Dreams, Sleep, and Consciousness

Interweaving the Neurocognitive Theory of Dreaming with New Theories of Sleep and Consciousness

G William Domhoff

DREAMS, SLEEP, AND CONSCIOUSNESS

Dreams, Sleep, and Consciousness presents the first scientifically based explanation of how dreams, sleep, and consciousness interconnect since the beginning of the neuroimaging era. This groundbreaking book introduces a fully developed neurocognitive theory of dreaming that encompasses the development of dreaming in children and provides detailed quantitative findings demonstrating how dreams reveal personal concerns.

The book features two innovative theoretical frameworks. The new "adaptive inactivity theory of sleep" explains why the sleeping brain shows varying activation levels and how this enables dreaming. The "multistate hierarchical model of consciousness" explains both why consciousness occurs and how dreaming fits within this three- level theory. Key features include comprehensive coverage of dreaming during the sleep- onset process and detailed analysis of the waking/ arousal process, revealing how rapidly consciousness returns despite morning grogginess— the optimal time for dream recall.

This essential resource targets undergraduate and postgraduate students in psychology, neuroscience, sleep medicine, and consciousness studies. It provides invaluable new ideas for researchers in sleep laboratories, clinicians specializing in sleep disorders, and neuroscientists investigating consciousness. The book also provides crucial insights for anyone interested in dream research, cognitive neuroscience, or sleep medicine.

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AN INTRODUCTION TO THE THREE THEORIES UTILIZED IN THIS BOOK

The purpose of this book is to place an updated version of a recent theory of dreaming within the context of a new theory of sleep on the one side and a new theory of consciousness on the other. The three theories—the neurocognitive theory of dreaming, the adaptive inactivity theory of sleep, and the multistate hierarchical model of consciousness—were developed separately and independently by three psychologically trained empirical researchers on the basis of three very different research literatures. All three theories reached their current formulations between 2019 and 2023 (Domhoff, 2022, 2023; LeDoux, 2019, 2020a; Siegel, 2022b, 2022d).

The discussion of the three theories in this introductory chapter, along with an indication of how they can be interwoven, attempts to provide readers with a sense of the issues and questions that animate the following nine chapters. In addition, the chapter provides a first look at the methods and systematic findings that will be used in the effort to answer the questions that will arise for readers as they examine the various aspects of each of the three theories. Put another way, the many issues that are left unanswered in this chapter will be addressed in succeeding chapters.

Before turning to the overviews of the three theories and how they can be related to each other, it should be added that the book makes every attempt to use replicated findings that derive from studies with large sample sizes and clearly defined and established means of analyzing the data. There is also a preference for concepts and conclusions that are based on the use of two or more different methods. Finally, it should be emphasized that this book provides a synthesis of the three separate theories, so it is of necessity selective in dealing with the wide range of theories and the growing bodies of literature that exist in all three fields of studies that it draws upon.

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The Neurocognitive Theory of Dreaming

The neurocognitive theory of dreaming was developed on the basis of neuroimaging studies of the sleeping brain in the late 1990s, as well as new research on the impact of brain lesions on dreaming (Domhoff, 2000b, 2003, Chapter 1). In particular, it focused on the periods of "Rapid Eye Movement" (REM) sleep that occur four to six times in the course of a night's sleep, along with "the conceptual system of schemata and scripts" that "generates the process of dreaming" (Domhoff, 2003, p. 9). It also had a developmental dimension from the outset and a focus on quantitative studies of dream reports that were collected in both laboratory and non-laboratory settings (e.g., Foulkes, 1982; Hall, 1966b; Hall et al., 1982; Hall & Van de Castle, 1966).

The theory was later updated on the basis of a growing wave of waking neuroimaging studies, a meta-analysis of neuroimaging studies of REM sleep, and further quantitative studies of dream content (Domhoff, 2022). The neurocognitive theory of dreaming now suggests that dreaming is based on the cognitive process of "simulation," defined as "a particular kind or subset of thinking, which involves imaginatively placing oneself in a hypothetical scenario and exploring possible outcomes" (Schacter et al., 2008, p. 42). Simulations also can be defined as "imaginative constructions of hypothetical events or scenarios" (Buckner et al., 2008, p. 20). In fact, these definitions sound like they were created with dreaming in mind.

The defining feature of dreaming is therefore the sense of being a participant in, or an observer of, an unfolding series of events. These simulated events often take place in vivid sensory environments and almost always include other humans and/or animals (Domhoff, 2022, p. 8, for this definition of dreaming.). Then, too, dreaming is sometimes thought of as an actual experience for a few seconds after awakening, even while at least partially realizing that it didn't "really" happen.

Given this unique sense of what a dream is like, it is therefore not a dream if a participant in a sleep-dream laboratory study reports seeing an image of her mother after an awakening by the experimenter. This image most likely occurred during "Non-REM 3" (N3) sleep, which is also called "slow-wave sleep." It is also a different kind of mental experience if a participant reports thinking about a conversation with his sister or brother during the previous one or two days. This type of report is sometimes made after an awakening from "Non-REM 2" (N2) sleep, which is a more activated stage of sleep than N3 sleep.

And it is still another experience—a dream—for a participant to report after an awakening from REM sleep, when the brain is sometimes even more activated than it is during waking, that she was standing in her family's backyard, discussing a sporting event with her father, while he was building a small shed. To further complicate matters, that hypothetical dream might have been experienced during N2 sleep in the 1.5–2.5 hours before the morning awakening, when brain activation levels are gradually increasing to wake-like levels.

Dream researchers therefore have been aware since the early 1960s that it is important to phrase their questions to the participants in their studies in ways that make clear that they “want to know about the extent and quality” of the participants’ “mental experience during the period of sleep preceding the awakening” (Rechtschaffen et al., 1963, p. 409). They therefore use phrases such as “what were you experiencing just before I called you” and “was there anything going through your mind just before I called you?” (Foulkes & Vogel, 1965, p. 232; Rechtschaffen & Foulkes, 1965, p. 1151). It is through this type of open-ended approach that dream researchers learned that the participants sometimes are seeing a static image of a person or object, or thinking about a discussion that occurred during the previous day or two. They also learned that most participants in effect define what they had been experiencing as a “dream” if the experience included visual, auditory, or kinesthetic imagery, or if they felt as if they were in a different physical setting than they were actually in at the time they reported the dream (Foulkes, 1962, p. 17).

