01 - 16.1 Normal Sleep

16.1 Normal Sleep

Normal Sleep and Sleep-Wake Disorders 16.1 Normal Sleep Sleep is one of the most significant of human behaviors, occupying roughly one third of human life. It is a universal behavior that has been demonstrated in every animal species studied, from insects to mammals. Sleep is a process the brain requires for proper functioning. Prolonged sleep deprivation leads to severe physical and cognitive impairment and, eventually, death. Sleep may appear to be a passive process but in fact can be associated with a high degree of brain activation. There are several distinct types of sleep that differ both qualitatively and quantitatively. Each type of sleep has unique characteristics, functional importance, and regulatory mechanisms. Selectively depriving a person of one particular type of sleep produces compensatory rebound when the individual is allowed to sleep ad lib. Sleep is particularly relevant to psychiatry since sleep disturbances can occur in virtually all psychiatric illnesses and are frequently part of the diagnostic criteria for specific disorders. The ancient Greeks ascribed the need for sleep to the god Hypnos (sleep) and his son Morpheus, also a creature of the night, who brought dreams in human forms. Dreams have played an important role in psychoanalysis. Freud believed dreams to be the “royal road to the unconscious.” They have figured prominently in art and literature from ancient times to the present. ELECTROPHYSIOLOGY OF SLEEP Sleep is made up of two physiological states: non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. In NREM sleep, which is composed of stages 1 through 4, most physiological functions are markedly lower than in wakefulness. REM sleep is a qualitatively different kind of sleep, characterized by a high level of brain activity and physiological activity levels similar to those in wakefulness. About 90 minutes after sleep onset, NREM yields to the first REM episode of the night. This REM latency of 90 minutes is a consistent finding in normal adults; shortening of REM latency frequently occurs with such disorders as narcolepsy and depressive disorders. For clinical and research applications, sleep is typically scored in epochs of 30 seconds, with stages of sleep defined by the visual scoring of three parameters: electroencephalogram (EEG), electro-oculogram (EOG), and electromyogram (EMG) recorded beneath the chin. The EEG records the rapid conjugate eye movements that are the identifying feature of the sleep state (no or few rapid eye movements occur in NREM sleep); the EEG pattern consists of low-voltage, random, fast activity with sawtooth waves (Fig. 16.1-1); the EMG shows a marked reduction in muscle tone. The

criteria defined by Allan Rechtschaffen and Anthony Kales in 1968 are accepted in clinical practice and for research around the world (Table 16.1-1). FIGURE 16.1-1 Electroencephalogram patterns for stages of human sleep and wakefulness. REM, rapid eye movement. (From Butkov N. Atlas of Clinical Polysomnography. Medford, OR: Synapse Media; 1996, with permission.) Table 16.1-1 Stages of Sleep—Electrophysiological Criteria

In normal persons, NREM sleep is a peaceful state relative to waking. The pulse rate is typically slowed five to ten beats a minute below the level of restful waking and is very regular. Respiration is similarly affected, and blood pressure also tends to be low, with few minute-to-minute variations. The body musculature resting muscle potential is lower in REM sleep than in a waking state. Episodic, involuntary body movements are present in NREM sleep. There are few, if any, REMs and seldom do any penile erections occur in men. Blood flow through most tissues, including cerebral blood flow, is slightly reduced. The deepest portions of NREM sleep—stages 3 and 4—are sometimes associated with unusual arousal characteristics. When persons are aroused 30 minutes to 1 hour after sleep onset—usually in slow-wave sleep—they are disoriented, and their thinking is disorganized. Brief arousals from slow-wave sleep are also associated with amnesia for events that occur during the arousal. The disorganization during arousal from stage 3 or stage 4 may result in specific problems, including enuresis, somnambulism, and stage 4 nightmares or night terrors. Polygraphic measures during REM sleep show irregular patterns, sometimes close to aroused waking patterns. Otherwise, if researchers were unaware of the behavioral stage and happened to be recording a variety of physiological measures (aside from muscle tone) during REM periods, they undoubtedly would conclude that the person or animal they were studying was in an active waking state. Because of this observation, REM sleep has also been termed paradoxical sleep. Pulse, respiration, and blood pressure in humans are all high during REM sleep—much higher than during NREM sleep and often higher than during waking. Even more striking than the level or rate is the variability from minute to minute. Brain oxygen use increases during REM sleep. The ventilatory response to increased levels of carbon dioxide (CO2) is depressed during REM sleep, so that no increase in tidal volume occurs as the partial pressure of carbon dioxide (PCO2) increases. Thermoregulation is altered during REM sleep. In contrast to the homoeothermic condition of temperature regulation during wakefulness or NREM sleep, a poikilothermic condition (a state in which animal temperature varies with the

