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# Processes Influencing Wakefulness

Excerpted from *Sleep: Excessive Sleepiness*

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Figure 1

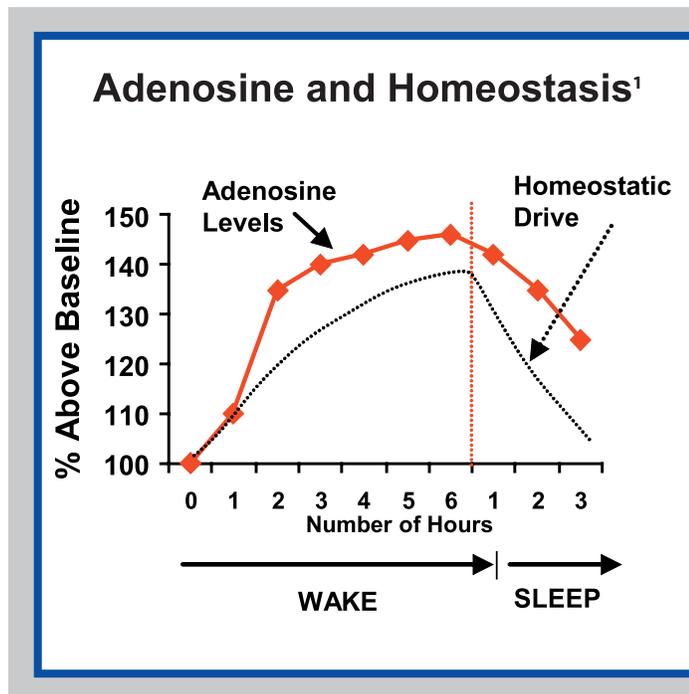
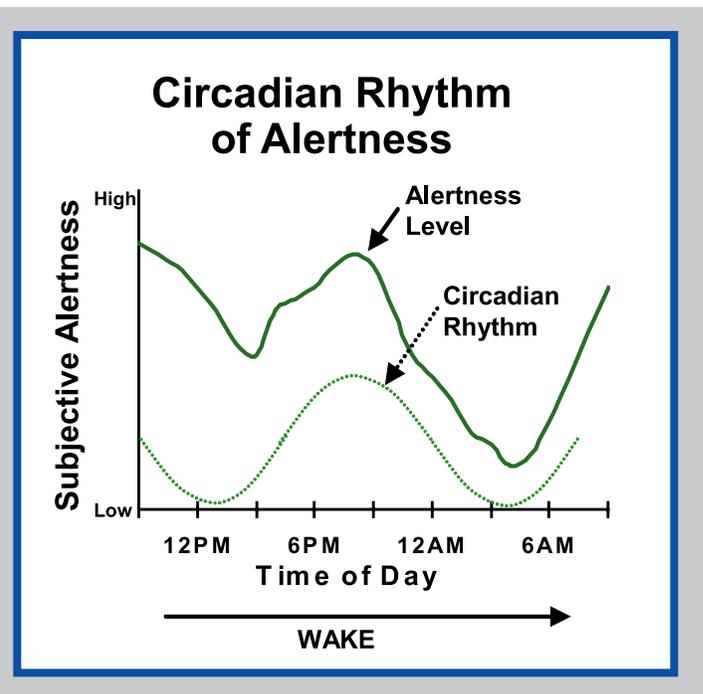


Figure 2



**Figure 1:** There are two main processes controlling sleep/wake cycles. During wakefulness, the homeostatic drive for sleep gradually increases as the body becomes more fatigued and decreases as the body rests during sleep. Similarly, the homeostatic factor, adenosine, accumulates in the basal forebrain during prolonged wakefulness and decreases during recovery sleep in cats.

**Figure 2:** The other major process controlling the sleep/wake cycle is the endogenous circadian rhythm. Circadian influences on arousal can be seen in the average subjective alertness level of humans across a 24-hour period of wakefulness.

While many factors can influence arousal, such as hunger and activity, there are two overriding processes to consider. The homeostatic drive for sleep rises during waking periods and is relieved during sleep. In other words, a person builds up a sleep debt when awake and pays it off during sleep. It is this homeostatic drive that leads to feelings of excessive sleepiness during a state of sleep deprivation. If sleep is disrupted, such as in patients with sleep apnea, the homeostatic drive is not fully relieved and contributes to increased sleepiness the following day. This type of sleep debt may not be readily repaid through more sleep since the sleep itself is abnormal and non-restorative.