As the examples in the preceding paragraphs make clear, the neurocognitive theory of dreaming leads to the conclusion that it is not useful to define dreaming as simply any form of mental activity that occurs during sleep. This is because several different forms of cognitive activity occur during sleep (Kamiya, 1961, for a detailed account of the various forms of cognitive activities during sleep, and especially for a summary on pp. 168–170; Pagel et al., 2001, for the several different definitions of dreaming). In addition, there are still other forms of cognitive activity that can occur during brief arousals from sleep and in various atypical events during sleep. They include such frightening events as “night terrors” and “sleep paralysis,” both of which can become confused with dreams (e.g. Avidan, 2017; Domhoff, 2022, pp. 6–8, for a brief summary of the various non-dream types of experiences during the night; Iranzo, 2022; Yale Medicine, 2024).

Then, too, people suffering from severe insomnia have atypical activation patterns during sleep (Kay et al., 2016). In some cases, people insist they are awake, even though EEG (electroencephalogram) studies suggest they are asleep (e.g., Aquino et al., 2024; Bressera et al., 2025; Kay et al., 2016, for overviews of different types of insomnia). Still other studies make clear that post-traumatic stress disorder (PTSD) patients, who suffer from frequent nightmares, have expanded activation networks during sleep (Domhoff, 2022, pp. 47, 237 for a summary of past findings; Ebdlahad et al., 2013; Germain et al., 2013; Mysliwiec et al., 2014; Simor et al., 2013). The nighttime events mentioned in this and the previous paragraph are discussed in Chapter 9.

All of these different cognitive activities and events during a person's nighttime in bed—some of which occur while they are asleep, some while they are awake for a few seconds to several minutes—have to be set to one side for the time being to develop a plausible theory of dreaming. That is, it is first of all necessary to develop a "foundational" theory of dreaming, which involves a full focus on "understanding core processes" in everyday non-patient populations (Ochsner & Kosslyn, 2014b, p. 482). Only then is it possible to develop "translational" models that can be applied to one or another atypical kind of dreaming.

The interweaving of the neurocognitive theory of dreaming with the adaptive inactivity theory of sleep and the multistate hierarchical model of consciousness in this book provides an opportunity to strengthen the theory by demonstrating its compatibility with what is known about both sleep and waking consciousness. This interweaving makes it possible to show how the neurocognitive network that gives rise to dreaming comes to be ascendant over the waking multistate consciousness network as the sleep-onset process unfolds. The neurocognitive network that supports dreaming is also ascendant during the periodic REM periods, and often during the N2 sleep that occurs most frequently during the 1.5–2.5 hours before the spontaneous morning awakening. (During slow-wave N3 sleep, which occurs most frequently in the middle of the night, no neurocognitive network is connected enough to generate more than static imagery or an isolated thought, according to the neurocognitive theory of dreaming.)

In addition, the neurocognitive theory of dreaming is strengthened by research on the "arousal networks" that make it possible for a rapid return to self-aware consciousness during the spontaneous morning awakening. These studies also show that there is a slower return to full alertness, which helps to explain why this groggy period of drifting waking thought often leads to dream recall. These very useful findings, along with studies of brain lesions that lead to the loss of consciousness, are discussed in Chapter 8.

The interweaving of the neurocognitive theory of dreaming with the new theory of sleep and the new theory of consciousness also makes it possible for the neurocognitive theory of dreaming to explain how dreaming relates to waking consciousness. Looked at from the perspective of waking consciousness, dreaming can be understood as an intensified form of mind-wandering, imagining, and daydreaming that does not include the component of self-awareness. This conclusion brings dreaming closer to what is known about waking human thought than was possible in the past. This comparison of dreaming with waking consciousness is presented in Chapter 9.

The Adaptive Inactivity Theory of Sleep

The adaptive inactivity theory of sleep provides an excellent nighttime context for the neurocognitive theory of dreaming. First and foremost, this theory can explain the varying causes of brain activation during sleep, which provide the necessary support for the neurocognitive network that produces dreaming. To begin with, it can explain the activation levels and functional connectivity among neural substrates that make the neurocognitive process of dreaming possible in the 4–6 REM periods that occur each night. Second, it can also explain the activation levels and functional connectivity that make dreaming possible at various times during the sleep-onset process, and in N2 sleep in the approximately 1.5–2.5 hours before spontaneous morning awakenings.

In addition, it is consistent with the discovery that the sleep cycle in humans living in indigenous societies without electricity is linked to the ambient temperature cycle, not to the light–dark cycle, as it is in other known diurnal primates. Similarly, it can explain why humans in indigenous societies without electricity sleep for nearly an hour longer in the cold winter months than they do in the warm summer months.

According to the adaptive inactivity theory, sleep first of all can be understood as one instance of a more general strategy of energy conservation that is pervasive in the long evolutionary histories of both plants and the earliest animals, well before mammals and birds first appeared (Siegel, 2022b, 2022d). By characterizing adaptive inactivity in terms of reduced metabolism and decreased energy consumption, the theory places the phenomenon of sleep in the context of issues that are essential to all life forms—the acquisition, use, and conservation of energy.

Also, the theory can explain why there is a periodic occurrence during sleep of the highly activated form of sleep called REM sleep, for which there is as yet no generally accepted adaptive function. The evolutionary explanation for REM sleep suggested by the adaptive inactivity theory of sleep—the restoration of a waking-level brain temperature that keeps the brain at adequate activation levels for waking functioning—is based on comparative, lesion, and experimental studies that are discussed in Chapter 6. It is parsimonious and plausible within the context of currently available evidence.

At the same time, the adaptive inactivity theory is fully compatible with the various cellular-level adaptive processes that occur during sleep in many, but not all, mammals. According to the adaptive inactivity theory, these other adaptive processes were added to sleep later in the evolutionary history of mammals. Moreover, there is no evidence that any of these other adaptive theories of sleep can explain the activation patterns that support dreaming during the sleep-onset process and NREM 2 sleep late in the sleep period, as well as during REM sleep.

