CHAPTER TWENTY-FIVE

SLEEP AND DREAMING

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Introduction

The majority of our behavioral and cognitive lives are spent in the waking state — a time during which activities viewed as essential to personal existence and continuation of the species are accomplished. It is therefore to be expected that for many the waking state is likely to be considered “the sole portion of ... existence that ‘counts’ in any way, sleep appearing as ‘time out’ from the game of living” (Kleitman 1963, p. 3). However, although sleep may appear to constitute an interruption of the critical activities of wakefulness, it is indisputable that the alternation between sleep and wakefulness is essential to “normal” existence in all higher life forms. The importance of sleep to normal waking activities can be immediately appreciated when the well-documented adverse effects of sleep reduction on waking behavioral and psychological functions are considered — effects extending from decreased alertness and impaired performance (Gillberg & Åkerstedt 1994; Monk 1991) to death (Bentivoglio & Grassi-Zucconi 1997; Eversen 1995; Horne 1988). Clearly, these two states interact in a complementary and synergistic relationship to maintain and extend life. Although the precise nature of this co-dependence has, to a great extent, been obscured by a lack of detailed knowledge regarding the physiology and psychology of sleep, recent advances in these areas have provided significant insights into these puzzling within- and between-state variations and relationships.

It is at the same time surprising and revealing that sleep should support any form of cognitive activity — surprising since at first glance it is difficult to imagine the purpose of mental activity during such sustained periods of disengagement from the environment, and revealing because of the unexpected psychophysiological relationships the presence of such activity implies. Still, if concepts subscribing to the interaction or psychophysiological parallelism of mind—body relationships are even closely approximated, then it would be expected that the marked behavioral and physiological sleep—wakefulness differences would be reflected in equally marked differences in the characteristics of associated cognitive activity. In this instance, state-dependent expectations are apparently reinforced: unlike the generally more organized, rational, self-directed nature of waking cognition, cognitive activity during sleep is seemingly disorganized, distorted, and subject to little volitional control. This distinctive cognitive behavior — not associated with an abnormal state or condition, yet so apparently different from waking mental activity — has been provided with an appropriately distinctive name: dreaming.

Historical Background

The relative inaccessibility of processes underlying sleep and dreaming fostered wide-ranging speculation regarding the nature and function of these activities. Early theories attributed sleep to various changes in the distribution, temperature, or constitution of blood, and many considered the difference between sleep and death simply a matter of degree (Kleitman 1963; Nitz 1993). Later concepts extending into the early twentieth century localized sleep to the brain and ascribed many functions to this state, including enhancing digestion, creating new “animal spirits” required for waking behavior, and eliminating potentially harmful “humors” from the body (Wittern 1989). Paralleling these notions were beliefs that dreams contained messages foretelling the future, revealed cures for illnesses, or provided unique access to the unconscious (Kramer 1994; Webb 1993). These various conceptualizations had in common a view of sleep as a unimodal state and dreams as sporadic, relatively rare events.

Although sleep and dreaming have long been sources of fascination and speculation, scientific interest in these
behaviors significantly intensified in the twentieth century. In the second edition of his classic text summarizing information regarding sleep and wakefulness, Kleitman (1963) listed over 4,000 references, of which less than 2% referred to publications before the twentieth century. However, the most marked acceleration of experimental studies into the nature of sleep physiology and psychology can be traced to the mid-twentieth century, when Eugene Aserinsky, a physiology doctoral student at the University of Chicago, observed episodes of eye movement activity during sleep in what were the first whole-night polygraphic recordings of such activities (Aserinsky 1953). Although he observed they were slower than waking eye movements of comparable amplitude and was more impressed with their "jerkiness" than their velocity, Aserinsky nevertheless elected to characterize this as "rapid eye movement" or REM activity, in large part to avoid "the anticipated taunts relative to the popular slang meaning of 'jerk'" (Aserinsky 1996, p. 218).

This observation – utilizing a newly emerging technology that made possible long-term recordings of electrophysiological activities – led to a series of publications that revolutionized and redirected thinking regarding both the nature of sleep and the occurrence of dreaming (Aserinsky & Kleitman 1953, 1955; Dement 1955; Dement & Kleitman 1957a,b; Dement & Wolpert 1958a,b). The finding of recurring episodes of physiological activation embedded within sleep that were unlike either wakefulness or the remainder of sleep flew in the face of existing concepts of sleep as a unitary, passive state. So unique were these rapid eye movement periods that they prompted investigators to consider REM sleep as a third state of existence (Dement 1969; Snyder 1966; Steriade & McCarley 1990). Not only did these REM periods deviate in their physiological characteristics from other normal states, but upon awakening from these episodes subjects commonly reported dreaming, suggesting that an objective index had been identified for determining "the incidence and duration of periods of dreaming" (Aserinsky & Kleitman 1953, p. 274).

Although electrographic recordings of brain wave and oculomotor activities assisted in the discovery of REM sleep and its association with dreaming, these observations did not require such technological assistance. Determination of whether an individual is asleep can be made subjectively with reasonable reliability, and movements of the eyes are readily apparent from associated displacements of the corneal bulge under the eyelids. Furthermore, because of the prominence of visual images in dream reports, it had long been speculated that dreams would be accompanied by eye movements (Griesinger 1868; Ladd 1892). Given such considerations, why hadn't these remarkable periods of physiological and cognitive activation – which occur nightly, are distributed across the night, and which may last 20 minutes or longer – been previously discovered? In a publication in which he chronicled the discovery of REM sleep, Aserinsky (1996) considered this question as follows:

The obvious answer must lie in human behavior. Since the first REM period is not obvious during the first couple of hours of sleep, and cyclicity would require a still longer period of observation, the discovery of REM would have required an obsessive, highly motivated individual to peer continually for hours at a sleeper's eyes. This would explain the failure of the layman to discover REM, but what about scientists who are infamous for both obsessiveness and motivation, and thus should have looked for the eye movements? My guess is that no one was sufficiently driven to spend an inordinate amount of time to fill in the gaps of sleep studies in which the position of the eyes was noted by occasional lifting of the sleeper's eyes. (pp. 226–7)

The technological capability of recording physiological measures over long periods of time may not have been required for the discovery of REM sleep, but it was essential for the subsequent exploration and detailing of the general physiology of sleep. Although Aserinsky (1996) considered the relationship of rapid eye movements in sleep to dreaming as “almost incidental with respect to its import in understanding brain function” (p. 226), it was the linkage of sleep-state physiology to sleep-state cognitive activity that provided the major impetus for the next two decades of sleep and dream research and established the foundation for what could be considered the "new sleep research." Furthermore, this focus on psychophysiological relationships during sleep presented an opportunity to determine if such relationships are maintained across states and, consequently, to provide a broader understanding of mind–body relationships. Even before specific physiological sleep–wakefulness differences were determined, it was apparent that these states differed along significant dimensions, among which was the profound change in level of consciousness. Relative to wakefulness, there is a dramatic decrease in awareness of both the external and internal physical environments during sleep, as reflected by increased sensory thresholds to external and internal stimulation as well as by an absence of appreciation of significant physiological variations, such as galvanic skin response activation during slow-wave sleep or breathing cessation associated with sleep apnea (Guilleminault 1994; Johnson 1973). With few exceptions (e.g., lucid dreaming), this decrease in awareness is accompanied by a general loss of volitional control over physiological and psychological processes. The relative inaccessibility of sleep processes, together with the associated greatly diminished awareness and control, created both real and apparent obstacles to the scientific study of these behaviors. Still, the very factors that complicated the study of these processes also removed or attenuated potentially confounding variables commonly associated with investigations during wakefulness – for example, stress, expectations, and undefined variations in
level of arousal – raising the possibility that relationships either obscured by or absent during wakefulness would be unmasked during sleep.

**Physical Context**

Questions concerning why and how wakefulness–sleep state alternations occur have motivated speculation and inquiry into the mechanisms of these variations. Early views of sleep – as the passive behavioral default that results when wakefulness-maintaining activities from specific sensory (Bremer 1937, 1938) or nonspecific brainstem reticular pathways (Moruzzi & Magoun 1949) were withdrawn – had to be modified to incorporate evidence of active sleep-promoting processes. This evidence was provided by brainstem and cortical stimulation and lesion studies (reviewed in Jones 1994; Steriade & McCarley 1990) as well as by indications of active control processes effecting and modulating sleep, such as recurring periods of activated (REM) sleep and predictable sleep pattern variations across the night (i.e., the sleep cycle). The separation of sleep-promoting mechanisms into passive and active categories provided a conceptual framework within which studies could be formulated and interpreted. However, technological advances permitting more discerning anatomical and neurophysiological evaluations of systems and processes underlying sleep and waking behavior made it apparent that the passive–active dichotomy was too simplistic, and that sleep initiation and maintenance most likely involved cascading effects and interactions resulting from both the passive effects of functional deafferentation and the activation of structures with hypnogenic properties. The search for specific brain regions or centers whose activation might be essential to the occurrence or promotion of sleep identified several candidates: the solitary tract nucleus in the medulla, the preoptic basal forebrain area, the anterior hypothalamus, and the brain stem raphe nuclei for non–rapid eye movement (NREM) sleep; and the pons for REM sleep (see Jones 1994; Steriade & McCarley 1990).