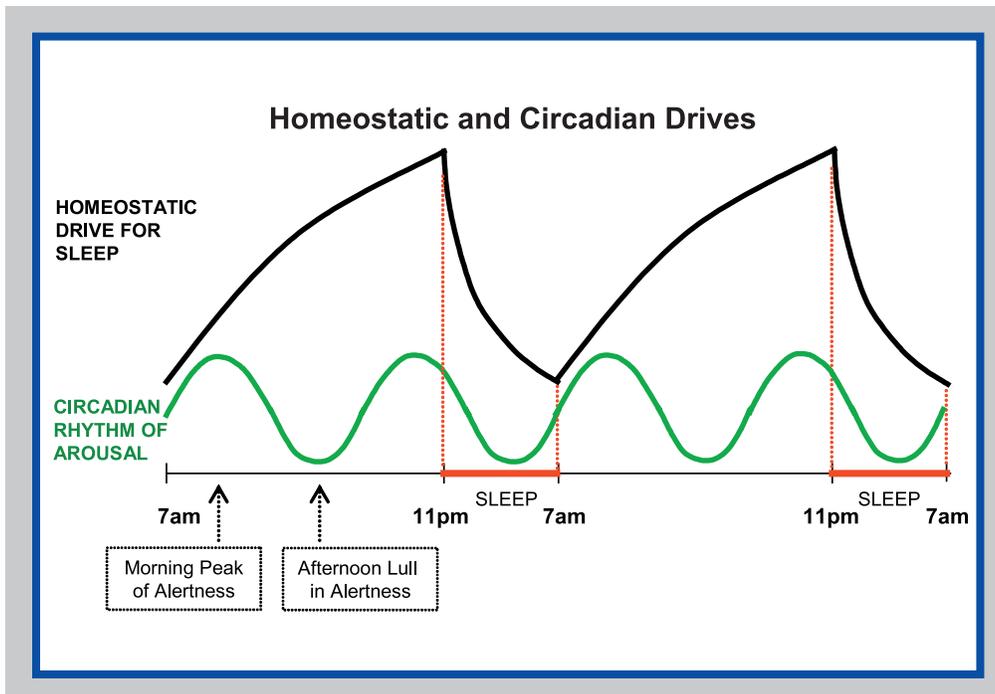
The energy metabolite, adenosine, has been hypothesized as a homeostatic regulator of sleep (Basheer et al. 2004). Prolonged wakefulness results in an accumulation of extracellular adenosine, due to the breakdown of adenosine triphosphate (ATP) during

neural activity. Adenosine reduces arousal by inhibiting cholinergic projection cells in the basal forebrain and promotes sleep by indirectly activating neurons in the VLPO (the sleep-promoter). During sleep, adenosine levels decline, supporting the idea that one function of sleep is to replenish energy resources.

Circadian rhythms affect nearly all physiological systems, including body temperature, hormone release, cell proliferation, and sleep/wake cycles. Circadian influences prepare the brain to be alert during the day by augmenting activity of arousal circuits, and to rest during the night by dampening arousal circuits. This influence can easily be demonstrated during sleep deprivation; even after missing an entire night of sleep, people tend to get a "second wind" in the early morning, as the internal clock prepares the brain for daily activity. Variations in the natural circadian rhythm of individuals account for why some people are "morning-types" while others may be "night owls."

A person builds up sleep debt when awake and pays it off during sleep.

Figure 3



**Figure 3:** In reality, one’s alertness is the sum of both homeostatic and circadian drives, determined by the time of day and one’s recent sleep history. Illustrated here is the homeostatic process superimposed upon the endogenous circadian rhythm of arousal. Due to this physiological interaction, individuals are likely to feel a greater level of arousal during the morning and less arousal in the early afternoon. At night, the homeostatic drive peaks just as the circadian arousal is cycling to its lowest point, allowing one to sleep.

The interaction of circadian and homeostatic processes predicts how sleepy or alert a person feels throughout the day. In the morning, the circadian influence on arousal is high and the drive for sleep is low so people tend to feel very alert. The afternoon lull in alertness that most people experience is due to an increasing drive for sleep at a time when the circadian influence on arousal is low. Excessive sleepiness can occur when a person’s circadian rhythm is out of sync with the sleep/wake schedule they follow, such as in shift-work sleep disorder. People with this sleep disorder have a hard time paying off their sleep debt since they are trying to sleep when circadian arousal levels are high. ❖

Reference

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