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*Review Article*

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# Why Sleep Matters: The Hidden Power Behind Rest

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**ABSTRACT**
This review article summarizes the fundamental structure of sleep, how each stage takes a major role in regulating effectiveness of human memory and mood. The circadian rhythm, governed by the suprachiasmatic nucleus (SCN), synchronizes bodily functions with the 24-hour light-dark cycle, while adenosine accumulation creates homeostatic sleep pressure. The glymphatic system, active during deep sleep, clears neurotoxic waste from the brain. Sleep cycles alternate between non-rapid eye movement (NREM) and rapid eye movement (REM) phases, each supporting distinct neurophysiological functions such as memory consolidation and emotional regulation. Disruption of these processes leads to impaired cognition, mood instability, and metabolic dysfunction.

**Keywords:** Sleep Architecture; Circadian Rhythm; Adenosine; Glymphatic System; Memory; Emotion Regulation

## Introduction

In today's fast-paced society, wakefulness is often equated with productivity and success. The popular phrase "I'll sleep when I'm dead" perfectly illustrates how rest is undervalued in modern life. Sleep, a state that occupies nearly one-third of our lifetime and appears to be nothing more than a pause filled with dreams, in fact performs powerful biological functions. It underlies how we memorize information and maintain mental stability.

This review explores the hidden processes behind daily sleep, describes the brain structures involved, and examines how sleep influences memory and emotional balance. By the end of reading, the author hopes to give a boarder awareness of sleep deprivation consequences for a modern person.

## Circadian Cycle

Human organisms are instructed by two main systems, that make a person feel sleepy. One of them is the circadian cycle; it is a human 24-hour internal clock.

It's a group of nerve cells in the hypothalamus, which is located among others brain structures of the limbic system, forming a structure called the suprachiasmatic nucleus (SCN). The SCN's location is strategic: it sits at the intersection of the optic nerves, which transmit information about light from the external environment. When light reaches the photoreceptors, it activates the SCN, which then sends signals to the pineal gland, a tiny structure in the epithalamus, to inhibit the synthesis of melatonin, our sleep hormone, which peaks right before bedtime, making us feel sleepy [1].

However, artificial light, especially blue light from our phones, deceives the SCN by "hiding" the fact that night is approaching. An example can be a person who taking more than 20 minutes to fall asleep when scrolling through phone screen or the Mammoth Cave experiment from 1938, which mistakenly estimated that the human cycle is around 28 hours during the project, when not knowing light influence on cycle [2].

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It's important to mention that not only does light play a role in sleep pattern building. The concept of 'zeitgeber', which was first described in Jürgen Aschoff work where he found that certain external cues, influence the timing of these internal clocks. The mechanism is based on a rewards approach, when behavior adjusts to environmental factors. Without zeitgebers, the circadian rhythm is said to be free running, which means that human daily habits aid him to structures better sleeping patterns according to his schedule [3].

In everyday language, we often describe people as "night owls" or "morning larks." Approximately 40% of individuals are morning types; 30% are evening types, and the remainder fall between the two. Unfortunately, societal schedules favor early risers, which can disadvantage night-oriented individuals. From an evolutionary perspective, however, this variation likely served a purpose: having both early and late sleepers within a group ensured vigilance throughout the night, reducing vulnerability to predators.

**Sleeping Pressure: Regulatory Hormones. Glymphatic system**

The second sleep regulator is sleeping pressure, governed primary by adenosine molecules. With every movement, thought, or any other energy-consuming process, adenosine nucleotides are produced by breaking down ATP or adenosine triphosphate. Raised level of adenosine will activate its own receptors called A1R and A2aR, which are located in the hypothalamus and basal forebrain. This binding triggers a cascade of cellular events that ultimately decrease neuronal activity and increase sleepiness [4,5].

Caffeine acts as a competitive antagonist of adenosine receptors. However, during 5–7 hours of receptor blocking, adenosine will still be accumulating. Once caffeine is metabolized, adenosine rapidly binds to its receptor, resulting in a double effect or 'caffeine crash'. [ From book 'Why we sleep' by Matthew Walker].