Further, the adaptive inactivity theory of sleep is the only adaptive theory of sleep that systematically addresses the large variations in sleep duration among mammals, which range from about 20 hours a day in one species of bats to as little as 2.1 hours per day in African bush elephants, and to little or no sleep at all in at least some species of dolphins and porpoises. It can also explain the relatively short sleep periods (5.7–7.1 hours) and the aforementioned seasonal variations in the amount of sleep that are experienced by humans living in two indigenous hunting-gathering societies in the southern half of Africa, and one indigenous hunting-horticultural society in the southern half of South America. The theory presents evidence and analysis to suggest that sleep duration is shaped by the energy-acquisition, predator-avoidance, and temperature-maintenance strategies that are necessary for survival within a specific ecological niche.

Drawing upon the adaptive inactivity theory of sleep, dreaming during the sleep-onset process can be explained by the brain temperatures that remain at or near waking levels during these few transitional minutes. Thanks to the theory's emphasis on REM sleep as a brain-heating mechanism, it can explain dreaming during REM periods on the basis of the elevated temperatures and high activation levels in specific brain areas, which occur about every 90 minutes during the course of the sleep period and together account for about 20%–25% of total human sleep time. Finally, the theory can explain the dreaming that occurs during N2 sleep in the 1.5–2.5 hours before a spontaneous morning awakening. It does so on the basis of the built-in, 24-hour pattern of circadian rhythms, which gradually raise brain temperatures in preparation for spontaneous morning awakenings.

The adaptive inactivity theory of sleep also makes it possible to explain why there is little or no dreaming during N3 sleep. This low-activation, slow-wave stage of sleep cannot sustain the functional connectivity among the relevant neural substrates that is necessary for the neurocognitive process of dreaming to occur. This emphasis on lower brain temperatures in N3 sleep, which occupies about 35%–40% of total sleep time in humans, also makes it possible to explain the reports of static imagery or isolated thoughts after N3 awakenings in the middle of the night.

The adaptive inactivity theory is discussed in detail in Chapter 6 and used to understand several unique features of human sleep at the outset of Chapter 7.

The Multistate Hierarchical Model of Consciousness

Just as the adaptive inactivity theory of sleep provides an excellent nighttime basis for the neurocognitive theory of dreaming, the multistate hierarchical model of consciousness provides an ideal theoretical framework for explaining how dreaming relates to self-reflective, self-knowing *waking* consciousness (LeDoux, 2019, 2020a).This theory is based on a further extension of a "higher-order" theory of consciousness that was developed by several colleagues (Brown et al., 2019, Lau & Rosenthal, 2011, LeDoux, 2017, #3331; LeDoux & Lau, 2020; LeDoux et al., 2020, for empirical evidence developed by psychologists and neuroscientists that supports a "higher -order" approach).

The higher-order network has the capacity to carry out the self-reflective thought that makes self-knowing consciousness possible. In making these claims, the theory draws specifically upon the emphasis on "one kind of consciousness (autonoetic) that characterizes the workings of one kind of memory (episodic)," as stated by memory theorist Endel Tulving (2005, p. 5). The theory thereby focuses on exactly the kind of self-aware, self-reflective consciousness that is of relevance in distinguishing between consciousness and dreaming. More specifically, the theory explains how it is possible for individual participants to reflect upon the fact that they are thinking specific thoughts about themselves. In addition, they can make verbal reports to researchers about these self-related thoughts, with "verbal self-report" serving as the most crucial evidence for "measuring conscious experiences" (LeDoux & Brown, 2017, p. E2017).

The multistate hierarchical model of consciousness consists, first, of lower-order sensory networks, which receive and then send forward new sensory information from both the external world and the body. This sensory information is then processed by the episodic, semantic, and schematic cognitive networks at the intermediate level. These intermediate-level networks then "re-represent" the newly updated and revised schemas and concepts to the higher-order network, which makes decisions based on the new information. Taken together, it is this multistate hierarchical model that explains self-reflective, self-knowing consciousness. An overview of the multistate hierarchical model is presented in Figure 1.1.

The multistate hierarchical model of consciousness encompasses the neurocognitive theory of dreaming within its intermediate level (Domhoff, 2023, for the initial statement of the relationship between the two theories). The intermediate level not only includes the memory networks and cognitive schemas mentioned in the previous paragraph. It also includes much of the self-system and the neural substrates that support simulation, imagination, mind-wandering, and daydreaming.

Within the context of the multistate hierarchical theory, the relative deactivation of the higher-order network throughout the sleep period immediately suggests that dreaming is not a form of autonoetic (self-knowing) consciousness. Instead, it is a form of fact-knowing ("noetic") consciousness, which relies on semantic memory, as discussed more fully in Chapter 9 as part of a comparison of dreaming and consciousness (Domhoff, 2023; see LeDoux & Lau, 2020, for a discussion of noetic and autonoetic memory; and Tulving, 2005, for an original statement of these ideas). The truncated nature of the neurocognitive network that supports dreaming, limited as it is to several of the neural substrates that support the intermediate networks, explains the relative absence of both external sensory in-puts in dreams and

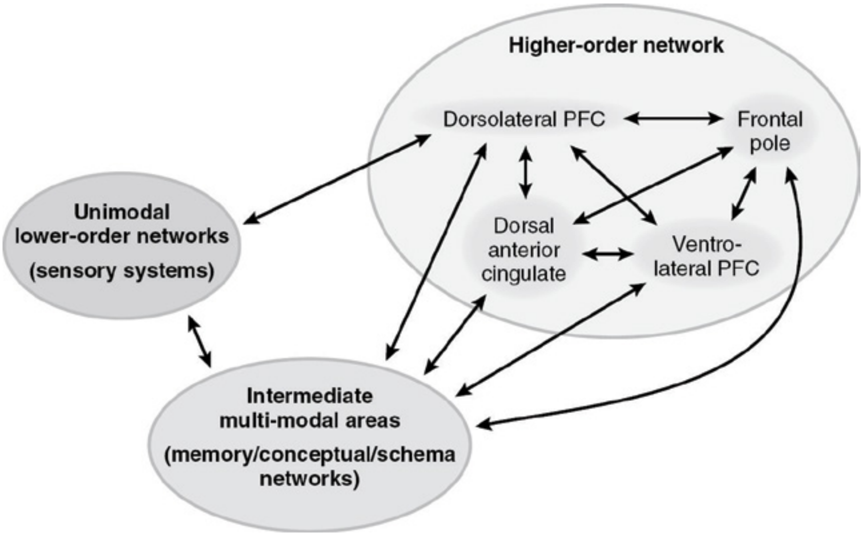


FIGURE 1.1 A schematic graphic of the relationships among the levels in the multistate hierarchical model of consciousness: The unimodal lower-order networks, the multi-modal intermediate areas, and the higher-order network.