changes in the temperature of the surrounding medium) prevails during REM sleep. Poikilothermia, which is characteristic of reptiles, results in a failure to respond to changes in ambient temperature with shivering or sweating, whichever is appropriate to maintaining body temperature. Almost every REM period in men is accompanied by a partial or full penile erection. This finding is clinically significant in evaluating the cause of impotence; the nocturnal penile tumescence study is one of the most commonly requested sleep laboratory tests. Another physiological change that occurs during REM sleep is the near-total paralysis of the skeletal (postural) muscles. Because of this motor inhibition, body movement is absent during REM sleep. Probably the most distinctive feature of REM sleep is dreaming. Persons awakened during REM sleep frequently (60 to 90 percent of the time) report that they had been dreaming. Dreams during REM sleep are typically abstract and surreal. Dreaming does occur during NREM sleep, but it is typically lucid and purposeful. The cyclical nature of sleep is regular and reliable; a REM period occurs about every 90 to 100 minutes during the night (Fig. 16.1-2). The first REM period tends to be the shortest, usually lasting less than 10 minutes; later REM periods may last 15 to 40 minutes each. Most REM periods occur in the last third of the night, whereas most stage 4 sleep occurs in the first third of the night. FIGURE 16.1-2 Sleep pattern in a young, healthy subject. REM, rapid eye movement. (From Gillian JC, Seifritz E, Zoltoltoski RK, Salin-Pascual RJ. Basic science of sleep. In: Sadock BJ, Sadock VA, eds. Kaplan & Sadock’s Comprehensive Textbook of Psychiatry. 7th ed. Vol. 1. Philadelphia: Lippincott Williams & Wilkins; 2000:199, with permission.) These sleep patterns change over a person’s life span. In the neonatal period, REM sleep represents more than 50 percent of total sleep time, and the EEG pattern moves from the alert state directly to the REM state without going through stages 1 through 4. Newborns sleep about 16 hours a day, with brief periods of wakefulness. By 4 months of age, the pattern shifts so that the total percentage of REM sleep drops to less than 40 percent, and entry into sleep occurs with an initial period of NREM sleep. By young adulthood, the distribution of sleep stages is as follows: NREM (75 percent) Stage 1: 5 percent

Stage 2: 45 percent Stage 3: 12 percent Stage 4: 13 percent REM (25 percent) This distribution remains relatively constant into old age, although a reduction occurs in both slow-wave sleep and REM sleep in older persons. SLEEP REGULATION Most researchers think that there is not one simple sleep control center but a small number of interconnecting systems or centers that are located chiefly in the brainstem and that mutually activate and inhibit one another. Many studies also support the role of serotonin in sleep regulation. Prevention of serotonin synthesis or destruction of the dorsal raphe nucleus of the brainstem, which contains nearly all the brain’s serotonergic cell bodies, reduces sleep for a considerable time. Synthesis and release of serotonin by serotonergic neurons are influenced by the availability of amino acid precursors of this neurotransmitter, such as L-tryptophan. Ingestion of large amounts of L-tryptophan (1 to 15 g) reduces sleep latency and nocturnal awakenings. Conversely, L-tryptophan deficiency is associated with less time spent in REM sleep. Norepinephrine-containing neurons with cell bodies located in the locus ceruleus play an important role in controlling normal sleep patterns. Drugs and manipulations that increase the firing of these noradrenergic neurons markedly reduce REM sleep (REM-off neurons) and increase wakefulness. In humans with implanted electrodes (for the control of spasticity), electrical stimulation of the locus ceruleus profoundly disrupts all sleep parameters. Brain acetylcholine is also involved in sleep, particularly in the production of REM sleep. In animal studies, the injection of cholinergic-muscarinic agonists into pontine reticular formation neurons (REM-on neurons) results in a shift from wakefulness to REM sleep. Disturbances in central cholinergic activity are associated with the sleep changes observed in major depressive disorder. Compared with healthy persons and nondepressed psychiatric controls, patients who are depressed have marked disruptions of REM sleep patterns. These disruptions include shortened REM latency (60 minutes or less), an increased percentage of REM sleep, and a shift in REM distribution from the last half to the first half of the night. Administration of a muscarinic agonist, such as arecoline, to depressed patients during the first or second NREM period results in a rapid onset of REM sleep. Depression can be associated with an underlying supersensitivity to acetylcholine. Drugs that reduce REM sleep, such as antidepressants, produce beneficial effects in depression. Indeed, about half the patients with major depressive disorder experience temporary improvement when they are deprived of sleep or when sleep is restricted. Conversely, reserpine (Serpasil), one of the few drugs that increase REM sleep, also produces depression. Patients with dementia of the Alzheimer’s type have sleep disturbances characterized by reduced REM and slow-wave sleep. The

