

Module 23

Sleep Patterns and Sleep Theories

Module Learning Objectives

- 23-1** Describe how our biological rhythms influence our daily functioning.
- 23-2** Describe the biological rhythm of our sleeping and dreaming stages.
- 23-3** Explain how biology and environment interact in our sleep patterns.
- 23-4** Describe sleep's functions.

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Sleep—the irresistible tempter to whom we inevitably succumb. Sleep—the equalizer of teachers and teens. Sleep—sweet, renewing, mysterious sleep. While sleeping, you may feel “dead to the world,” but you are not. Even when you are deeply asleep, your perceptual window is open a crack. You move around on your bed, but you manage not to fall out. The occasional roar of passing vehicles may leave your deep sleep undisturbed, but a cry from a baby’s room quickly interrupts it. So does the sound of your name. Electroencephalograph (EEG) recordings confirm that the brain’s auditory cortex responds to sound stimuli even during sleep (Kutas, 1990). And when you are asleep, as when you are awake, you process most information outside your conscious awareness.

Many of sleep’s mysteries are now being solved as some people sleep, attached to recording devices, while others observe. By recording brain waves and muscle movements, and by observing and occasionally waking sleepers, researchers are glimpsing things that a thousand years of common sense never told us. Perhaps you can anticipate some of their discoveries. Are the following statements true or false?

1. When people dream of performing some activity, their limbs often move in concert with the dream.
2. Older adults sleep more than young adults.
3. Sleepwalkers are acting out their dreams.
4. Sleep experts recommend treating insomnia with an occasional sleeping pill.
5. Some people dream every night; others seldom dream.

All these statements (adapted from Palladino & Carducci, 1983) are *false*. To see why, read on.

Biological Rhythms and Sleep

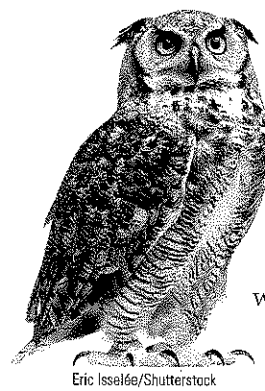
Like the ocean, life has its rhythmic tides. Over varying periods, our bodies fluctuate, and with them, our minds. Let’s look more closely at two of those biological rhythms—our 24-hour biological clock and our 90-minute sleep cycle.

“I love to sleep. Do you? Isn’t it great? It really is the best of both worlds. You get to be alive and unconscious.” -COMEDIAN RITA RUDNER, 1993

Circadian Rhythm

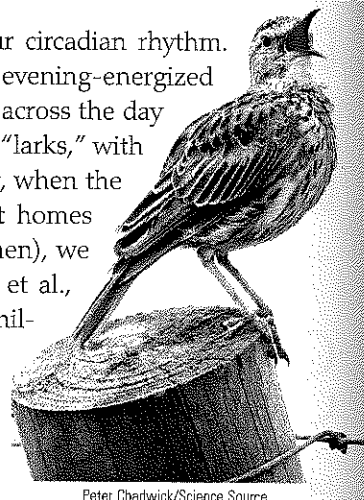
23-1 How do our biological rhythms influence our daily functioning?

The rhythm of the day parallels the rhythm of life—from our waking at a new day's birth to our nightly return to what Shakespeare called "death's counterfeit." Our bodies roughly synchronize with the 24-hour cycle of day and night by an internal biological clock called the **circadian rhythm** (from the Latin *circa*, "about," and *diem*, "day"). As morning approaches, body temperature rises, then peaks during the day, dips for a time in early afternoon (when many people take siestas), and begins to drop again in the evening. Thinking is sharpest and memory most accurate when we are at our daily peak in circadian arousal. Try pulling an all-nighter or working an occasional night shift. You'll feel groggiest in the middle of the night but may gain new energy when your normal wake-up time arrives.



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Age and experience can alter our circadian rhythm. Most teens and young adults are evening-energized "owls," with performance improving across the day (May & Hasher, 1998). Most older adults are morning-loving "larks," with performance declining as the day wears on. By mid-evening, when the night has hardly begun for many young adults, retirement homes are typically quiet. At about age 20 (slightly earlier for women), we begin to shift from being owls to being larks (Roenneberg et al., 2004). Women become more morning oriented as they have children and also as they transition to menopause (Leonhard & Randler, 2009; Randler & Bausback, 2010). Morning types tend to do better in school, to take more initiative, and to be less vulnerable to depression (Randler, 2008, 2009; Randler & Frech, 2009).



