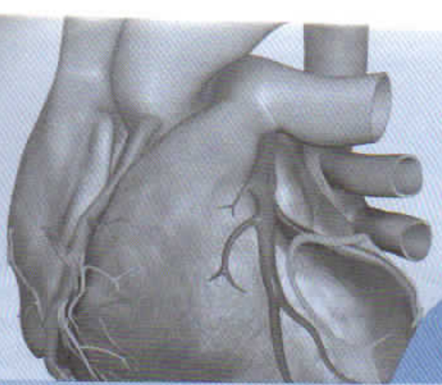

CHAPTER 43

The Science of Sleep

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Drowsy driving kills more than 1,550 people a year in the United States and causes 71,000 injuries, according to the National Highway Traffic Safety Administration, which estimates there are 100,000 sleep-related crashes a year.[1]

LEARNING OBJECTIVES

By the end of this chapter, students will be able to:

- Describe the physiological processes that control sleepiness and wakefulness.
- Connect how disruptions in those processes place an individual at risk for injury or other disease.
- List the most common sleep disorders.
- Discuss how sleep disorders impact the public's health.

INTRODUCTION

No doubt, the consequences of **sleep** loss are significant. Historic tragedies have been linked to fatigue-related human error, among them the Exxon *Valdez* oil spill[1] and the NASA *Challenger* shuttle explosion.[2] The grave outcomes of events like these are just some of the reasons why improved understanding of the biology of sleep and wake can lead to improved quality of life and safety.

Emerging science and advances in technology now are allowing us to examine sleep at a level of detail never before possible. In addition to documenting the more obvious consequences of poor sleep, scientists are increasingly exploring what happens during sleep at the neurological and physiological levels. What they are discovering is that sleep provides more benefits than previously thought and is absolutely crucial to promoting health and maintaining physiological processes.

So why is sleep so important? Although we naturally think of sleep as a time of rest and recovery from the stresses of everyday life, research is revealing that sleep is a dynamic activity, during which many processes vital to health and well-being take place. New evidence shows that sleep is essential to helping maintain mood, memory, and cognitive performance. It also plays a pivotal role in the normal function of the endocrine and immune systems. In fact, studies show a growing link between sleep duration and a variety of serious health problems, including obesity, diabetes, hypertension, and depression.

It is no exaggeration to say that some of the most pressing problems we face as a society may be linked to poor sleep. Drowsiness in sleep-deprived drivers is likely the cause of more than 100,000 crashes, 71,000 injuries, and more than 1,550 deaths each year.[3] In addition, sleep disorders are estimated to cost Americans over $100 billion annually in lost productivity, medical expenses, sick leave, and property and environmental damage.[4] On a personal level, we all know how miserable we feel after a night of poor sleep.

Despite the fact that at least 40 million Americans report having sleep problems, more than 60 percent of adults have never been asked about the quality of their sleep by a physician, and fewer than 20 percent ever initiated a discussion about it.[5] Clearly, sleep's impact on health and well-being is under-recognized. But the growing body of knowledge about the complex structure, function, and mechanisms of sleep as well as the consequences when sleep is lost or disturbed, should serve as a wake-up call for making sleep a public health priority.

BASIC SCIENCE FACTS/KEY CONCEPTS REVIEW

To understand the importance of sleep, it is helpful to know something about the basic mechanisms of the **sleep-wake cycle.** This cycle, which consists of roughly 8 hours of nocturnal sleep and 16 hours of daytime wakefulness in humans, is controlled by a combination of two internal influences: sleep **homeostasis** and **circadian rhythms**.