Source: Adapted with permission from LeDoux (2020a).

the absence of reflective self-awareness concerning the dreamer's current state. It also explains several other cognitive deficiencies in dreaming, such as the absence or near absence of episodic memories and figurative thinking. These conclusions are supported on the basis of empirical studies that are discussed in Chapter 9.

This new context for the neurocognitive theory of dreaming is very useful because it makes possible more fine-grained comparisons of dreaming and consciousness. In particular, the strong emphasis on memory systems in the multistate hierarchical model contrasts with the perceptual emphasis that is found in several theories of consciousness (LeDoux & Lau, 2020, for a critique of perception-oriented theories of consciousness; Seth & Bayne, 2022, for a general comparison of theories of consciousness, in which several theorists concern themselves with visual perception).

Although the higher-order network is the final level that is necessary for consciousness to occur, it is also important to repeat that the neural substrates in the intermediate level are essential. This is because consciousness is the property of the overall network, which consists of many brain areas and subnetworks working together. Consciousness therefore is not possible unless the areas at the intermediate level are mature and intact. This point will become readily apparent in Chapter 8, in which the loss of consciousness due to specific lesions in areas at the intermediate level is discussed as part of the general emphasis on arousal networks in that chapter.

The Default Network as Building Block and Red Thread

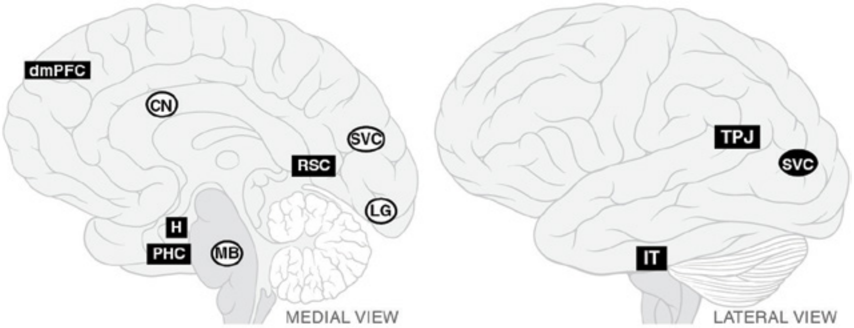
With the neurocognitive theory of dreaming now situated between the adaptive inactivity theory of sleep on the one side and the multistate hierarchical model of consciousness on the other, the remainder of this introductory chapter provides further basic background information that relates to all three of the theories discussed above. It does so by focusing on the only waking neurocognitive network—the *default network*—that is in part activated at specific times during sleep. The default network is unique in that it is an essential part of the intermediate level in the multistate hierarchical model of consciousness and is also the primary basis for dreaming.

The default network was first discovered in the early 2000s and has been a source of increasing attention ever since (Gusnard et al., 2001; Gusnard & Raichle, 2001; Raichle et al., 2001). It consists of "multiple interacting subsystems," and the main neural substrates that support it are well established, but the full scope of the neural substrates that support the default network is a work in progress (Andrews-Hanna et al., 2014, pp. 33–35 for the quoted phrase and the updates between 2003 and 2014; Girn et al., 2024, for an analysis that expands the default network). Twenty years after its discovery, one of the pioneers in mapping the default network reported evidence that its discovery "has revolutionized our understanding of the workings of the human brain" (Menon, 2023, p. 2469).

The existence of the default network first came to the attention of dream researchers around 2005–2007 (e.g., Maquet et al., 2005; Pace-Schott, 2007, pp. 137–140). Its likely importance to dreaming was clear to an increasing number of dream researchers just a few years later (e.g., Domhoff, 2011; Eichenlaub et al., 2014; Fox et al., 2013; Hartmann, 2011). Still, the high probability that portions of the default network are essential in the understanding of dreaming and dream content has been only gradually and partially acknowledged by many dream researchers. In this book, though, the default network is a central building block in developing a better understanding of both dreaming and waking consciousness. It provides the red thread that runs throughout the rest of the book.

As noted earlier in the chapter, the neurocognitive theory of dreaming first of all builds upon neuroimaging studies of both the waking and sleeping brain. This combination of waking and sleeping neuroimaging studies makes it possible to delineate the neurocognitive network that engenders dreaming in considerable detail. Due to the discovery of the default network in the early 2000s, it is now possible to say that the neurocognitive network that supports dreaming is based on relatively activated neural substrates located in *portions* of the frontal medial and parietal regions of the brain that are part of the default network, along with *portions* of the sensory network and the sensorimotor network. (The somewhat cumbersome and awkward-sounding term—“relatively activated,” along with its counterpart, “relatively deactivated”—is used in cognitive neuroscience to make clear that brain areas and neurocognitive networks do not turn “on” or “off” but instead are only more or less activated in terms of their relationships to each other.)

More specifically, the neurocognitive network that produces dreaming includes (1) several of the areas in two subsystems within the default network, which are called the *dorsomedial prefrontal cortex subsystem* and the *medial temporal cortex subsystem*; (2) the secondary visual cortex, which lies within the larger sensory network; and (3) a movement-supporting region within the sensorimotor network, called the caudate nucleus, which is involved in motor control, learning, and other functions in waking life. Figure 1.2 presents an



Substrates within the default mode network	Dorsomedial prefrontal cortex subsystem	• Dorsomedial prefrontal cortex	dmPFC
		• Inferior temporal cortex	IT
		• Temporoparietal junction	TPJ
	Medial temporal cortex subsystem	• Hippocampus	H
		• Parahippocampal cortex	PHC
		• Retrosplenial cortex	RSC
Substrates not in the default mode network	Occipital cortex	• Secondary visual cortex (V2-V5)	SVC
		• Lingual gyrus (visual processing)	LG
	Subcortical regions	• Caudate nucleus (movement)	CN
		• Pons/midbrain (arousal, activation)	MB

FIGURE 1.2 Several of the main neural substrates that subserve the neurocognitive process of dreaming.