Paralleling and complementing these studies were those capitalizing on developments in the detection and localization of biochemistry in the peripheral and central nervous systems and exploring how these compounds were related to state determination. Although the notion of a chemical hypnogenic factor had been hypothesized early in the twentieth century (Pieron 1913), the technology necessary to effectively pursue this line of inquiry was not available until the 1950s and 1960s; since that time, this technology has become increasingly sensitive and sophisticated. Studies using these techniques have implicated interactions among a wide range of chemicals that exert sleep- or wakefulness-promoting influences and have reinforced those focused on anatomical or neurophysiological aspects of sleep in demonstrating the complexity of systems involved in determining states of sleep and wakefulness. These compounds – produced centrally and peripherally as neurotransmitters, neuromodulators, or neurohormones – have been variously localized to neurons, cerebrospinal fluid, and blood (for reviews see Jones 1994; Krueger & Karnovsky 1995; Steriade & McCarley 1990). These quests for sleep centers and chemical sleep factors have proven to be highly informative and heuristically beneficial, and the outcomes of these studies have been summarized as follows: "no sleep or wake state in toto can be said to have a center and ... few, if any, components of waking–sleep states have 'a center'" (Steriade & McCarley 1990, p. 21); and "no single chemical neurotransmitter, neuromodulator, or neurohormone has been identified that is necessary or sufficient for the generation and maintenance of sleep or waking. Instead, multiple factors and systems are involved in the onset and maintenance of these states" (Jones 1994, p. 157). The idea of distributed and interacting systems is being increasingly utilized in theoretical formulations integrating neuronal and neurochemical processes that attempt to explain state determination (Krueger et al. 1995; McCarley & Hobson 1975). Ultimately, understanding the mechanisms responsible for state determination and the relationship of these mechanisms to behavior will provide insights into the function of sleep – an enigma that continues to elude resolution (Rechtschaffen 1998).

**Social Context**

It requires little reflection to appreciate that the results of scientific investigations may be unintentionally influenced by such aspects of the experimental process as the laboratory environment, measurement apparatus, experimental demands, and the presence of investigators. These factors may exert what have been termed “reactive measurement effects” (Campbell 1957) on study outcome measures. Recognizing that the sleeping environment, sleep behavior, and associated personal thoughts (dreams) of individuals are usually considered among the most private of behavioral domains, attempts to study these behaviors would seem to require obtrusive intervention and present multiple opportunities for reactive measurement effects. In attempts to control for or at least minimize such effects, investigators have applied several techniques or procedures. For example, in addition to assuring subject confidentiality with respect to study results, it has proven helpful to introduce subjects to the laboratory environment, procedures, and personnel prior to undertaking sleep recordings. Still, in view of the apparent intrusiveness of procedures necessary to evaluate sleep physiology, statements referring to such procedures as “noninvasive” and “minimally sleep disturbing” would seem to underestimate the sleep disturbance expected under these conditions. However, studies of sleep in populations across the pediatric to geriatric age range during the past 45 years have clearly established
that most subjects can, and do, sleep well under these circumstances. Commonly, the initial nights in the laboratory are accompanied by sleep disturbance in the form of increased latencies to sleep onset, more body movements, and fragmentation of sleep patterns. Since sleep patterns normally stabilize subsequent to this initial period, these variations have been considered to be transient responses to the novel sleeping environment and instrumentation. This adaptation phenomenon has been termed the “first night effect” (Agniew, Webb, & Williams 1966). Once adaptation has occurred, the night-to-night stability of many sleep measures is remarkable. This consistency is expressed across several variables, including the amounts and cyclic characteristics of sleep stages (see Figure 3 in the next section), autonomic measures (heart rate and variability—Pivik et al. 1996; see Figures 5 and 6), and specific electrographic events (K-complexes—Johnson 1973; ponto-geniculo-occipital spike activity—Jouvet 1972). The development of portable instrumentation to record physiological parameters necessary for sleep-wakefulness differentiation and sleep staging has allowed the comparison of results from recordings made in subjects’ home environments with those obtained from the same subjects studied in the laboratory. That such comparisons have revealed minimal between-condition differences (Sewitch & Kupfer 1985) attests to the general robustness of sleep processes and the adaptability of subjects.

Concerns regarding the influence of experimental factors on sleep mentation reports have focused on (i) possible confabulation by subjects in the interest of pleasing the investigator and (ii) the extent to which the laboratory environment may directly affect the content in these reports. The potential for experimental confounds due to confabulation is always of concern in situations where other procedures (e.g., physiological or performance indices) cannot be used as corroborative measures. This issue, of long-standing concern to investigators studying sleep mentation, was effectively addressed by Rechtschaffen (1967) in a series of logical considerations to be used as guidelines for evaluating the acceptance of such reports as true representations of sleep experiences. These guidelines are briefly summarized as follows (Pivik 1986, p. 393).

1. Parsimony — interpretations requiring the fewest assumptions are favored.
2. Prevalence — phenomena known to occur most frequently are favored over those of rare occurrence. For example, in the absence of indications of impaired memory in the recall processes in wakefulness, the subject’s postarousal report is accepted as a valid representation of his or her experience, rather than questioned on the grounds of cognitive impairment.
3. Plausibility — an extension of the prevalence guideline, which, however, “gives special emphasis to frequency and occurrence in given situations” (Rechtschaffen 1967, p. 7). For example, although it could be assumed that subjects are lying when questioned about the presence and details of dream experiences, on the basis of current understanding of the motivational factors promoting lying, one would consider it unlikely that subjects would lie so consistently about dream reports.

4. Private experience — in the absence of objective indices, there is a strong tendency to accept the existence of phenomena if they have been part of one’s own experience.

As might be expected, elements of the experimental environment or procedures may be incorporated into dream reports (Domhoff & Kamiya 1964; Okuma, Fukuma, & Kobayashi 1976). Although some content differences may exist between dreams collected at home and those collected in the laboratory (Lloyd & Cartwright 1995; Weisz & Foulkes 1970), these differences are minor. A more significant issue relates to whether dreams collected in the laboratory are so influenced by the experimental conditions that they provide an unfaithful representation of the subject’s dream life — depicting it as more mundane, realistically oriented, or coherent than it may be (Dorus, Dorus, & Rechtschaffen 1971; Snyder 1970). The studies just cited indicating content similarities between home and laboratory dreams (when collected under similar sampling conditions) suggest that reports collected in the laboratory do not provide an unrepresentative view of dream content and processes. Furthermore, it has been argued (Foulkes & Cavallerio 1993) that spontaneous recall of dreams in the home environment may, in fact, present an atypical view of dream content because laboratory dreams are better sampled and home dreams that are remembered may be so because of bizarre, emotional, or vivid characteristics.

Inferential Context

Every area of scientific endeavor is confronted with unique methodological challenges, but for sleep research the usual challenges — such as satisfying criteria fundamental to the reliable and valid measurement of physiological and cognitive processes — are compounded by the need to obtain these measures from the sleeping organism while maintaining state integrity and continuity. This state maintenance is, and continues to be, critical to the recognition of physiological indices that may be used as more discrete and objective correlates of sleep behaviors and also to the valid assignment of behaviors to their proper state domain.

In this regard, it is instructive to consider how demand characteristics differ between studies conducted during wakefulness and sleep, the methodological challenges these differences create, and how some of these challenges have been resolved. During waking investigations, which generally extend for a few minutes up to perhaps two hours, subjects are aware of transducers attached to their bodies and can comply with instructions to avoid or minimize behaviors (such as body movements and eye
blinks) that might compromise the quality of the recordings. By comparison, sleep recordings normally last at least 6–8 hours, and sleeping subjects do not have volitional control over biological sources of artifact, such as the frequent adjustments in body position that take place during the course of a normal night of sleep (Altschuler & Brebbia 1967; DeKoninck, Lorrain, & Gagnon 1992; Kleitman 1963). Accordingly, it was necessary to develop procedures to more securely attach transducers for reliable recordings over these extended periods of time, and it has often been necessary to design special devices or techniques to access measures of interest while minimizing sleep disturbance. For example, electrodes used to record the electro-oculogram (EOG) also detect brain waves or electroencephalographic (EEG) signals (see Figures 1 and 2, S1–S4), and to obtain eye movement recordings not contaminated by these signals required transducers that could be applied to the eyelids to register mechanical movements of the eye (Baldrige, Whitman, & Kramer 1963; Gross, Byrne, & Fisher 1963). Although such cross-talk is diminished when low-amplitude, fast-frequency EEG activity predominates (e.g., during waking and REM sleep) and does not generally compromise state identification, even at these times EEG events may influence EOG recordings.
(Iacono & Lykken 1981) and EOG events may influence EEG recordings (see Chapters 2 and 3 of this volume). In order to investigate variations in spinal monosynaptic reflex activity recorded from leg musculature, a method of leg restraint was devised that maintains the positions of stimulating and recording electrodes without altering reflex responses or disturbing sleep as a result of excessive restraint (Mercier & Pivik 1983; Pivik 1971; Pivik & Dement 1970). A variety of devices that can be comfortably inserted into the external auditory canal have been developed for: controlling stimulus delivery in sleep auditory arousal threshold (Busby, Mercier, & Pivik 1994) or evoked potential (Campbell & Bartoli 1986) studies; providing measures of middle ear muscle activity by converting changes in sound pressure level to variations in impedance (Pessa & Roffwarg 1972); and measuring core body temperature by means of a thermistor positioned near the eardrum (Palca, Walker, & Berger 1981). In addition to these examples, the field of sleep disorders medicine has developed many novel approaches to assess physiological functioning during sleep (see Kryger, Roth, & Dement 1994).

The amount of data collected in even the most fundamental of sleep studies using electrographic techniques is formidable. Over an 8-hr period, a single channel of EEG recording (at the recommended paper speed of 10 mm/sec) will trace a trail on paper extending 0.2 miles or, if digitized, will require approximately 25 megabytes of computer storage space. When it is considered that multiple channels of physiological information are commonly recorded for 2–5 nights, the magnitude of the associated information acquisition, processing, and storage requirements can be appreciated. Increasingly, sleep investigations are utilizing
new developments in computer technology that make these challenges more manageable and greatly facilitate associated data analysis (Armitage 1995a; Kubicki & Herrmann 1996). Examples of the application of computerized methods of analysis to an autonomic measure (heart rate) and EEG are presented in the next section in Figures 4–6 and 7–8, respectively.

