the insomnia. Insomnia is common in hospital patients and is a major complaint about hospital services; partly it is due to a strange place, partly to a natural anxiety about illness, and partly to the very many disturbances that can occur such as noises, lights, conversations, etc. It is particularly problematic for patients on intensive and coronary care-units, where lights are on all night, and staff are continually monitoring, changing drips, and sucking out airways. If sleep does indeed assist in bodily recuperation and repair then deprivation in hospital (see Fig. 19.5), particularly after major surgery, should be of great concern.

Acute insomnia is treated effectively with drugs such as the short-acting benzodiazepines which have little HANG-OVER EFFECT the next day.

Barbiturates should not be used at all, both because they are addictive and abused, and because they specifically reduce active sleep. Tolerance develops rapidly to all hypnotic drugs and they should only be used for a few days or weeks at a time, as an immediate solution to an acute problem. If a continuing mild hypnotic is needed then hot milky drinks, such as Ovaltine or Horlicks, are effective at inducing sleep, presumably because of their tryptophan content, and small (but not large) doses of alcohol can also help relax a patient and encourage sleep.

Psychological treatments of insomnia are effective and of particular benefit in chronic problems where drugs have failed. RELAXATION TRAINING takes as a starting point that poor sleepers cannot sleep because they are over-aroused, perhaps due to anxiety. Patients are given RELAXATION TRAINING, either in groups or with the aid of a tape-recorded commentary, such as successive tensing and relaxing of particular muscle groups. Patients use their relaxation sequence on going to bed, and sleep usually follows. STIMULUS CONTROL THERAPY asks what associations the subject has learned to the stimulus of going to bed. If a patient typically reads in bed, listens to the radio, watches television, or even studies, then an association has been learned between bed and *activity*. Bed must be associated only with sleep, and the patient instructed only to go to bed when sleepy and to carry out no activity other than sleeping in the bedroom (with the exception of sexual activity, which probably also has a direct soporific effect); if sleep does not occur within ten minutes of going to bed, then the patient should get up and do something else. During the day naps must be avoided and getting up should occur at a regular time. Controlled trials show such therapy to be effective and lasting. CONDITIONING has also been attempted, by associating the action of a hypnotic drug (the unconditioned response) with the ticking of a metronome (the conditioned stimulus), so that in the future the playing of the metronome at bedtime will itself induce sleep as a conditioned response.

Several abnormal processes can occur during sleep, usually during particular phases. NIGHTMARES are bad dreams, occurring during active sleep, and waking the sleeper suddenly. They are different from NIGHT TERRORS or PAVOR NOCTURNUS which occur during stage 4 of quiet sleep, particularly in children, and are associated with an overwhelming terror or fear, without any specific recall of dream content, or of reasons for the fear. SOMNAMBULISM, or sleep-walking, also occurs during stage 4 sleep, as do HEAD-BANGING, BRUXISM (continual, noisy teeth grinding), and ENURESIS (bed-wetting), all being more common in children and typically 'grown out of'. Enuresis is well treated by behaviour therapy: a detector under the sheet rings an alarm at the first traces of wetness, waking the child before the bladder empties, and associating the sensation of a full bladder with waking and going to the toilet. Active sleep can show problems of homoeostatic regulation, with irregular respiration and heart-beat: SLEEP APNOEA, when breathing ceases, occurs in adults, particularly if they have chronic obstructive airways disease, and in infants, where it is associated with SUDDEN INFANT DEATH SYNDROME (cot-death).