loss of cholinergic neurons in the basal forebrain has been implicated as the cause of these changes. Melatonin secretion from the pineal gland is inhibited by bright light, so the lowest serum melatonin concentrations occur during the day. The suprachiasmatic nucleus of the hypothalamus may act as the anatomical site of a circadian pacemaker that regulates melatonin secretion and the entrainment of the brain to a 24-hour sleep-wake cycle. Evidence shows that dopamine has an alerting effect. Drugs that increase dopamine concentrations in the brain tend to produce arousal and wakefulness. In contrast, dopamine blockers, such as pimozide (Orap) and the phenothiazines, tend to increase sleep time. A hypothesized homeostatic drive to sleep, perhaps in the form of an endogenous substance—process S—may accumulate during wakefulness and act to induce sleep. Another compound—process C—may act as a regulator of body temperature and sleep duration. FUNCTIONS OF SLEEP The functions of sleep have been examined in a variety of ways. Most investigators conclude that sleep serves a restorative, homeostatic function and appears to be crucial for normal thermoregulation and energy conservation. As NREM sleep increases after exercise and starvation, this stage may be associated with satisfying metabolic needs. Sleep Deprivation Prolonged periods of sleep deprivation sometimes lead to ego disorganization, hallucinations, and delusions. Depriving persons of REM sleep by awakening them at the beginning of REM cycles increases the number of REM periods and the amount of REM sleep (rebound increase) when they are allowed to sleep without interruption. REM-deprived patients may exhibit irritability and lethargy. In studies with rats, sleep deprivation produces a syndrome that includes a debilitated appearance, skin lesions, increased food intake, weight loss, increased energy expenditure, decreased body temperature, and death. The neuroendocrine changes include increased plasma norepinephrine and decreased plasma thyroxine levels. Sleep Requirements Some persons are normally short sleepers who require fewer than 6 hours of sleep each night to function adequately. Long sleepers are those who sleep more than 9 hours each night to function adequately. Long sleepers have more REM periods and more rapid eye movements within each period (known as REM density) than short sleepers. These movements are sometimes considered a measure of the intensity of REM sleep and are related to the vividness of dreaming. Short sleepers are generally efficient, ambitious, socially adept, and content. Long sleepers tend to be mildly depressed, anxious, and socially withdrawn. Sleep needs increase with physical work, exercise, illness, pregnancy, general mental stress, and increased mental activity. REM periods increase

after strong psychological stimuli, such as difficult learning situations and stress, and after the use of chemicals or drugs that decrease brain catecholamines. Sleep-Wake Rhythm Without external clues, the natural body clock follows a 25-hour cycle. The influence of external factors—such as the light-dark cycle, daily routines, meal periods, and other external synchronizers—entrain persons to the 24-hour clock. Sleep is also influenced by biological rhythms. Within a 24-hour period, adults sleep once, sometimes twice. This rhythm is not present at birth but develops over the first 2 years of life. Some women exhibit sleep pattern changes during the phases of the menstrual cycle. Naps taken at different times of the day differ greatly in their proportions of REM and NREM sleep. In a normal nighttime sleeper, a nap taken in the morning or at noon includes a great deal of REM sleep, whereas a nap taken in the afternoon or the early evening has much less REM sleep. A circadian cycle apparently affects the tendency to have REM sleep. Sleep patterns are not physiologically the same when persons sleep in the daytime or during the time when they are accustomed to being awake; the psychological and behavioral effects of sleep differ as well. In a world of industry and communications that often functions 24 hours a day, these interactions are becoming increasingly significant. Even in persons who work at night, interference with the various rhythms can produce problems. The best-known example is jet lag, in which, after flying east to west, persons try to convince their bodies to go to sleep at a time that is out of phase with some body cycles. Most persons adapt within a few days, but some require more time. Conditions in these persons’ bodies apparently involve long-term cycle disruption and interference.

REFERENCES

Barclay NL, Gregory AM. Quantitative genetic research on sleep: A review of normal sleep, sleep disturbances and associated emotional, behavioural, and health-related difficulties. Sleep Med Rev. 2013;17(1):29–40. Benca RM, Cirelli C, Rattenborg NC, Tononi G. Basic science of sleep. In: Sadock BJ, Sadock VA, eds. Kaplan & Sadock’s Comprehensive Textbook of Psychiatry. 8th ed. Vol. 1. Philadelphia: Lippincott Williams & Wilkins; 2005:280. Genderson MR, Rana BK, Panizzon MS, Grant

MD, Toomey R, Jacobson KC, Xian H, Cronin-Golomb A, Franz CE, Kremen WS, Lyons MJ. Genetic and environmental influences on sleep quality in middle-aged men: A twin study. J Sleep Res. 2013;22(5):519–526. Gillin JC, Seifritz E, Zoltoski RK, Salin-Pascual R. Basic science of sleep. In: Sadock BJ, Sadock VA, eds. Kaplan & Sadock's Comprehensive Textbook of Psychiatry. 7th ed. Vol. 1. Philadelphia: Lippincott Williams & Wilkins; 2000:199. Jenni OG. How much sleep is "normal" in children and adolescents? Normal sleep duration in children and adolescents. JAMA Pediatr. 2013;167(1):91–92. Potts KJ, Butterfield DT, Sims P, Henderson M, Shames CB. Cost savings associated with an education campaign on the diagnosis and management of sleep-disordered breathing: A retrospective, claims-based US study. Popul Health Manag. 2013;16(1):7–13. Richardson GS. The human circadian system in normal and disordered sleep. J Clin Psychiatry. 2005;66(Suppl 9):3–9. Rosipal R, Lewandowski A, Dorffner G. In search of objective components for sleep quality indexing in normal sleep. Biol Psychology. 2013;94(1):210–220.

Revision #1
Created 2026-01-04 19:51:04 UTC by Omar Ayman
Updated 2026-01-04 19:51:04 UTC by Omar Ayman