The organizing principle which imposed meaning on these extensive data (and which was key to the recognition of REM sleep as a discrete entity) involved discerning and clustering patterns of activity into larger blocks of behavior termed "states and stages." These concepts, often loosely applied, are important to distinguish because of the significantly different implications they carry for the conceptualization and understanding of behavior. In the physical world the difference between states is often quite distinct; for example, the defining state characteristics of H2O when it exists in a liquid, frozen, or gaseous form are clearly evident. In living organisms, however, where behaviors are based on complex interactions among a variety of systems, state definition is often more equivocal and more judgmental. Still, as indicated by the following definitions, even under these more complex conditions there is common agreement regarding criteria for state determination. For instance, a state may be defined as: "a cluster of attributes whose simultaneous and repeated occurrence is highly unique" (Dement & Mitler 1974, p. 278); "a recurring temporally enduring constellation of values of a set of indicator variables of the organism" (Steriade & McCarley 1990, p. 8); or "constellations of functional patterns and physiological variables which may be relatively stable and which seem to repeat themselves" (Prechtl et al. 1968, p. 200). According to these criteria, existence in mammals generally may be partitioned into three states — namely, wakefulness, REM sleep and NREM sleep.

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Figure 3. Sleep profiles depicting variations in sleep stages (ordinate) as a function of time asleep (abscissa). These profiles, based on seven consecutive nights of baseline sleep in a young adult, illustrate the stability of sleep patterns across nights, the presence of patterned oscillations between REM (darkened rectangles) and NREM sleep (i.e., sleep cycle), and the decrease in stage-4 and increase in REM sleep as a function of sleep time within a given night. Reprinted with permission from Pivik 1986, © The Guilford Press.
If a *state* may be likened to the gestalt that emerges from associated, defining attributes, then a *stage* represents the identification of progressive within-state changes in these attributes. These component stages are defined by relatively precise but nevertheless arbitrary criteria. Referring again to the different states H₂O may assume, it is possible to define stages of transition bridging these states as a function, for example, of precise temperature and pressure variations. By analogy, the NREM sleep state in humans has been divided into four stages based on EEG criteria. Although REM sleep has been differentially examined on the basis of the presence or absence of various activities (e.g., eye movements or autonomic activation), further fragmentation of REM sleep into stages has not been proposed.

To arrive at valid and enduring state and stage criteria necessitates the development of an adequate and reliable descriptive database from which such criteria can be derived. The initial set of such criteria for sleep states and stages was proposed within five years of the discovery of REM sleep and the use of all-night polygraphic recordings of sleep electrophysiology (Dement & Kleitman 1957a), but it would be more than another decade before standardized scoring manuals would be developed. These manuals defined criteria for the reliable scoring and interpretation of electrophysiological sleep recordings based on the evaluation of 20–30-sec epochs (Anders, Emde, & Parmelee 1971; Rechtschaffen & Kales 1968), and they provided a reasonable solution for managing the large data sets associated with such studies. The choice of the specific scoring epochs for chunking sleep behavior was not specifically rationalized and did not reflect a validated 20- or 30-second behavioral sleep unit. Instead, it was most likely based on several practical factors, including discriminability of recordings, reduction of an extensive database to more manageable dimensions, and providing the best fit between physiological data and technical parameters of recording instrumentation. It is of historical interest in this regard that the early electrographic recordings of human sleep were conducted using a recorder that every 20 or 30 seconds cut a moving strip of paper on which variations in brain potentials were traced (Loomis, Harvey, & Hobart 1938). A caveat to the use of such relatively long scoring epochs is the resultant smoothing of the dynamic flux of physiological changes that occurs within briefer time intervals, giving the impression that sleep states are played out in a very stable and continuous manner and that state and stage transitions are relatively abrupt.

The extent to which the duration of the scoring epoch contributes to this impression was underscored in an investigation in which 24-hour recordings of sleep in the cat were analyzed using a 3-sec scoring interval (Ferguson et al. 1969). With this procedure it was found that uninterrupted intervals of either wakefulness or NREM sleep were quite brief, about one or two minutes. Briefer scoring intervals have also been applied in humans to provide more precise assessments of variations in normal (Ogilvie & Wilkinson 1984; Pivik, Busby, & Brown 1993) or disruptive physiological processes during sleep (ASDA 1992). However, obtaining information of such temporal precision presents additional data processing and conceptual demands. For example, in terms of data processing, using 3-sec scoring intervals in the 24-hr animal recordings increases the number of individual data samples to be analyzed tenfold (i.e., from 2,880 to 28,800). Focusing on ever briefer intervals also requires valid and reliable scoring criteria for these intervals and, most importantly, raises the question of what is the smallest meaningful unit of sleep behavior that can be practically determined. The feasibility of analyzing extended data sets using more discrete time intervals has been significantly facilitated by computer technology. However, when such technology has been applied to studies of sleep, the convention of reporting computerized results based on 20–30-sec (or longer) intervals has been generally maintained (Armitage 1995b; Itil 1969, 1970; Sussman et al. 1979).

Microepoch analyses of physiological variables during sleep provide a more faithful representation of the actions and interactions of these variables; moreover, the resulting enhanced microstructural view of sleep variables may help resolve questions relating to sleep–wakefulness interactions that remain unanswered. For example, the basis for what constitutes a “refreshing” night of sleep remains undetermined, but there is growing emphasis on sleep continuity as an important contributing factor (Carskadon, Brown, & Dement 1982; Stepanski et al. 1984). In this regard, it has been shown that discrete interruptions of sleep, either spontaneously occurring or resulting from external stimulation, can be associated with enhanced daytime sleepiness and reports of significantly reduced sleep quality, even though these disturbances may not effect a significant reduction in total sleep time (Roehrs et al. 1994; Stepanski et al. 1987).

As new methods of data acquisition and analysis have developed, the descriptive picture of sleep physiology has become increasingly detailed and has provided information relevant to the study of psychophysiological relationships during sleep. Still, accounts of thought processes can be directly accessed or confirmed only by means of verbal communication. Although verbalization may occur during both REM and NREM sleep, intelligent dialog with a sleeping subject has not been initiated or maintained, and attempts to provide subjects with posthypnotic suggestions to relate ongoing mentation without awakening have been unsuccessful (Arkin 1978; Arkin et al. 1970). Inferences can be made about thought processes from nonverbal measures—for example, motor responses (Berger & Oswald 1962b; Dement & Wolpert 1958b; Shimizu & Inoue 1986; see also Chapter 3) or autonomic responses (Hobson, Goldfrank, & Snyder 1965; Laberge, Greenleaf,
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& Kedzierski 1983; see Chapters 6, 8–10, and 20 of this volume). But such inferences are most reliably determined during wakefulness in the context of a controlled experiment and not during sleep, when directional control over subjects’ behavior and associated thought processes is minimal if not absent. Furthermore, although some variation in state can be said to occur when subjects are required to provide a verbal report of immediately preceding experiences, this shift is much greater for the reporting of sleep mentation where a major between-state change must occur (sleep to wakefulness) as compared to the relatively minor within-state change associated with wakeful reports of waking experiences. The more extreme nature of the state change required to access reports of sleep cognition distinguishes studies of sleep mentation from others, which do not feature such marked disparity between the conditions of experience and reporting.

The inability to more directly and immediately access cognitive activity in the sleeping subject, coupled with aspects of sleep physiology that differ remarkably from those commonly associated with cognitive activity during wakefulness, prompted skepticism regarding whether postawakening reports reflected cognitive activity occurring during sleep. Alternative explanations considered included suggestions that the reports reflected hypnopompic experiences generated in the process of waking up (Goblot 1896) or were intentionally contrived in the interest of pleasing the experimenter. Experimental data addressing these concerns will be presented once fundamental attributes of sleep physiology and psychology have been considered.

Sleep Physiology and Psychology: Descriptive Aspects

Nearly two decades before the discovery of REM sleep, Loomis, Harvey, and Hobart (1937, 1938) recorded EEG activity in sleeping subjects and described five sequential brain potential patterns, which they referred to as “stages or states of sleep” (Loomis et al. 1938, p. 421). These patterns (designated A, B, C, D, and E), generally similar across subjects and occurring reliably across recording sessions in the same subjects, were characterized as follows: A, intermittent alpha activity; B, low-voltage potentials (theta); C, the occurrence of 14-Hz spindles; D, spindles in conjunction with 1-Hz delta waves; and E, increased delta activity with less conspicuous spindling (Loomis et al. 1938). It was noted that “during the night of sleep a sleeper continually shifts back and forth from one state to another, either spontaneously or as the result of stimuli” (p. 422). These investigators did not comment on the remarkable implication of their findings that sleep was not the unitary phenomenon it had been traditionally considered to be. It was to be another two decades before a more comprehensive differentiation of EEG patterns during sleep – using numbers instead of letters to designate stage and including the newly discovered state of REM sleep – was presented (Dement & Kleitman 1957a). It was also in the late 1950s that a second fundamental characteristic of sleep was recognized: sleep stage pattern variations across the night are largely predictable from night to night, indicating the existence of a sleep cycle (Dement & Kleitman 1957a; see also Figure 3).

The discovery of REM sleep and the sleep cycle had far-reaching implications for both biological and psychological processes during sleep. Physiologically, in contrast to previous thinking that sleep occurred passively in response to the absence of wakefulness, these findings indicated that sleep was governed by active mechanisms. Furthermore, since the extended time intervals involved in stage and cycle variations could not be explained by short-term neurophysiological processes, it was necessary to invoke neurochemical mechanisms with longer time constants. In terms of concepts of sleep cognition, these discoveries had equally dramatic effects. Now that dreaming could be associated with a physiological state that occurred predictably each night and that (in the adult) normally accounted for one quarter of each night of sleep, beliefs that dreams occurred only sporadically and under special conditions had to be rejected.