Notes: For a more detailed account of the neural substrates that underlie dreaming, see Fox et al. (2013), Uitermarkt et al. (2020), and Domhoff (2022).

overview of several of the main neural substrates that give rise to dreaming whenever they are sufficiently activated to be functionally connected to each other and thereby constitute a neurocognitive network for dreaming. But it also has to be cautioned that the exact contours of the neurocognitive network that supports dreaming are not as yet fully established.

Further, it is important to add, as will be discussed in detail in Chapter 2, that this network only becomes fully ascendant if the higher-order network that directs waking thought—which is considered to be part of the *frontoparietal control network (FPCN)* in this book, for reasons that will be discussed below—has become relatively deactivated. This relative deactivation of the FPCN is accompanied by the relative deactivation of portions of the default network that link with the FPCN. These relative deactivations within the border regions of the default network are the final step in creating the isolation of the portions of the default network that make dreaming possible.

During directed waking thought, the various areas in the default network that support dreaming are entirely at the service of the several brain networks involved in perception and cognition. For example, areas in the default network have a major role in semantic memory schemas and conceptualizing, and still others support language and mental imagery (Bar, 2011; Moulton & Kosslyn, 2011). Neural regions within the default network also provide support for the "social brain," which is the cognitive system that makes possible the complex social relations that characterize human groups (Amft et al., 2015, p. 1031; Lieberman, 2013). Importantly, the neural substrates underlying the default network are also essential in supporting the self-system (Abraham, 2013; Levorson et al., 2025; Meyer & Lieberman, 2018; Tan et al., 2022). The default network's involvement in semantic memory, mental imagery, the social brain, and the self-system is highly relevant to the neurocognitive theory of dreaming because the cognitive capacities it supports are the basis for the quantitative findings on dream content that are discussed in Chapters 3 and 4.

However, when the FPCN is not fully focused on the many types of external and internal stimuli that arrive continuously every second of the day, the two subsystems in the default network mentioned above, the dorsomedial prefrontal cortex subsystem and the medial temporal cortex subsystem become relatively more activated in comparison to the externally oriented networks in the brain. It is at this point that mind-wandering and/or daydreaming may occur. The increased activation of the two subsystems of the default network at this time also has been shown to be relevant to dreaming by a waking neuroimaging study in which the participants were asked to think, first, about the person's present situation (called the "present self" condition), and then about personal situations that would arise in the future (the "future self" condition) (Andrews-Hanna, Reidler, Sepulcre, et al., 2010).

This experimental study found that the dorsomedial prefrontal cortex subsystem is preferentially activated when the participants were asked to think about their "present self"; on the other hand, the medial temporal cortex subsystem is preferentially activated when the participants are thinking about their "future self" (Andrews-Hanna, Reidler, Sepulcre, et al., 2010, pp. 554, 559). According to the neurocognitive theory of dreaming, portions of these two subsystems work together to produce dreaming when the FPCN is relatively deactivated (Domhoff, 2022, Chapter 2; Domhoff & Fox, 2015; Fox et al., 2013).

As discussed in the next subsection, the FPCN and the default network are not the only neurocognitive networks that are active during waking. Important though they are, they are only two of seven networks that are essential in providing a more complete description of perception and cognition.

The Seven-Network Framework for Analyzing Perception and Cognition

The neurocognitive theory of dreaming and the multistate hierarchical model of consciousness can be augmented and refined when they are encompassed within an empirically derived seven-network parcellation for analyzing perception and cognition. Framing the understanding of both dreaming and consciousness within the seven-network framework makes it possible to draw upon a wider literature in neurocognitive psychology. It also makes the neurocognitive theory of dreaming and the multistate hierarchical model of consciousness more accessible and familiar to a wider range of neurocognitive researchers. This framework was derived from neuroimaging data collected from 1000 participants, which is now available as part of the large Harvard Dataverse collection of brain scans (Buckner et al., 2014, on the Dataverse; Yeo et al., 2011, for the first full presentation of the seven-network parcellation).

The analysis further showed that many studies of perception and cognition can be organized and understood on the basis of the complex and constantly changing interactions among these seven basic networks. A number of studies using varying methods have reported a similar network structure (L. Fan et al., 2021; Gordon et al., 2016; Paquola et al., 2025; Power et al., 2011; Schaefer et al., 2018; Uddin et al., 2019; Yan et al., 2023; Yuan et al., 2024).

Five of the seven networks are nonlinear, nonhierarchical, and complexly intertwined "association" networks. They are based on neural substrates that are located in several different parts of the brain. These association networks are often identified as central points ("nodes") in the overall brain network because they are frequently part of the shortest pathways that link various brain regions (Bertolero et al., 2018; Bullmore & Sporns, 2009; Watts & Strogatz, 1998). The two sensory networks, on the other hand, are localized in specific brain regions and function in a linear and hierarchical fashion (Domhoff, 2022, pp. 16–22, for a detailed discussion of the network organization of the human brain in the context of the neurocognitive theory of dreaming). The names of these seven networks, and a brief characterization of each of them in terms of their roles in waking thought and perception, are provided in Table 1.1.

The primary function of the FPCN, which is briefly characterized in the first row of Table 1.1, is to synthesize the information that it receives from other brain networks and to make decisions and issue top-down commands on the basis of this information. It is also the basis for the sense of self-knowing (the sense that a person is having a certain thought)—which is, at the very least, a key element of consciousness, a topic that is discussed more fully in Chapter 9. More generally, the FPCN serves executive functions in relation to the other six networks and is often called the "executive network." In this book, it is shown to be the main basis for the higher-order network in the multistate hierarchical model of consciousness.