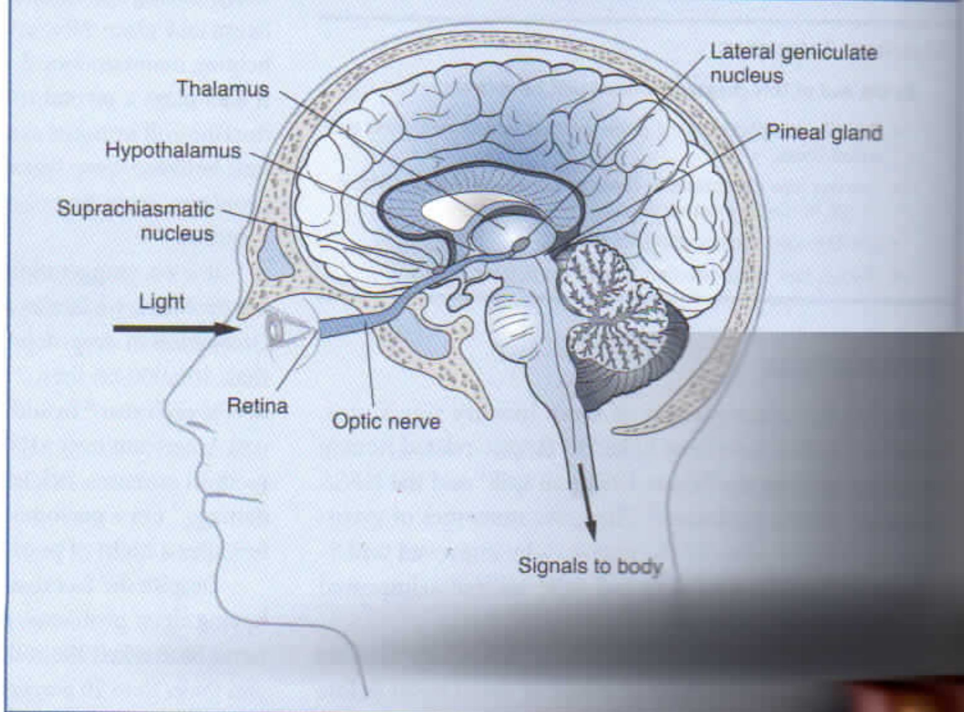
Homeostasis is the process by which the body maintains a "steady state" of internal conditions such as blood pressure, body temperature, and acid-base balance. The amount of sleep each night is also under homeostatic control. From the time that we wake up, the homeostatic drive for sleep accumulates, reaching its maximum in the late evening when most individuals fall asleep. Although the neurotransmitters of this sleep homeostatic process are not fully understood, there is evidence to indicate that one may be the sleep-inducing chemical, adenosine. As long as we are awake, blood levels of adenosine rise continuously, resulting in a growing need for sleep that becomes more and more difficult to resist. Conversely, during sleep, levels of adenosine decrease, thereby reducing the need for sleep. Certain drugs, like caffeine, work by blocking the adenosine **receptor**, disrupting this process.

Sleep loss results in the accumulation of a sleep debt that must eventually be repaid. When we stay up all night, for example, our bodies will demand that we make up each hour of lost sleep—by napping or sleeping longer in later cycles—or suffer the consequences. Even the loss of one hour of sleep time that accumulates for several days can have a powerful negative effect on daytime performance, thinking, and mood.

Circadian rhythms refer to the cyclical changes—like fluctuations in body temperature, hormone levels, and sleep—that occur over a 24-hour period, driven by the brain's biological "clock." In humans, the biological clock consists of a group of neurons in the **hypothalamus** of the brain called the **suprachiasmatic nucleus** (SCN) (Figure 43-1). These internal 24-hour rhythms in physiology and behavior are synchronized to the external physical environment and social/work schedules. In humans, light is the strongest synchronizing agent. Light and darkness are external signals that "set" the biological clock and help determine when we feel the need to wake up or go to sleep. In addition to providing synchronization in time between various rhythms, the circadian clock also helps promote wakefulness.

Thus, the homeostatic system tends to make us sleepier as time goes on throughout the waking period, regardless of whether it's night or day, while the circadian system tends to keep us awake as long as there is daylight, prompting us to sleep as soon as it becomes dark. Because of the complexity of this interaction, it is generally agreed that sleep quality and restfulness are best when the sleep schedule is regularly synchronized to the internal circadian rhythms and that of the external light-dark cycle: when we try to go to bed and wake up at around the same time each day, even on days off and

FIGURE 43-1 The Brain.



Source: Sleep-Wake Cycle: Its Physiology and Impact on Health, ... at http://www.sleepfoundation.org. Reprinted with ...

weekends. Moreover, the circadian system is particularly intolerant of major alterations in sleep and wake schedules, as anyone who has traveled cross-country by plane or worked the graveyard shift can attest.