Although the scoring criteria in the Dement and Kleitman (1957a) publication provided descriptions of EEG frequency, amplitude, and waveform characteristics associated with sleep stages, an interlaboratory scoring reliability study conducted by Monroe (1969) revealed an unacceptable level of scoring differences across laboratories. Preliminary reports of Monroe’s findings were instrumental in the development of a Manual of Standardized Terminology, Techniques and Scoring for Sleep Stages of Human Subjects (Rechtschaffen & Kales 1968), which presented more precise definitions of sleep states and stages and provided the standardized criteria since used for the recording and reliable analysis of adult human sleep. Figures 1 and 2 provide examples of physiological variations characteristic of sleep and wakefulness as well as within-stage sleep stage differentiations described in that manual. These figures illustrate not only basic measures required for sleep evaluation (EEG, EOG, and EMG; channels A, B, C, and H) but also include optional measures, such as recordings of vertical eye movements (channel D) and autonomic activity (channels E, F, and G). In these tracings, wakefulness (AW and W) is associated with a low-voltage, mixed-frequency EEG that may contain varying amounts of alpha (8–12-Hz) activity. Wakefulness is also usually associated with blinking, rapid eye movements, and variations in the levels of tonic facial EMG activity.

As accurately described 30 years previously (Davis et al. 1938), alpha activity is attenuated in the transition from wakefulness to sleep. There is a concurrent slowing of EEG activity, with an increase in 4–7-Hz theta activity coupled with the sporadic occurrence of vertex sharp
Figure 4. Analyses of heart rate across a night of sleep based on computer-determined beat-to-beat (RR) intervals. The upper graph depicts a sleep histogram with associated RR interval plots. In the middle graph, each RR interval (RRn) is plotted against the subsequent interval (RRn+1) to produce a graph known as a Poincaré plot, reflecting the beat-to-beat dispersion for specific heart rate intervals as well as interbeat interval variability as heart rate changes. Expanding the two-dimensional Poincaré plot into three dimensions (lower figure) more clearly illustrates the density distribution of graphed values. In this Poincaré plot and those in Figures 5 and 6, RR interval values (both axes) extend from 0 to 1.4 sec in 100 msec intervals.
waves (see Figure 1, SI). The transition from wakefulness to stage 1 is also accompanied by slow horizontal eye movements, and facial muscle tonus is usually decreased relative to that of relaxed wakefulness (Figure 1). Stage 2 is characterized by the intermittent occurrence of K-complexes and 12–14-Hz spindle activity against a relatively low-amplitude, mixed-frequency background (Figure 2). Stages 3 and 4, which together constitute "slow-wave sleep," differ from stage 2 and from each other in the amount of delta (0.5–4-Hz) activity present in each scoring epoch. Stage 3 epochs must contain 20%–50% — and stage-4 epochs more than 50% — of this activity. Defining characteristics of REM sleep include a relatively low-voltage, mixed-frequency EEG without K-complexes or spindles, the sporadic occurrence of eye movements, and reduced levels of submental and facial EEG activity (Figure 2). Although not required for REM sleep determination, other distinctive EEG features that may be present include bursts of theta activity (sawtooth waves) preceding clusters of eye movements (Berger, Olley, & Oswald 1962), and alpha activity 1–2 Hz slower than the subject’s waking alpha frequency (Johnson et al. 1967).

These criteria underscore the emphasis on EEG activity for discriminating state and stages — an emphasis which for NREM sleep is absolute and which for REM sleep includes also a requirement of relatively reduced EMG activity. Paradoxically, REM sleep can occur in the relative (i.e., epochs within REM periods without eye movement) or absolute (as in the congenitally blind; Berger et al. 1962) absence of the very parameter for which the state was initially named.

The following quotation (Pivik 1986, p. 384) places the Rechtschaffen and Kales scoring criteria in a broader physiological context and notes fundamental ways in which these criteria describe the difference between sleep and wakefulness.

1. The presence of waveforms unique to sleep — for example, endogenously determined K-complexes, 12 to 14 Hz spindle activity, vertex sharp waves, and frontal sawtooth waves.
2. The prevalence and concentration of activities — for example, the enhancement of slower EEG frequencies (delta and theta), and the concentration of these and other activities, such as eye movements or galvanic skin responses (GSRs), at specific times of the night. With respect to EEG activity, computerized analyses have shown that in only rare instances is the EEG composed of a single frequency; even in the desynchronized low-

Figure 5. Whole-night Poincaré plots for two subjects (K and L) on two consecutive baseline nights (night 3, left column; night 4, right column). In these graphs, the within-subject consistency and between-subject variability across nights are notable. Reprinted with permission from Pivik, Bushy, Gill, Hunter, & Nevins, “Heart rate variations during sleep in preadolescents,” Sleep, vol. 19, pp. 117–35. Copyright 1996 American Sleep Disorders Association and Sleep Research Society.

...voltage EEG of wakefulness in normal individuals, there is a small but nonetheless real component of delta activity present (Lubin, Johnson, & Austin 1969; Hoffman et al. 1979). The shift away from the higher frequencies associated with arousal during wakefulness and the concentration on slower activities are what make sleep unique.

3. The predictable constellations of physiological patterns that occur — for example, concentrations of delta activity are associated with high GSR activation during slow-wave sleep, and indices of cortical, ocular-motor, and autonomic arousal are associated with sustained muscular inhibition during REM sleep.

Sleep profiles (Figure 3) are useful for representing such general sleep characteristics as latencies, cyclicity, stage distribution, and relative amounts of sleep disturbance. However, these graphs do not communicate more rapid physiological variations that occur as sleep patterns play out across the night and that are often most frequent during shifts between states and stages. These transitional
periods reflect shifting physiological priorities, the determinants of which are not well understood. Among these state transitions, one that has been the focus of great interest is the sleep onset period. Although most investigators identify sleep onset with the presence of stage-1 EEG patterns, others (Agnew & Webb 1972; Johnson 1973; Ogilvie, Wilkinson, & Allison 1989) – because of inconsistencies in the covariation of psychological and behavioral measures with EEG criteria for sleep – have argued for considering initial stage 2 as sleep onset. It is clear that the EEG changes that take place at sleep onset (Figures 1, 7, and 8) do not occur in physiological isolation. For example, several measures – including oculomotor activity in the form of slow horizontal eye movements (Foulkes & Vogel 1965; Rechtschaffen & Kales 1968), variations in skin potential (Hori 1982), decreased ventilation (Naifeh & Kamiya 1981; Trinder et al. 1992), and decreased heart rate (Pivik & Busby 1996; Zemaityte, Varoneckas, & Sokolov 1984) – may anticipate stage-1 EEG changes by several seconds. Such systematic and coordinated changes across systems are consistent with concepts of physiological state. However, the relationship between these physiological changes and the point of perceptual disengagement from the waking environment is imperfect, as indicated both by studies of sleep onset mentation (Foulkes & Vogel 1965; Vogel, Foulkes, & Trosman 1966) and by researchers' ability to elicit behavioral responses to external stimulation (in some individuals) in stage 1 and, to a lesser extent, in the initial moments of stage 2 (Ogilvie & Wilkinson 1984; Ogilvie et al. 1989). Another indication that transitions between states or stages are commonly not achieved abruptly is reflected in the practice of many investigators not to accept a single epoch of stage 1 or stage 2 as the time of sleep onset but rather to require several consecutive epochs of these stages for this determination (Born, Muth, & Fehm 1988; Mercier, Pivik, & Busby 1993; Reynolds et al. 1983).

Associated with global patterns of state change across the night are predictable variations in the presence and distribution of physiological activity within sleep stages. For example, stage 4 occurs predominantly in the first third of the night and REM sleep in the last third (Williams, Agnew, & Webb 1964, 1966; see Figure 3) – observations reflected in the exponential decrease in delta activity across the night as determined from more recent computerized analyses of EEG sleep data (Feinberg et al. 1978; Feinberg, Fein, & Floyd 1980). Other notable stage-related physiological variations include: increases in body movements and K-complexes just prior to REM periods (Dement &
Kleitman 1957a; Halasz et al. 1977; Pivik & Dement 1968); reduced incidence of K-complexes and increased spindle activity in the few minutes subsequent to REM periods (Azumi, Shirakawa, & Takahashi 1975; Pivik & Dement 1968); the relative difficulty in engaging REM mechanisms early in the night, as indicated by the brevity or even omission of a REM period within the first two hours of sleep (Berger & Oswald 1962a; Dement & Kleitman 1957a; Roffwarg, Muzio, & Dement 1966); and increased density of eye movements as a function of time both within individual REM periods and within REM periods across the night (Aserinsky 1969, 1971).

It might be expected that state and stage distinctions made in the 1950s would undergo significant modification when subjected to the scrutiny of intense investigation over several decades. However, those definitions have been preserved, and the ensuing research has detailed characteristics of physiological measures that, although not integral to stage determination, have nevertheless served to reinforce and extend our understanding of state physiology. Prominent among these observations is the presence of generalized physiological activation during REM sleep, including increases in the rate and irregularity of respiratory (Aserinsky 1965; Snyder et al. 1964) and cardiovascular (Pivik et al. 1996; Snyder, Hobson, & Goldfrank 1963; Snyder et al. 1964) activities. Electrodermal activity in REM sleep is limited in incidence and is more similar in form to responses of this system during wakefulness (Broughton, Poire, & Tassinari 1963; Hauri & Van de Castle 1973b). These variations occur against a background of centrally mediated inhibition of facial and submental musculature and spinal monosynaptic reflexes (Berger 1961; Hodes & Dement 1964; Jacobson et al. 1964; Jouvet & Michel 1959; Pompeiano 1966, 1967).