Even with all this accumulated adenosine in our body throughout the day, people are able to wake up feeling refreshed. It leads to the assumption that 'waste products', among them beta- amyloid proteins, which are linked to the progression of Alzheimer's disease, are removed from the organism. The lead role during this process takes a glymphatic system, which primarily works during slow-wave sleep (NREM stage 3). During this part of the sleep cerebrospinal fluid has an ability to move from more surfaced subarachnoid meninges of the brain into deeper areas of it with help of relaxation within tissues. Without sufficient deep sleep, toxic waste products can accumulate, potentially contributing to neurodegenerative disease progression [6].

**Polysomnography: Electrical Activity of a Sleep**

To better understand sleep, it is important to acknowledge that all our brain activity is a set of different electrical signals between neurons, which connect by synapsis. Those signals were first determined in 1924 by Hense Berger by using electro cephalogram, a key component of polysomnography [7].

Polysomnography includes monitoring of eye movements (EOG), muscle activity or skeletal muscle activation (EMG), and heart rhythm (ECG), but the one that person in majority time sees on the graph is EEG. It observes the frequency of neuron activity through electrodes attached to different areas of a scalp. The main unit is Heltz, which helps to divide neuron activity into alpha (8–13 Hz), beta (13–30 Hz), delta (0.5–4 Hz), and theta (4–7 Hz). With combination of previously mentioned detected factors American scientist named Loomis was able labeled different stages of sleep with simple letters: A, B, C, D, E [8].

In 1952, two scientists, Aserinsky and Kleitman, made a big discovery. They noticed that during sleep, people sometimes have rapid eye movements, and at other times, their eyes stay still. They provided a clear deferrization of sleep which we broadly use nowadays: REM and non-REM (with it 3 stages) [7].

**Sleep Architecture**

Our sleep is not first 4 hours of NREM and then 4 h of other, instead it is a set of cycle each 90 minutes which has different amounts of NREM and REM sleep in it. Within each cycle there is a predictable alternation between each stage which is called ultradian rhythm. NREM is stronger at the start of the night, but as morning approaches, REM starts to take over. To have a gainful output of each stage from a cycle, humans need to sleep through them in an approximate 4-5 time. Based on this fact, estimated worldly approved time of sleep in 8 hours (5 stages multiplied by 90minutes= 450min/60=7,5h) [9].

To comprehend the idea behind switching interaction of stages within cycle, it is important to understand the function behind each stage.

During wake time, the human brain produces around 30–40 waves per second, while in deep NREM sleep, numbers decrease by 10 times. Therefore, instead of having a dramatic decrease in brain activity to enter the most vivid stage of sleep, the organism has 2 transitions.

One of them is NREM stage 1. This is a brief, maximum 7 minutes, stage which is mostly observed during the first part of sleep and appears between wakefulness and sleep. During this stage, the person can easily awaken, and the muscle tone still remains.

As brain activity, temperature, heart rate decreases and eye movement stop completely, humans enter an unconscious state of stage 2 of NREM sleep. Disconnection from real life comes due to the K-complex (a burst of high-voltage activity around 100 qV with a frequency of 1–1.7 minutes). K-complex helps analyze the external factors which come into the thalamus (gate for information in our brain) without a need to fully engage the brain from a sleepy state. On diagraph, the K-complex is always followed by sleeping splinders or a high burst of voltages with higher frequency at about 0,5-1.5 seconds. They also play a role in blocking activity of the thalamus, along with connecting it with the brain cortex. The latest makes a great contribution to the learning process by transferring short-term memory from

the hypothalamus into different areas of the cortex. It also correlates with a dream state, but to a lesser amount than in REM. Studies show that after a long learning process, during the wake time, the amount of sleeping splinders increases proportionally. Taking into consideration all the important features which this stage provides, humans spend around 15– 20 minutes on it during the first period and increase the amount closer to the morning hours, which costs around 50% of the sleep amount [10,11].