The conclusion that the FPCN is the main basis for the higher-order network first of all draws upon a large-scale synthesis of a wide range of studies, which suggests that areas within the FPCN are responsible for both

TABLE 1.1 The seven networks involved in perception and cognition

Network	*Organizational form*	*Main functions supported*
Frontoparietal control network (FPCN)	Associational, interweaved	Top-down control, hierarchical reasoning, executive regulation
Default network	Associational, interweaved	Internally focused, semantic memory, self-system, imagination
Salience/ventral network	Associational, interweaved	Attention-shifting, alerting
Dorsal attention network	Associational, interweaved	Focused thought, task-oriented
Limbic network	Associational, interweaved	Memory, reward, empathy
Visual network	Hierarchical, linear	Processes information on static and moving objects, spatial information
Sensorimotor network	Hierarchical, linear	Processes external physical stimuli and internal sensations

Notes: The associational networks are "small-world" networks, which are characterized by clustering, short paths between neurons, and a large general component (Bertolero et al., 2018; Bullmore & Sporns, 2009; Domhoff, 2022, p. 16 for a summary; Watts & Strogatz, 1998). The importance of small-world networks in understanding dream content in individual dream series is discussed in Chapter 4.

consciousness and directed thought (Levy, 2024). This synthesis leads to the conclusion that all of the “most recent theories underlying the concept of consciousness/awareness” rely on “a largely distributed network of brain regions in which the lateral prefrontal cortex plays an important role” (Levy, 2024, p. 797). Second, it concludes that “The way the involvement of the lateral prefrontal cortex in consciousness/awareness is usually described fully overlaps with what is required to achieve a goal-directed behavior” (Levy, 2024, p. 797).

In other words, the FPCN supports consciousness as well as directed thought and hierarchical reasoning, which are the building blocks for top-down commands. This synthesis then places the anterior regions of the prefrontal cortex, which are the final necessary regions that make human consciousness possible, squarely within the FPCN (Levy, 2024, pp. 797, 799, 806). Still other work discussed in Chapter 9 of this book is consistent with this conclusion and more fully explains why it is useful to place the higher-order network within the FPCN (e.g., Burgess et al., 2007; Christoff, 2014; Christoff & Gabrieli, 2000; Christoff et al., 2003; Dixon et al., 2014b, 2018; Henseler et al., 2011; LeDoux, 2019, pp. 256–257).

As will be detailed in Chapter 2, the FPCN has a very close working relationship with the second network characterized in Table 1.1, the default network, which is in turn an important part of the intermediate level in the multistate hierarchical model of consciousness (Andrews-Hanna et al., 2014, p. 31, Box 2, and pp. 34–35, for the ways in which the seven-network analysis augmented and reshaped prior understandings of the contours of the default network). And, as already noted above, and is reemphasized here, portions of the default network are central to the neurocognitive theory of dreaming because they provide the main basis for dreaming when the FPCN is relatively deactivated. In addition, and as also noted earlier, portions of the default network are essential to consciousness. Finally, the default network also has a role in the arousal process that underlies spontaneous awakenings from sleep, as will be discussed in Chapter 8.

The FPCN is importantly aided by two “attention networks,” which help it maintain focus and attention on external tasks. The *dorsal attention network* and the *salience/ventral network*—which are listed in Table 1.1—also work closely with the FPCN in modulating the default network, as discussed in Chapter 2. The *limbic network*, which is the fifth and final of the association networks, contributes to many different processes, such as reward and memory, and also has a role in the creation of emotions, which are discussed in Chapter 9.

The Activation and Arousal Networks in the Brain

As the use of the word “activation” in several places in the first few pages of this chapter makes clear, the seven brain networks could not function without sufficient cortical activation. This activation derives from several interacting neurophysiological networks in subcortical areas of the brain. These networks have their starting point in the brainstem, an area at the base of the brain that is about the size of an adult human thumb. More exactly, the origins of the activation networks are located in the upper levels of the brainstem in two adjacent areas, the *pons* and the *midbrain*.

The neurochemical activation signals originating in the pons/midbrain, which are called "neurotransmitters," are sent ("propagated") to the basal forebrain and the hypothalamus. After receiving further input from the basal forebrain, the hypothalamus propagates its neurochemical information to the thalamus, which has many connections with cortical brain regions. Figure 1.3 provides an overview of the brain areas that constitute the "engine room" of the brain.

The brain areas depicted in Figure 1.3 are not only involved in brain activation during waking. They also are involved in the sleep-onset process and in the generation of REM periods during sleep. Further, these same small areas are essential to arousal from sleep, which leads to the almost instantaneous return to waking consciousness. (The sleep-onset process is discussed in Chapter 5, the REM-generation network is discussed in Chapter 6, and arousal from sleep, as mentioned above, is discussed in Chapter 8.)

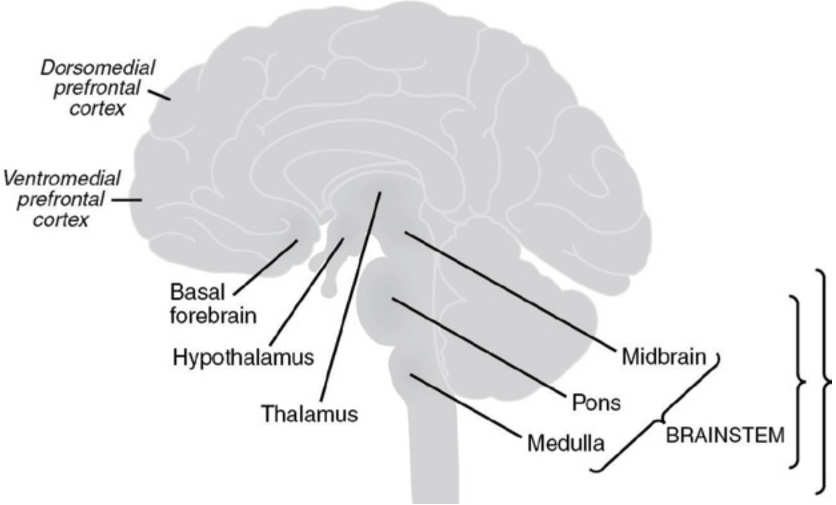


FIGURE 1.3 Six subcortical areas of the brain that are essential in brain activation and deactivation.

Note: Two cortical areas in the default network (in italics) are shown for perspective.

The Importance of Lesion Studies in Demonstrating Causality

Although the neurocognitive theory of dreaming relies heavily on neuroimaging research, it also makes use of studies of brain lesions, which can be caused by brain injuries, brain diseases, or surgical procedures. In effect, lesion studies based on accidents or brain diseases are similar to a series of accidental "experiments," in which the impacts of "focal" (small, circumscribed, narrowly focused) brain lesions in all parts of the brain are assessed. By asking patients if their lesions have led to any changes in their dreaming, these studies provide crucial first-person testimony with regard to the areas in the brain that are and are not necessary for normal adult dreaming. In the case of lesions created by surgical procedures, they are often meant to treat brain conditions such as seizures, which are usually caused by epilepsy. In the case of surgical lesions that are made for scientific purposes, they are carried out on non-human mammals after being approved by institutional review boards at universities or governmental agencies.