Compared with REM sleep, physiological activation in the majority of NREM sleep is unremarkable. Exceptions to this generalization are the unusual levels of autonomic, hormonal and motor activation present during slow-wave sleep, particularly stage 4. During stage 4, there is commonly a dramatic increase in electrodermal activity (Broughton et al. 1965; Johnson & Lubin 1966; see Figure 2), which, in its extreme, has been referred to as “GSR storms” (Burch 1965). Normally, electrodermal activation of this intensity would suggest an enhanced level of arousal, yet arousal threshold during stage 4 is the highest of all sleep stages (Bonnet & Moore 1982; Busby et al. 1994; Goodenough et al. 1965; Lammers & Badia 1991). Consequently, the excessive electrodermal activity during stage 4 has been considered to result from the release of subcortical brain areas involved in the production of these responses from inhibition by higher centers and not to index arousal.
somnias,” occur (Roffwarg 1979). These disorders are characterized by varying degrees of motor and autonomic activity and include such behaviors as sleep walking, sleep talking, enuresis, night terrors, and confusional arousals. For more detailed consideration of the nosology, description, and treatment of these and other sleep-related disorders, the interested reader is referred to the *International Classification of Sleep Disorders Diagnostic and Coding Manual* (DCSC 1990) or to the text entitled *Principles and Practice of Sleep Medicine* (Kryger et al. 1994).

The initial wave of psychophysiological studies of sleep that followed the discovery of REM sleep were driven by the emphatic physiological distinctions between REM and NREM sleep and were essentially studies of state relationships. They were significantly influenced by the belief that REM sleep provided an objective measure of dreaming and that dreaming occurred only during these periods. For the most part, these studies reported a high incidence (approximately 80%) of recall following arousals from REM sleep — although subsequent investigations also detected subjects who typically fail to recall dreams (Goodenough 1978; Goodenough et al. 1959) — and a relative mental void in NREM sleep (less than 10% recall). However, reports suggesting that mental activity was present during NREM sleep (Goodenough et al. 1959) continued to accumulate, so that by 1967 data were available from nine studies reporting NREM recall values ranging from 23% to 74% (reviewed in Foulkes 1967). To some extent, the apparent discrepancy between the early and later studies regarding the presence of NREM mentation can be attributed to differences in what investigators were willing to accept as a dream. The early studies relied on an intuitive and implicit understanding of the nature of dreaming and consequently did not provide an operational definition of this variable. The first study to provide some clarification in this regard was published in 1957 and entitled “The Relation of Eye Movements during Sleep to Dream Activity: An Objective Method to the Study of Dreaming” (Dement & Kleitman 1957b). In this study, subjects were queried upon awakening as to “whether or not they had been dreaming”; only those reports that related a “coherent, fairly detailed description” (p. 341) of the sleep mental experience qualified as dreams. Reports of having dreamed “without recall of content, or vague fragmentary impressions of content” (p. 341) were considered negative and disregarded. Based on these criteria, observations

enhanced physiological arousal (Johnson 1973; Johnson & Lubin 1966; see also Chapter 8). Slow-wave sleep is also the time when approximately 80% of the total daily secretion of growth hormone is released (Born et al. 1988; Sassin et al. 1969; Takahashi, Kipnis, & Daughaday 1968) and during which a variety of arousal disorders, termed “para-

Figure 8. These illustrations expand the 8-min time base charted for bilateral central recordings depicted in the upper and middle panels in Figure 7 and present absolute power data in 4-sec bins. Using modified Rechtschaffen and Kales (1968) criteria, each 4-sec bin was classified into state categories as indicated in the legend. These figures demonstrate the complexities in EEG variations across hemispheres and nights in a single subject during the transition from wakefulness to sleep. Reproduced with permission from Pivik, “The several qualities of sleepiness: Psychophysiological considerations,” in Monk (Ed.), *Sleep, Sleepiness and Performance*. Copyright 1991 John Wiley & Sons Limited.
conformed to the commonly reported REM–NREM recall differentiation (80% recall in REM and 7% in NREM). These early studies, restrictive as they were with respect to dream definition, nevertheless provided an important insight into the nature of the dreaming process—namely, that in most individuals this process occurs with its greatest intensity during REM sleep.

It became obvious that a systematic and effective evaluation of mental activity during sleep would require a more detailed operational definition of what would be accepted as a dream, and many such definitions have been advanced. For example, the dream has been variously characterized as a “verbal report describing an occurrence involving multisensory images and sensations, frequently of a bizarre and unreal nature and involving the narrator himself” (Berger 1967, p. 16); “the presence of any sensory imagery with development and progression of mental activity” (Kales et al. 1967, p. 556); “any occurrences with visual, auditory or kinesthetic imagery” (Foulkes 1962, p. 17); a “multidimensional conglomerate of a hallucinatory belief in the actual occurrence of an imagined experience which, in turn, tends to be an extended visual, sometimes bizarre, drama” (Antrobus et al. 1978b, p. 40); or simply “thinking” (Foulkes 1978, p. 3).

The range of definitions represented by these examples places various constraints on which reports would be accepted into the “dreaming” data set, consequently tailoring the perception of the general nature of cognitive activity during sleep and more profoundly affecting the incidence of acceptable reports of dreaming occurring outside the confines of REM sleep. However, when reports elicited from arousals during sleep were examined using more permissive criteria that allow more fragmentary and less perceptual reports to be accepted as data, the presence of a much more extensive mental life during sleep was revealed. Lifting these definitional restrictions primarily affected the amounts of recall from NREM sleep arousals, with observations of more than 50% recall not being uncommon (Foulkes 1962; Goodenough et al. 1959; Herman, Ellman, & Roffwarg 1978; Molinari & Foulkes 1969; Pivik & Foulkes 1968; Zimmerman 1970). As suggested by the substantial increase in amounts of NREM recall that became apparent once a more relaxed definition of sleep mentation was used, there are qualitative distinctions that differentiate REM and NREM reports. The major differences that have been repeatedly observed (Antrobus 1983; Foulkes & Rechtschaffen 1964; Pivik 1971; Rechtschaffen, Verdone, & Wheaton 1963a) may be summarized as follows:

- reports obtained in periods of REM activity showed more organismic involvement in affective, visual and muscular dimensions and were more highly elaborated than non-REMP reports. REMP reports showed less correspondence to the waking life of the subjects than did reports from spindle and delta sleep. The relatively frequent occurrence of thinking and memory processes in spindle and delta sleep was an especially striking result. (Foulkes 1962, pp. 24–5)

Distinctions between REM and NREM amounts of recall and associated qualitative report characteristics seemed to imply a fundamental difference in cognitive activity during these states, with more complex, vivid, and bizarre “dreaming” during REM sleep and less developed, more mundane “thinking” during NREM sleep. However, NREM reports of dreaming have been observed to be as common (Goodenough et al. 1965) or more common (Bosinelli et al. 1968; Foulkes 1960, 1962; Pivik 1971; Pivik & Foulkes 1968; Rechtschaffen, Vogel, & Shaikun 1963b; Zimmerman 1968) than NREM thinking reports. Still, when reports from the two kinds of sleep are contrasted directly via paired comparison, judges are generally able to reliably discriminate REM from NREM reports (Bosinelli et al. 1968; Monroe et al. 1965). An exception to this discriminability is the NREM mentation elicited following arousals during sleep onset. Reports of mental activity at this time share many features with REM sleep reports that make it difficult to discriminate between them, including incidence, hallucinatory dramatic quality, and report length (Foulkes, Spear, & Symonds 1966; Foulkes & Vogel 1965; Vogel 1978; Vogel et al. 1966) as well as perceptual and emotional qualities (Vogel, Barrowclough, & Giesler 1972). Two implications of the recognition that dreamlike mentation occurred outside REM sleep were (i) REM sleep deprivation could not be equated with dream deprivation (Dement 1960) and (ii) REM sleep dreams were not vital to psychological normality during wakefulness (Sampson 1965, 1966; Vogel 1975; Vogel et al. 1975).

Subsequent research has confirmed the characteristics of NREM mentation outlined in cognitive sleep studies conducted during the initial 15 years following the discovery of REM sleep. Yet, despite the weight and persistence of such evidence, there was substantial reluctance to acknowledge the validity of mental activity during sleep occurring outside REM sleep. Although it was necessary to consider other plausible explanations for reports of NREM mentation—such as viewing them as artifacts of arousal generated in the process of waking up, or confabulated in an effort to please the investigators, or reflecting recall of mental activity from previous REM periods—skepticism remained even when such possibilities had been effectively countered. Foulkes (1967, p. 31) offered several probable reasons for this unwillingness to accept the authenticity of NREM mentation despite convincing arguments to the contrary:

(a) while the low-voltage random EEG of REM sleep is compatible with the existence of ongoing thought processes, the high-voltage, low-frequency EEG of NREM is not;
(b) a report of a mental experience is not credible unless supported by public behavioral or physiological observation; and,
REM sleep is so vastly different physiologically from NREM sleep that there must also be a vast psychological difference between the two, such as vivid dreaming vs. little or no mental activity.

This quotation is consistent with the emphasis on physiological correlates as validating indices of psychological experience. Although they provide useful guidelines, a dependence on such physiological correlates can, in the extreme, command an unsupportable degree of mind–body isomorphism. The points outlined by Foulkes serve to illustrate the extent to which prevailing theoretical thinking can promote expectations that interfere with scientific objectivity. The concept of NREM mentation was no more iconoclastic than that of recurrent phases of physiological activation occurring during sleep, yet the latter reports were not met with the same degree of skepticism as reports of NREM mentation. Even though the association between REM sleep and dreaming dramatically altered existing views regarding the nature of dreaming, dreaming was already accepted as a sleep-related cognitive event. Furthermore, because visual experiences are perhaps the most common and compelling components of dreams, the finding that the experience of dreaming appeared to be associated with these periods of rapid eye movements simply confirmed prior expectations. Aserinsky (1966) explicitly refers to this situation when he notes that “the prospect that these eye movements may be associated with dreaming did not arise as a lightning stroke of insight” (p. 217) since the notion of “an association of the eyes with dreaming is deeply engrained in the unscientific literature and can be categorized as common knowledge” (p. 218).