NREM stages 3 and 4 are basically categorized under one definition of delta wave sleep (slow-wave stage) or deep sleep. Those stages are associated with restoration time when muscles are completely relaxed, and there is no response to environmental factors. During this stage, the cerebrospinal fluid of the glymphatic system of an organism has a unique chance to penetrate a more inside layer of our brain rather than just a subarachnoid one. With such an option, the previously mentioned, accumulated waste of the brain cortex can be cleared out. During the first part of the sleep cycle, the organism sets a main goal of restoring energy and cleaning waste by being about 20–40 minutes deep sleep. Therefore, the major amount of deep sleep is at the beginning, while when morning approaches, the amount of REM sleep increases. By the end of each cycle, we pass back through lighter sleep stages (in a kind of U shape), or briefly wake up, though most people don't remember these awakenings as they last only seconds, and enter a stage similar in brain signals to awake-REM [11].

At the beginning of different stages, examination with EGG was identifying REM and stage 1 as one. However, it was mentioned that in one of the stages, rapid eye movement appeared, which proved a name for the dreaming stage of our sleep — REM. During this stage, the thalamus opens again to play the role of projector for our vivid dreams, which is the result of high activity of the brain to interconnect new memories with older one giving them emotional and a new way of looking form. As a way of keeping us still in bed while our brain has the same electrical activity as shutting out wake take, REM is associated with atonia, completing the paralyzation of most muscles an eye [12].

Most of the time, people tend to forget their dreams, since REM is mainly concentrated on boosting warriors' connection between area and society, rather than memory consolidation. Because of this, different chemicals are produced, and, upon weakening time, the human might have only a slight recognition of his dream.

Under normal circumstances, you don't enter a REM sleep until you've been asleep for about 90 minutes. As the night goes on, the REM stages get longer, especially in the second half of the night. While the first REM stage may last only a few minutes, later stages can last for around an hour. In total, REM stages make up around 25% of sleep-in adults.

If we had one long NREM phase and one long REM phase, that "dialogue" between stages would be lost. It would dramatically decrease the ability of an organism to shift from one stage to another, making him stuck in an inactive state. This would have led to a problem with memory consolidation, creativity, etc.

**Memory consolidation and Emotion Stabilization**

All previously described stages hold a common function of sleep for human organisms - straightens and produces synaptic connections between neurons within the brain, which is a network of them. Those connections act as railways for transporting signals whose carry information from the environment or the organism itself.

In terms of memory, the consolidation of those trails enables people to recall and memorize information, as well as to forget them [13]. From the experiments, the most effective at memorizing facts was shown in NREM stage 2 with her sleeping splinders and K-complexes. During the day, a person accumulates information within a so-called short-term memory within their hippocampus. As night approaches and a human stop to receive signals from the environment, his brain gains an ability to revisit the ones already consumed. An active mechanism within our brain helps us clear out unnecessary pieces of information so that we can retain the most relevant for long-term storage of the cortex. The sleeping splinder plays the role of 'sorter' who transfers information to different areas of the cortex to connect them with already existing memory or by building up a new neuron connection. It's important to highlight that if the synaptic pass wasn't activated by the active recalling, it's therefore degrading the connection and the memory fades [14].

After a sleepless night, people are more irritable, anxious, or prone to mood swings. That's no coincidence. Connection between our emotional center (limbic system) which includes amygdala (is where many of our emotions are generated) and the prefrontal cortex, also straightens during night's sleep. It plays the role of the "emotion regulator," keeping our emotional responses in check, whether positive or negative. With sleep deprivation, this connection weakens. Studies have shown that after just one night of sleep deprivation, amygdala activity can increase by as much as 60%. In other words, without sleep, our emotional brain goes overdrive, reacting more intensely to every trigger, whether it's something good or bad. This isn't exactly a healthy way for our mind to process the world [15].

Sleep also acts as an emotional "therapy session." Both REM and NREM sleep help people to regulate and process emotions, reducing leftover stress or emotional residue from the day.

Even nightmares have a purpose. They allow the brain to replay intense emotions in a safe space, so we can eventually leave them behind [ From book 'Why we sleep' by Matthew Walker]

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