Not coincidentally, studies of both sleep and consciousness also make use of both experimental and accidental lesions. For example, experimental lesions in the lateral pons and lower midbrain in animal models lead to the complete loss of REM sleep. These studies thereby established that the small network in the upper brainstem, which was discussed above, is both necessary and sufficient for REM sleep to occur (Siegel, 2022c, pp. 68, 73). Accidental brain lesions in the brainstem and the default network, which can lead to "disorders of consciousness"—the clinical category for the various types of loss of consciousness, based on lesions in different brain regions—also have been important in studying foundational parts of the consciousness network. As noted in the previous section of this chapter, the impact of some of these lesions is discussed in Chapter 8 (e.g., Edlow et al., 2024; Fernández-Espejo et al., 2012; Laureys et al., 2005; J. Li et al., 2021; Vanhaudenhuyse et al., 2011; Vogt & Laureys, 2005). Lesions in the FPCN, on the other hand, usually lead to more subtle defects in consciousness, such as attention deficits and deficiencies in planning, for reasons stated in Chapter 9 (LeDoux et al., 2020, p. 255; Odegaard et al., 2017).

In the case of dreaming, lesion studies first of all provide independent support for the neuroimaging findings concerning the neural substrates that support the neurocognitive process of dreaming. These studies also provide causal evidence that portions of the default network are both necessary and sufficient to produce dreaming in adolescents and adults when there is (1) a relative deactivation of the other six brain networks; (2) an occlusion of external stimuli; and (3) a sufficient level of brain activation. Similarly, lesion studies can provide causal evidence that lesions in specific areas in the secondary visual cortex are necessary for visual imagery to occur during dreaming. Lesions in these areas also can have specific causal effects

TABLE 1.2 A few of the regions of the brain needed and not needed for dreaming

Region of brain	*Neurocognitive network*	*Effect on dreaming of lesions in this area*
Ventromedial prefrontal cortex	Default network	Loss of dreaming
Temporoparietal junction	Default network	Loss of dreaming
Medial occipitotemporal cortex	Sensory network	Distortion or loss of visual imagery
Primary visual cortex	Sensory network	No impact
Dorsolateral prefrontal cortex	Frontoparietal control network	No impact

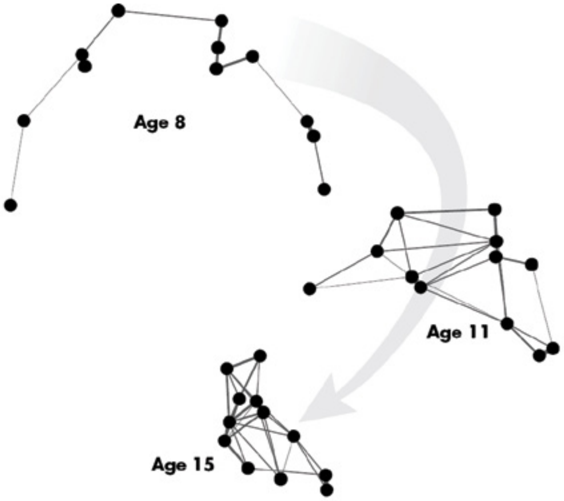
on particular aspects of visual imagery, such as the loss of the ability to recognize faces.

Stated very generally, accidental, medical, and experimental studies show that lesions in areas that provide support for the neurocognitive network that generates dreaming lead to the loss of dreaming, or to the alteration of dreaming. This is direct causal evidence for the importance of these regions for dreaming. On the other hand, focal lesions in any brain area outside of this neurocognitive network do not have any impact on the continuance of dreaming. These findings are of major significance. They provide direct causal evidence that "experimental" lesions outside the neurocognitive network that supports dreaming, whether due to accidents or diseases, do not alter this network. Table 1.2 provides an overview of the location of a few of the lesions that do and do not impact dreaming.

More generally, the neurocognitive theory of dreaming, by drawing upon both neuroimaging studies and lesion studies, claims that dreaming, like consciousness, is a property of a specific neurocognitive network. If that network is not intact, dreaming is defective in some way or does not occur at all. The use of both neuroimaging and lesion studies can also be understood in methodological terms as providing "convergent validity," in which two very different methodologies lead to the same result (Cronbach & Meehl, 1955, for one early statement of this important methodological approach in psychology).

Studies of the Development of Dreaming in Children and Adolescents

In addition to neuroimaging and lesion studies, the neurocognitive theory of dreaming also draws upon maturational studies of the default network, laboratory studies of the development of dreaming, and studies of the development of waking cognition in children from preschool through middle school. These studies separately and unexpectedly discovered that (1) the



age	dream content
3–5	Dreaming is very rare if not non-existent; static imagery; very short
5–7	Social interactions occur, but dreamer is often not in the action
7–9	Dreamer more often has a central role in the dream; longer reports
9–11	Dreams adult-like in frequency and complexity
13–15	Dreaming becomes more adult-like in content as well as complexity

FIGURE 1.4 Maturation of connectivity in the default network from ages 8 to 15.

Note: The networks become "smaller" at each age in this fictive configuration in order to depict the increasing functional connectivity within the default network.

Source: Adapted from Fair et al. (2009), under CC BY license.

default network does not reach an adult-like maturational level until ages 9–11 and (2) that dreaming is a gradual cognitive achievement that is not adult-like in frequency and complexity until that same age period (Domhoff, 2022, Chapters 6 and 7). Figure 1.4 provides a graphic overview of the changes in the default network from ages 8 through 15, and the table below the illustration presents an overview of the gradual development of dreaming.

Moreover, waking developmental studies by cognitively oriented psychological scientists show that children do not fully demonstrate "abstract, psychological self-knowledge" until ages 9–11 (Ross et al., 2024, p. 12). More generally, the cognitive capacities that support mental imagery, imagination, and simulation are not adult-like until late childhood. The importance of the maturation of the default network and the development of various cognitive capacities to the development of both dreaming and waking consciousness are discussed in Chapter 9.