Although not extensive, there was evidence of the kind of linkage between NREM reports and preawakening events that provided precisely the kind of “public evidence” demanded to validate NREM mentation. These preawakening events took the form of either spontaneously occurring activity, such as sleep talking (Arkin et al. 1970; Rechtschaffen, Goodenough, & Shapiro 1962) or experimentally induced incorporations of external stimuli (Foulkes 1967; Foulkes & Rechtschaffen 1964; Rechtschaffen et al. 1963a).

It is likely that a detailed search for observable physiological events to be correlated with, validate, and perhaps explain psychological activity during sleep would have occurred regardless of the REM–NREM mentation controversy. However, if the presence of cognitive activity during NREM sleep had been dismissed then these studies would have focused exclusively on REM sleep, and our appreciation of the physiological conditions and requirements underlying cognitive activity would have been significantly diminished. In this search for psychophysical measures that might best predict the presence of mental activity during sleep, it is not surprising that EEG activity – despite limitations in understanding the precise nature and origin of such activity (Niedermeyer & Lopes da Silva 1993) – would be a primary focus.

The similarity between EEG activity during waking and REM sleep has been previously noted, and Dement and Kleitman (1957a) suggested that generally this pattern was a better correlate of dreaming than were eye movements. Subsequent research has supported this impression. As EEG activity becomes more desynchronized, there is greater recall and the reports obtained contain more vivid and bizarre dreamlike material. Accordingly, arousals from sleep where the background EEG activity consists of low-voltage, mixed-frequency patterns (stage 1 and REM) produced the highest incidence of recall as well as recall of the most vivid, bizarre, and emotional nature (Dement 1955; Dement & Kleitman 1957b; Foulkes & Vogel 1965; Vogel et al. 1966) as compared to recall obtained from arousals where the sleep EEG is characterized by slower and higher-amplitude patterns (Armitage 1980; Pivik 1971; Pivik & Foulkes 1968). The positive relationship between levels of EEG activation and the quantity and quality of recall is consistent with findings of increased recall of more dreamlike material across the night (Foulkes 1966; Goodenough et al. 1959; Pivik & Foulkes 1968; Shapiro, Goodenough, & Gryler 1963; Verdone 1963, 1965), since there is marked reduction in slower EEG activity and a greater presence of faster frequencies in the second half of the night. As indicated in Figure 3, these variations reflect a concentration of slow-wave sleep early in the night and more stage-2 and REM sleep later.

This confounding of sleep stage and time of night frustrates attempts to determine independent relationships between these variables and aspects of sleep cognition. One approach to circumventing this confound has been to focus on stage 2, which is more prevalent later in the night yet normally occurs throughout the night. When stage-2 mentation is sampled across the night, increases in both recall and dreamlike quality in reports elicited later in the night have been observed (Arkin et al. 1978b; Pivik & Foulkes 1968). Although these findings suggest a time-of-night rather than background EEG influence on sleep mentation, computer analyses of all-night sleep EEG recordings have shown a covariation between EEG activity and time of night – that is, linear decreases across the night in alpha (Harman & Pivik 1996) and delta (Feinberg et al. 1980) bands, indicating that stage 2 early in the night contains greater amounts of slow EEG activity than later in the night. These observations underscore the importance of supplementing, where possible, standard analyses with procedures that may provide additional information. In this case, computer analysis more precisely quantifies the above-threshold delta activity (scoring criteria for stage 2 allow up to 20% per epoch of 75-μV delta activity) as well as activity occurring below the criterion level, thereby providing a more faithful representation of the amount of this activity within each epoch (Armitage 1995b).
Attention has also been drawn to the occurrence of synchronized fast EEG rhythms (20–40 Hz) during both wakefulness and sleep in animals and humans (Franken et al. 1994; Llinas & Ribary 1993; Steriade, Amzica, & Contreras 1996). These rhythms are most prevalent during wakefulness and REM sleep but have been detected during NREM sleep as well. The cognitive correlates of this activity are only beginning to be studied, and whether (or how) this activity might be implicated in aspects of consciousness and cognition remains to be determined (Kahn, Pace-Schott, & Hobson 1997).

The global time-of-night–EEG–sleep mentation relationships noted here indicate variations in mental activity over relatively long periods of time, but short-term temporal relationships between recall and physiological events have also been reported. For example, recall of REM sleep mentation is reduced if awakenings are made soon after a gross body movement (Dement & Wolpert 1958b; Wolpert & Trosman 1958). Other investigations have shown that duration of time in a sleep stage prior to arousal may influence the amount and quality of recalled material. Arousals made early in REM periods produce fewer reports and reports of less dreamlike quality relative to those obtained from arousals later in REM (Foulkes 1962; Kramer, Roth, & Czaya 1975; Whitman 1969). Although arousals from stage 4 generally produce less recall and recall that is less dreamlike than that from other sleep stages, such differences between stage 4 and stage 2 are minimized when the amount of within-stage time prior to awakening is controlled (Tracy & Tracy 1974). Furthermore, recall rates between REM and slow-wave sleep (SWS) are not as widely discrepant (89% versus 65%, respectively) when temporal factors such as time of night and time into stage are regulated (Cavallero et al. 1992).

The general differences in incidence and qualitative aspects of REM and NREM mentation favor the more “awake-like” stage-1 pattern as a reasonable predictor of dreamlike cognitive activity, but the fact that NREM sleep stages with quite different EEG patterns also support an extensive amount of cognitive activity — often dreamlike — forces the conclusion that these tonic background patterns are at best only global correlates of mental activity during sleep. This conclusion is further affirmed by observations of within-state variations and between-state similarities in the frequency and characteristics of recalled material. Clearly, the psychophysiological relationship between sleep cognition and EEG activity is imperfect.

The characterizations that developed from early studies in sleep cognition — REM sleep mentation as visual, bizarre experiences and NREM mentation as more thoughtlike and mundane — seemed to fit well with an extensive and developing literature in waking subjects that indicated cortical hemispheric specialization for different features of cognitive activity. Neurophysiological and psychophysiological studies in waking subjects assigned linguistic and analytical processes to the left hemisphere and visuospatial and holistic processes to the right hemisphere (Geschwind & Galaburda 1987). The electrophysiological measure that came to be accepted as a primary index of differential hemispheric EEG activation was the amount of alpha activity, since increases in this activity have been related to decreases in attention or effort. For example, higher alpha amplitude has been noted over the right hemisphere during performance on verbal tasks and over the left hemisphere on spatial tasks (Doyle, Ornstein, & Galin 1974; Galin & Ornstein 1972). Accordingly, global REM–NREM variations suggested differential cerebral hemispheric involvement, with the visuomotor loading of REM sleep dreams suggesting greater right-hemisphere involvement during REM sleep (Broughton 1975; Goldstein, Stolzfus, & Gardocki 1972). Close visual examination of EEG recordings may reveal interhemispheric differences in such activity across homologous sites, but quantification of such differences has relied almost exclusively on electronic processing of EEG recordings.

Although it is specifically formulated with respect to the amount of alpha activity, the concept of greater amplitude (or power) of EEG activity as an index of decreased cortical activation — and hence of reduced hemispheric involvement — has been generalized across EEG frequency bands and applied as well to total EEG power measures. At a strictly electrophysiological level, findings with respect to REM–NREM hemispheric activation have been inconsistent in supporting the right-hemispheric nature of REM sleep (Antrobus, Ehrliechman, & Wiener 1978a; Armitage, Hoffman, & Moffitt 1992; Bertini & Violani 1992; Doricchi & Violani 1992). The few studies that have specifically documented the extent of EEG lateralization in conjunction with concomitant sleep mentation have, with few exceptions (e.g. Angelieri, Scarpino, & Signorino 1984), not supported the postulated dichotomy between right-hemisphere REM and left-hemisphere NREM (Armitage et al. 1992; Cohen 1977; Guevara et al. 1995; Moffitt et al. 1982; Pivik et al. 1982). It should be emphasized, however, that interpretation of interhemispheric EEG sleep data is complicated by variations in subject characteristics, scalp recording sites, EEG frequency bands considered, and analytical procedures used (Armitage et al. 1992; Pivik et al. 1982; see also Chapter 2), and it may vary dynamically with specific features of ongoing mentation (Bertini & Violani 1992; Doricchi & Violani 1992).

In addition to EEG variables, efforts to determine psychophysiological correlates of mental activity during sleep have also examined autonomic and motor variables. Among autonomic measures investigated in this respect are heart and respiratory rates, electrodermal activity, and penile erections. In general, robust relationships between tonic levels of autonomic activity and either the incidence or qualitative aspects of recalled mentation have not been observed. Furthermore, when positive correlations have been
observed, they have often been in association with transient changes in these measures (for reviews see Pivik 1991a; Rechtschaffen 1973).

Perhaps most remarkable are the apparent dissociations between certain autonomic measures and cognitive activity during sleep. Prominent in this regard is the stormlike occurrence of electrodermal activity during stages 3 and 4 (Burch 1965). It would be expected that these high rates of electrodermal activity would have some impact on associated mental activity in terms of enhanced recall or qualitative aspects of recalled mentation, but such relationships have not been observed (Hauri & Rechtschaffen 1963; Pivik 1971; Tracy & Tracy 1974). Similarly, the increased blood flow to the genitalia during REM sleep, resulting in penile erections (Fisher, Gross, & Zuch 1963; Karacan et al. 1966) or clitoral engorgement (Cohen & Shapiro 1970), would suggest that the great majority of REM reports would contain overt sexual content. However, with the exception of lucid dreaming (La Berge 1985; La Berge et al. 1983), REM reports with manifest sexual features are relatively uncommon (Fisher 1966; Hall & Van de Castle 1966). It is interesting that lucid dreams containing sexual activity are associated with expected variations in some (respiration and skin conductance) but not all (heart rate) autonomic measures (La Berge 1985, 1992).