Disruptions of the Circadian System

What happens when circadian rhythms are disrupted? Not surprisingly, when we attempt to stay awake against the schedule dictated by our circadian clock, our mental and physical performance is greatly diminished. Conditions associated with a disruption of circadian rhythms include shift work, jet lag, and other circadian rhythm sleep disorders. In jet lag, times for sleep and wakefulness dictated by the internal circadian clock do not correspond with external cues in the new time zone. The result is excessive sleepiness, poor sleep, loss of concentration, poor motor control, slowed reflexes, nausea, and irritability. Those who perform shift work, particularly on night shifts, also may experience the effects of a disrupted circadian sleep-wake cycle; research shows that 10 percent to 20 percent of shift workers report falling asleep on the job. They also may suffer from diminished performance and alertness, and may be more prone to accidents. Strategies to re-align circadian rhythm, such as using light and **melatonin** can help. There is also evidence that taking a nap in the middle of a night shift may help. Naps—even as short as 20 minutes—can maintain or improve alertness, performance, and mood.

The Stages of Sleep

Although it is common to think of sleep as a time of "shutting down," sleep is actually an active physiological process. While metabolism generally slows down during sleep, all major organs and regulatory systems continue to function. In fact, sleep can be categorized into distinct stages. There are two types of sleep: ***rapid eye movement (REM) sleep*** and ***non-REM (NREM) sleep***. Changes in brain activity that take place are measured using an electroencephalogram (EEG).

NREM Sleep

NREM sleep is characterized by a reduction in physiological activity. As sleep gets deeper, the brain waves as measured by an electroencephalogram (EEG) get slower and have greater amplitude, breathing and heart rate slow down, and blood pressure drops. The NREM phase consists of four stages[6] (Figure 43-2):

- Stage 1 is a time of drowsiness or transition from being awake to falling asleep. Brain waves and muscle activity begin to slow down during this stage. People in stage 1 sleep may experience sudden muscle jerks, preceded by a falling sensation.
- Stage 2 is a period of light sleep during which eye movements stop. Brain waves become slower, with occasional bursts of rapid waves called sleep spindles, coupled with spontaneous periods of muscle tone mixed with periods of muscle relaxation. The heart rate slows and body temperature decreases.
- Stages 3 and 4 (which together are called slow wave sleep) are characterized by the presence of slow brain waves called delta waves interspersed with smaller, faster waves. Blood pressure falls, breathing slows, and body temperature drops even lower, with the body becoming immobile. Sleep is deeper, with no eye movement and decreased muscle activity, though muscles retain their ability to function. It is most difficult to be awakened during slow wave sleep. People who are awakened during these stages of sleep may feel groggy or disoriented for several minutes after they wake up. It also is during this stage that some children experience bedwetting, night terrors, or sleepwalking.

REM Sleep

REM sleep is an active period of sleep marked by intense brain activity. Brain waves are fast and desynchronized, similar to those in the waking state. Breathing becomes more rapid, irregular, and shallow; eyes move rapidly in various directions and limb muscles become temporarily paralyzed. Heart rate increases and blood pressure rises. This also is the sleep stage in which most dreams occur. Although the role each of these states plays in overall health is uncertain, having the right balance between them is believed to be important for obtaining restful, restorative sleep and for promoting processes such as learning, memory, mood, and ability to concentrate.

Sleep Architecture: The Right Mix of Sleep

Sleep research shows that adults of every age need, on average, a range of seven to nine hours of sleep each night; teenagers need about 9.5 hours, and infants generally require around 16 hours per day.[7] But just as important as the quantity of sleep is getting the right mix of REM and NREM sleep as well as shallow and deep sleep. In normal sleep, REM and NREM sleep alternate throughout the night according to a predictable pattern referred to as the "sleep architecture."[8] A complete sleep cycle consists of NREM and REM cycles that alternate every 90 to 110 minutes and is repeated four to six times per night.[9] Adults, on average, spend more than half of their total daily sleep time in stage 2 sleep, about 20 percent in REM sleep, and the remaining time in the other stages, but the amount of time spent in any given stage is not constant over the course of a night.[10] The first sleep cycles each night contain