Taken together with the neuroimaging and lesion studies discussed above, these studies of children provide further evidence of convergent validity for the neurocognitive theory of dreaming by adding a third independent method that leads to the same results. This triangulation of three separate methodologies—each with different strengths and weaknesses—further strengthens the overall analysis because they all lead to the same results (e.g., Webb et al., 1966/1981/2000, for one of the classic formulations of this "triangulation approach" to hypothesis testing).

Using Expectations about Dream Content to Test the Neurocognitive Theory of Dreaming

To test expectations about the likely nature of dream content that derive from the neurocognitive theory of dreaming, this book makes use of systematic findings on dream content that are based on quantitative content analyses of many thousands of dream reports collected in both laboratory and non-laboratory settings (e.g., Domhoff, 1996, 2022, Chapters 3 and 4; Hall & Van de Castle, 1966). These replicated findings on dream content make it possible to examine, for example, the extent to which the dreamer's current and ongoing personal concerns appear in dreams, and the degree to which the dreamer's waking social networks are reproduced in dreams. These results are discussed in Chapters 3 and 4.

In addition, the findings on dream content can be combined with more recent neuroimaging, lesion, and developmental discoveries to explain why dreaming has no adaptive evolutionary function, which has been the consensus view among cognitively oriented dream researchers since the early 1990s (e.g., Antrobus, 1993; Blagrove, 1992, 1996; Foulkes, 1993). Instead, it seems more likely that dreaming is an evolutionary by-product of the rapid selection for increasingly complex social cognition, imagination, and an enhanced self-system over the past 70,000–250,000 years. All of these recent cognitive adaptations provided enormous adaptive advantages for a bipedal, tool-making hominid that lived in increasingly larger social networks in extensive wooded grasslands and later in even more challenging ecological contexts (e.g., Hallett et al., 2025; Hare, 2017, p. 166; Henn et al., 2011). These adaptations add up to an enlarged, rewired, and more densely connected set of brain regions that could, for the first time in mammalian history, bring together the past and the present to imagine alternative ways to think and behave in the future.

In this view, waking simulations are a cognitive process that allows people "to mentally 'try out' different ways that upcoming events might play out without engaging in actual behaviors," a process that is sometimes called "episodic simulations" or "episodic prospecting" (Spreng et al., 2018, p. 23). In addition, the various regions of the brain that are in good part responsible for these new waking capabilities, which are largely located in the default network, also facilitated far greater cooperation, collaboration, and collective innovative advances in material culture than were possible for earlier hominids (e.g., Hare, 2017; Hare & Woods, 2020; Wrangham, 2019). When placed within this larger context, dreaming has an honorable lineage as a result of being a by-product of these important evolutionary adaptations.

In drawing these conclusions, however, it is also essential to note that the adaptive functions supported by the default network also involve interactions between the default network and the FPCN, as explained in Chapter 9. Thus, the waking adaptive evolutionary value of the default network does not necessarily carry over to the portions of the default network that are active during dreaming, as shown by discussions of the inadequacies of all adaptive theories of dreaming at various points in Chapters 2 and 10. That said, the dreaming brain often dramatizes waking personal concerns, as demonstrated in Chapters 3 and 4, such as ongoing grievances with family members and acquaintances. Dreams therefore have psychological meaning even though the process of dreaming is an evolutionary by-product.

Although dreaming does not appear to have any evolutionarily adaptive value, an impressive array of anthropological and historical studies carried out in several different parts of the world over the past 165–170 years nonetheless reveal that the puzzling and sometimes frightening nature of dreams has led humans to create both collective and personal uses for dreams. People in an extensive range of indigenous societies concluded that dreams are part of another world, a world in which a person's wandering soul meets other wandering souls. Dreaming thereby becomes one basis for believing in an afterlife, and also a basis for religion, for healing ceremonies, and for foretelling the future (e.g., Benjamin, 2014; Bulkeley, 2008; D'Andrade, 1961; Gregor, 1981b; LaBarre, 1972; Tylor, 1871/1958). Dreams are also used by some artists, poets, novelists, and many others as a basis for creative work or for a greater understanding of themselves (e.g., Barrett, 2001; Blagrove et al., 2019; Edwards et al., 2013; Epel & Nichols, 1993; Townley, 1998).

Conclusion

In addition to supporting the neurocognitive theory of dreaming, the robustness of the similar findings that result from these three very different methodologies—neuroimaging studies, lesion studies, and developmental studies—creates doubts about several theories of dreaming that were developed in the pre-neuroimaging era. To begin with, these three sets of findings, when joined with quantitative studies of dream content, refute clinical theories of dreaming, which blossomed in the first half of the 20th century (e.g., Freudian and Jungian theory). This point is discussed in more detail, with regard to Freudian theory as the prototype, in Chapter 10.

The new findings also create doubts about the post-1960s, neurophysiologically oriented theories that rely on the neural substrates that support REM sleep as their sole or primary basis. These REM-oriented neurophysiological theories tend to downplay or ignore neurocognitive networks and to doubt or ignore the psychological meaning that can be found in dream reports. The implications of systematic findings on dreaming and dream content for REM-oriented theories are discussed in Chapter 10.

Finally, the findings on dreaming and dream content that support a neurocognitive theory of dreaming also lead to grave doubts about theories claiming that waking activities and the events of the day are the stuff of dream content. Their emphasis on the incorporation of waking activities as the basis for dream content rests on the implicit assumption that the cognitive processes that are available during dreaming are by and large similar to those that operate during waking. This wake-state bias thereby downplays the imaginative nature of dreaming and ignores or minimizes the limitations on cognitive functioning during dreaming (Windt, 2015, pp. 9, 200, 309–310, 500, for the concept of a wake-state bias). The incorporation theory is discussed briefly in a later section of Chapter 4 and then analyzed more fully in Chapter 10.

Having presented overviews of the three theories, the methodologies used in studying them, and a glimpse of the empirical evidence that supports them now completed, it is possible to turn to more detailed discussions of the many claims that have been made in this chapter. This journey begins with an empirically based discussion of the contours of the unique neurocognitive network that supports dreaming. The claim of uniqueness for this network has important implications.