With the exception of occasional twitches and normal movements, sleep would appear to the casual observer to be a state of general motor quiescence – an impression physiologically documented for trunk and limb muscles that accompanies (and may slightly anticipate the onset of) REM sleep (Berger 1961; Jacobson et al. 1964). Because tonically reduced EMG activity is a defining characteristic of REM sleep, it is not possible to determine the relationship between this variable and ongoing mentation independent of that in other systems (such as those measured by EEG) that are also tonically active at this time. However, because of the variability in the timing of EMG inhibition and EEG desynchronization signaling REM sleep onset, it has been possible to systematically examine characteristics of NREM sleep mentation (generally in stage 2) immediately preceding REM sleep as a function of the presence or absence of tonic EMG inhibition. It was expected that the pre-REM decrease in facial and submental muscle activity might signal a shift to more REM-like mental activity, but instead these low-EMG pre-REM periods yielded fewer reports as well as reports that were less dreamlike than those from awakenings at high-EMG levels (Larson & Foulkes 1969; Pivik 1971).

**Tonic–Phasic Distinctions**

As indicated by the foregoing review and commented upon by others (Antrobus & Bertini 1992), the relationship between tonic physiological activation and cognitive activity is complex, with the strongest psychophysiological association to emerge being that between the presence of a stage-1 EEG pattern and recall of dreamlike mentation. Although the psychophysiological sleep studies conducted during the decade and a half following the discovery of REM sleep emphasized general state relationships, it had been apparent that – even though sleep stages were defined primarily in terms of tonic physiological criteria – the stages were nevertheless characterized by transient variations in these measures. In fact, a closer psychophysiological correspondence was generally obtained when reports were elicited following such abrupt variations. This improved relationship was reflected in increased recall and/or qualitative variations in recalled material and was observed across EEG, autonomic, and motor systems (Pivik 1986, 1991a).

Among such phasically occurring physiological activity, the relationship of one type of discrete motor activity

![Figure 9](image_url) An example of the correspondence between eye movements and dream content. Immediately following a series of horizontal nystagmoid eye movements (designated by dots) during REM sleep, the subject was awakened (vertical line, lower channel) and related a dream experience (viewing parallel parking lines while riding in a car) that provided the precise perceptual conditions required to elicit optokinetic nystagmus. In this example, the EMG recordings contain ECG (electrocardiograph) artifact made more prominent by the tonic EMG inhibition during REM sleep. However, this artifact does not interfere with the general purpose of EMG recordings during sleep (i.e., stage differentiation). Reprinted with permission from Pivik 1986, © The Guilford Press.
(eye movements) to REM sleep mentation has been most intensively investigated. These studies have evaluated this relationship not only in terms of general associations but also in trying to determine if a strict relationship existed between eye movements and dream images. In terms of the more nonspecific approach, although increased eye movement activity is commonly associated with enhanced recall, the magnitude of this relationship is not particularly remarkable (Pivik 1991a). Likewise, reports obtained in association with increased eye movement are often, but not consistently, more vivid and emotional (Ellman et al. 1974; Hobson et al. 1965). It is interesting to note that increased eye movement may not always be a good predictor of the amount of activity reported in the dream (Berger & Oswald 1962a; Firth & Oswald 1975; Hauri & Van de Castle 1973a; Pivik & Foulkes 1968).

The discovery of the association between REM sleep and dreaming confirmed the expectation that visual dreams would be accompanied by eye movements. It also suggested the corollary hypothesis that these eye movements were not random but were functioning as they would during wakefulness — to view the perceived images (in this case, dream images). This precise relationship between eye movements and dream imagery of REM sleep has come to be known as the “scanning” hypothesis (Roffwarg et al. 1962). Although intuitively appealing and appearing to provide an ideal opportunity for demonstrating the extent to which psychophysiological isomorphy can occur during sleep, attempts to substantiate this relationship have met with mixed success. Although examples of highly specific correspondence have been noted (Figure 9), demonstrating this relationship as a general feature of REM sleep has been largely unsuccessful (reviewed in Pivik 1991a; Rechtschaffen 1973). However, interpretation of these generally negative results needs to be tempered with an appreciation of the experimental demands inherent in such studies. These include (i) investigators highly skilled in interviewing procedures and techniques, with a detailed understanding of head–eye movement relationships, and (ii) highly motivated subjects who can awaken quickly and provide high-quality detailed recall of dream imagery and associated gaze shifts.

Insight into the difficulty of determining whether (or the extent to which) eye movements during REM sleep are scanning dream images was provided by an investigation conducted during wakefulness in which eye movements were recorded and subjects were periodically interviewed and requested to detail their eye movements in the few seconds prior to the interview (Bussel, Dement, & Pivik 1972). These reports were then correlated with the associated eye
movement recordings. It was observed that subjects' reports during wakefulness could not be related to polygraphically recorded eye movement activity with any greater reliability than has been possible in the REM dream–eye movement studies. There has been a resurgence of interest in this relationship, with indications of more positive associations between eye movement and imagery in lucid dreams (LaBerge 1992) as well as indirect support from studies using imaging technology indicating involvement of the same cortical areas in the control of both waking and REM sleep eye movements (Hong et al. 1995) and from studies using more nonspecific, correlational techniques associating numbers of eye movements with the amount of visual imagery in dream reports (Hong et al. 1997).

Interest in the association between more discrete variations in physiological activity during sleep and associated mentation—exemplified by the eye movement–REM dream imagery relationship—became part of a more general shift in focus from state to event relationships that significantly affected both physiological and psychophysiological sleep studies. The critical differentiation focused on the duration and temporal clustering of events: sustained or tonic activities lasting several seconds or minutes (e.g., background EEG and EMG stage correlates) were contrasted with sporadic or phasic activities lasting less than a second (e.g., muscle twitches, rapid eye movements, or K-complexes) or, at most, a few seconds (e.g., isolated transient autonomic variations). Initially based on such events during REM sleep in the cat (Moruzzi 1963), this reconceptualization was soon extended to NREM sleep events as well (Grosser & Siegal 1971). Notable influences of this
tonic–phasic distinction on psychophysiological studies of sleep included: (1) providing a structured physiological framework within which to consider these studies; (2) suggesting that REM–NREM physiological differences were quantitative and not absolute; and (3) providing what came to be considered a prototypic phasic event that served as a model in the search for the human analog of such activity – namely, the PGO spike. This event, named for the brain regions from which it was most readily recorded (i.e., the Pons, lateral Geniculate bodies, and Occipital cortex), acquired psychophysiological prominence in part because of the anatomical and sleep stage distribution of this activity. Consistent with both the visual emphasis in dreams and the high incidence of dream reports from REM sleep, PGO spikes were most prominent in the visual system during REM sleep (Brooks 1967, 1968; Jouvet 1972; see Figure 10). Furthermore, the occurrence of PGO spikes during NREM sleep – most intensely just prior to REM onset and less frequently at other times in the NREM cycle – held out promise that this activity might provide a physiologic correlate of NREM mentation.

The tonic–phasic distinction provided the theoretical orientation which dominated the field for many years and which continues to influence psychophysiological sleep studies (Antrobus & Bertini 1992; Pivik 1978, 1991a; Rechtschaffen 1973). This model prompted increasing numbers of studies comparing reports obtained from awakenings following episodes of tonic or phasic physiological activation during sleep, stimulated the search for physiological measures that might reflect activity of the phasic event system proposed by Moruzzi (1963; see Figure 11 for examples of the range of events examined in these studies), and led to the formulation of new proposals regarding the relationship between phasic events and sleep mentation (Hobson 1992; Hobson & McCarley 1977).

These investigations provided new insights into sleep physiology and psychophysiology, but they failed to indicate either that phasic events were a prerequisite for the presence of cognitive activity during sleep or that these events could be reliably related to specific qualitative measures of sleep mentation, such as the degree of cognitive processing of dream experiences (Foulkes & Pope 1973; Molinari & Foulkes 1969) or the presence of discontinuity and bizarreness within reports (Foulkes & Pope 1973; Ogilvie et al. 1982; Reinsel, Antrobus, & Wollman 1985; Watson 1972). Furthermore, there are unusual features differentiating sleep from waking cognitive activity that have received little attention in terms of either general or tonic–phasic physiological sleep correlates. Among these are what has been termed the “single-mindedness” and “nonreflectiveness” of dreams. Single-mindedness refers to “the strong tendency for a single train of related thoughts and images to persist over extended periods without disruption or competition from other simultaneous thoughts and images” (Rechtschaffen 1978, p. 97). It has been suggested that this attribute is a reflection of a combination of increased sensory thresholds and cortical activation during sleep (Reinsel, Antrobus, & Wollman 1992). Nonreflectiveness refers to the attenuation or arrest of judgmental processes during dreaming (Kleitman 1967; Rechtschaffen 1978) – that is, the general acceptance of events or images during dreaming without the critical evaluation that normally takes place during waking. This characteristic may reflect the possibility that an inherent feature of dreaming is the absence of the need for “a constant regulating function of self-evaluation” (Meier 1993, p. 64). The apparent limited use of evaluative information from waking cognitive experiences in this context implies either restricted access to such information during sleep or a discontinuity between selective waking and sleeping cognitive processes (Foulkes 1993).

**Sleep Cognition: Reconceptualizations**

For the first 25 years following the discovery of the relationship between REM sleep and dreaming, investigations into the psychology of sleep were largely physiologically driven. Nevertheless, there were concurrent lines of research that provided information regarding more general issues concerning both the circumstances under which dreaming occurs and the nature of dreams – research from which is emerging a significantly modified view of dreaming. In the process of documenting the apparent pervasiveness of mental activity across sleep stages, investigators provided insights into what may generally be considered the necessary and sufficient conditions for dreaming to occur. Studies of variations in mental activity during the transition from waking to sleep were particularly revealing in this regard. Early investigations identified four stages of EEG–EOG patterns occurring sequentially during this sleep onset period and studied the variations in mental activity associated with these stages, defined as:

1. alpha EEG, generally continuous with one or more REMs a few seconds prior to the “awakening”;
2. alpha EEG often discontinuous, with pronounced SEMs [slow eye movements] covering at least the 20–30 secs. of the record prior to the experimenter’s call;
3. descending Stage 1 EEG (almost always, but not necessarily, accompanied by SEMs); and, 4. descending Stage 2 EEG of at least 30 secs. but not more than 2.5 mins. duration (usually, but not necessarily accompanied by SEMs). (Foulkes & Vogel 1965, p. 233)

Mental activity – much of it dreamlike – was reported on 90%–98% of arousals from these stages.

The similarities between these reports and those from REM sleep were emphasized in subsequent studies (Foulkes et al. 1966; Vogel et al. 1972). Furthermore, reports of mental activity changed in a systematic way as subjects progressed from the alpha REM stage to stage 2. These
variations began with subjects initially relinquishing control over the course of mental activity, then becoming unaware of the environment, and finally losing reality orientation and having hallucinatory experiences (Vogel et al. 1966). These results suggested that reduced sensory input and subsequent abrogation of voluntary ideational control are essential for dream production. It is notable that when these conditions have been established in waking subjects—either in the context of classic sensory deprivation studies (e.g., Freedman, Grunebaum, & Greenblatt 1971) or under more benign conditions—dreamlike, bizarre, hallucinatory experiences have occurred (Foulkes & Fleisher 1975; Foulkes & Scott 1973; Reinsel et al. 1992; Singer 1978). These observations, coupled with accumulating evidence that REM and NREM reports were not so qualitatively dissimilar (Antrobus 1983; Cavallero et al. 1992; Foulkes & Schmidt 1983), led to the proposition of a single dream system or process that functions across states at different levels of activation (Cavallero & Cicogna 1993; Foulkes & Cavallero 1993). This conceptualization identifies REM sleep as one condition among many that would be expected to be accompanied by dreaming and thereby minimizes the expectation that REM sleep physiology will provide an explanation for dreaming (Foulkes & Cavallero 1993).

However, just as brain injury may affect the characteristics of cognitive activity during both wakefulness and sleep (Kerr 1993), so too must characteristics of sleep cognition be influenced by alterations of the functional architecture of the sleeping relative to the waking brain. Brain imaging studies in humans (Braun et al. 1997, 1998; Hong et al. 1995; Maquet et al. 1996) are beginning to document similarities and differences in cortical and subcortical activation between the waking and sleeping brain that may offer new possibilities for understanding specific dream characteristics. For example, the reported deactivation during REM sleep of areas of the frontal cortex known to be involved in integration of sensory information during wakefulness (Braun et al. 1997) may be consistent with the absence of reflectiveness characteristic of REM dream reports.

In addition to the findings indicating qualitative similarities between REM and NREM mentation, some reports have contradicted the generally accepted view of dreams as characteristically bizarre, unusual, and dramatic experiences that differ significantly from waking thought (Dorus et al. 1971; Foulkes et al. 1967; Snyder 1970). On the basis of these reports and others that compare, for example, the nature of dreams collected in home versus laboratory environments, Foulkes (1996) concluded that “representatively sampled dream experiences, in both content and form, have a texture not so vastly different from, or unfamiliar to, waking experience” (p. 615). These observations effectively demystify the dreaming process and, while acknowledging variations that occur as a consequence of state differences, nevertheless suggest fundamental cross-state similarities between waking and sleeping cognitive systems. Support for this commonality has been provided by studies indicating that individuals with waking cognitive or sensory defects (e.g., resulting from brain damage) show deficits consistent with these impairments in dream experiences (Doricchi & Violani 1992; Kerr 1993).

Another source of support comes from developmental studies of dreaming. These are particularly relevant not only because of their normative nature but also because features of the ontogeny of physiological aspects of sleep offer unusual opportunities to investigate the development of dreaming. Many of the physiological characteristics of sleep in the adult are not present in the newborn, but perhaps the most dramatic difference is the predominance of REM sleep at this time (40%–70% of total sleep time), with an approximation of adult levels of REM sleep not occurring until after the first year (Louis et al. 1997; Pikiv 1983; Roffwarg et al. 1966). The presence of large amounts of this state at a time in development when neuronal processes underlying central nervous system (CNS) maturation are highly active prompted Roffwarg et al. (1966) to suggest that REM-associated activity provided a source of endogenous stimulation important for aspects of normal CNS development. This hypothesis, which is consistent with the influence of activity-dependent factors on neural development, has received support from animal studies demonstrating that interruption of REM sleep phasic influences early in the postnatal period—either by REM sleep deprivation or suppression of PGO spike activity—impaired the course of visual system development (Marks et al. 1995; Oksenberg et al. 1996). However, to expect that the REM sleep–dreaming association so prominent in adults would be present in early development, when waking sensory and cognitive skills are only beginning to form, would require ascribing extraordinary psychological functions to the REM state. At what point does the REM sleep–dreaming relationship become evident, and with what implications for distinguishing cognitive processes during wakefulness versus sleep? Given the research emphasis on adult sleep physiology and psychology soon after the discovery of associations between dreams and REM sleep, it is not surprising that answers to these questions were not immediately forthcoming. When the results of studies of dreaming in early childhood were presented (Foulkes 1982; Foulkes et al. 1990, 1991), they revealed that (i) reports of REM dreams with formal properties of adult dreams did not become evident until the age of 8 or 9 and (ii) the processes required for imagery during waking and sleep develop in parallel. It was concluded that dreaming “is a symbolic process with strong cognitive prerequisites and with a developmental history much like that of waking symbolic thought [and waking consciousness]” (Foulkes 1996, p. 619). Consistent with this parallelism between waking and sleeping cognitive processes is the observation that visual imagery is absent in the dreams of the congenitally blind or those blinded before the age of 5 (i.e.,
before dreaming can be demonstrated) but present in those blinded at or after this time, when dreaming with properties essentially similar to those in adults occurs (Foulkes 1993; Kerr 1993).

Conclusions, Unanswered Questions, and Future Directions

Overviews of research fields too often emphasize unresolved issues or areas of contention and neglect to emphasize accomplishments. In little more than one generation, research into the related topics of sleep and dreaming has produced remarkable achievements and revelations. These areas, once almost exclusively the topic of anecdotal and speculative discussion, have been redefined by the application of rigorous scientific investigation — with resulting significant empirical revelations regarding the physiological and psychological nature of these ubiquitous human experiences. At the physiological level, enough has been discovered about sleep mechanisms, influences on these mechanisms, and normative aspects of sleep (McGinty et al. 1985; Montplaisir & Godbout 1990; Steriade & McCarley 1990) to permit the extensive differentiation of a variety of sleep abnormalities, many of which can now be effectively treated (DCSC 1990; Kryger et al. 1994). Nevertheless, questions remain regarding the processes underlying virtually every aspect of sleep control: the initiation, maintenance, and termination of sleep as a state as well as between- and within-sleep stage variations. These are truly complex questions, but the coupling of new molecular and genetic methods with those of anatomy, neurophysiology, and biochemistry (Cirelli, Pompeiano, & Tononi 1996; Pack & Mackiewicz 1996; Thakkar 1996) to address these issues offers real promise that they may be resolved.

In terms of the psychology of sleep, studies of sleep cognition have produced results that are no less remarkable. These investigations have broadened our understanding of the organization and formal characteristics of dreams, and they have demonstrated that dreaming is a pervasive behavior not restricted to a particular sleep stage or even to sleep (Antrobus & Bertini 1992; Cavallero & Foulkes 1993; Ellman & Antrobus 1991; Foulkes 1985). Furthermore, the evidence showing that this behavior requires cognitive abilites that normally are not developed until well into the first decade of life (Foulkes 1982, 1993) indicates that dreaming is not an automatic and inevitable consequence of REM sleep. The many empirical accomplishments resulting from years of research into sleep cognition have significantly informed us regarding many aspects of dreams and the dreaming process, but they have also raised new questions (e.g., what features and processes are common to, or distinguish between, cognitive activity during wakefulness and sleep?) and left us still contemplating fundamental questions, such as why dreams are so readily forgotten and whether dreaming has an adaptive function.

Dreaming is still most likely to be reported from the REM sleep state, yet — except for the general association between REM sleep physiology and dreaming — attempts to determine reliable links between sleep physiology and sleep cognition have been largely unsuccessful. Perhaps, as suggested by Rosenlicht and Feinberg (1997) for REM sleep (and as may apply to any situation where dreaming occurs), this apparent “gross psychophysiological mismatch” may reflect an inherent dissociation during dreaming that relates to physiological and/or psychological state function at that time. If, as Foulkes suggests for “minds capable of conscious representational and self-representational intelligence” (1997, p. 4), “dreaming is the form assumed by consciousness whenever there is residual but somewhat dissociated cognitive/cerebral activation in the relative absence of direction either from the person’s environment or from voluntary self-control” (p. 3), then perhaps these dissociations may be better understood in terms of the functional activation of various brain areas and systems at the time of the dream relative to that observed during nondream experiences. Promising indications that such understanding may not be beyond our reach can be found in the application of functional imaging technology to the study of physiological and cognitive processes during sleep (Braun et al. 1997, 1998; Hong et al. 1995; Maquet et al. 1996), in the refinement of instruments to evaluate features of these cognitive experiences such as “bizarreness” (Reinsel et al. 1992) and sensory qualities (Antrobus et al. 1987; Rechtschaffen & Buchignani 1992), and in the development of heuristic theoretical models that integrate these complex data (Antrobus 1993; Kahn et al. 1997). The continuing development of such technological and methodological procedures and their combined application in the same subjects at times associated with the occurrence of dreamlike mentation — as well as during wakefulness under conditions where levels of perceptual processing and symbolic cognition are controlled — will facilitate the identification of similarities and differences in cross-state processes. Such studies will most likely reveal that the sleep–wakefulness state barrier is more permeable than once thought and that the biological and cognitive processes defining these states are more meaningfully related than many previously imagined.

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