Peter Chadwick/Science Source

Sleep Stages

23-2 What is the biological rhythm of our sleeping and dreaming stages?

Sooner or later, sleep overtakes us and consciousness fades as different parts of our brain's cortex stop communicating (Massimini et al., 2005). Yet the sleeping brain remains active and has its own biological rhythm.

About every 90 minutes, we cycle through four distinct sleep stages. This simple fact apparently was unknown until 8-year-old Armond Aserinsky went to bed one night in 1952. His father, Eugene, a University of Chicago graduate student, needed to test an electroencephalograph he had repaired that day (Aserinsky, 1988; Seligman & Yellen, 1987). Placing electrodes near Armond's eyes to record the rolling eye movements then believed to occur during sleep, Aserinsky watched the machine go wild, tracing deep zigzags on the graph paper. Could the machine still be broken? As the night proceeded and the activity recurred, Aserinsky realized that the periods of fast, jerky eye movements were accompanied by energetic brain activity. Awakened during one such episode, Armond reported having a dream. Aserinsky had discovered what we now know as **REM sleep** (rapid eye movement sleep).

Similar procedures used with thousands of volunteers showed the cycles were a normal part of sleep (Kleitman, 1960). To appreciate these studies, imagine yourself as a participant. As the hour grows late, you feel sleepy and yawn in response to reduced brain metabolism. (Yawning, which can be socially contagious, stretches your neck muscles and increases your heart rate, which increases your alertness [Moorcroft, 2003].) When you are ready for bed, a

FYI

Dolphins, porpoises, and whales sleep with one side of their brain at a time (Miller et al., 2008).

circadian [ser-KAY-dee-an] **rhythm** the biological clock; regular bodily rhythms (for example, of temperature and wakefulness) that occur on a 24-hour cycle.

REM sleep rapid eye movement sleep; a recurring sleep stage during which vivid dreams commonly occur. Also known as *paradoxical sleep*, because the muscles are relaxed (except for minor twitches) but other body systems are active.

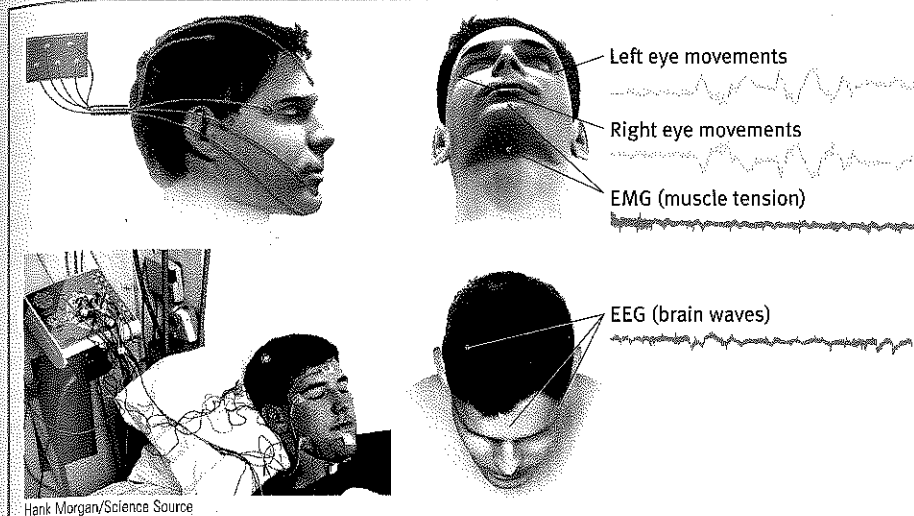


Figure 23.1

Measuring sleep activity Sleep researchers measure brain-wave activity, eye movements, and muscle tension by electrodes that pick up weak electrical signals from the brain, eye, and facial muscles. (From Dement, 1978.)

researcher comes in and tapes electrodes to your scalp (to detect your brain waves), on your chin (to detect muscle tension), and just outside the corners of your eyes (to detect eye movements) (FIGURE 23.1). Other devices will record your heart rate, respiration rate, and genital arousal.

When you are in bed with your eyes closed, the researcher in the next room sees on the EEG the relatively slow **alpha waves** of your awake but relaxed state (FIGURE 23.2). As you adapt to all this equipment, you grow tired and, in an unremembered moment, slip into **sleep** (FIGURE 23.3). The transition is marked by the slowed breathing and the irregular brain waves of non-REM stage 1 sleep. Using the new American Academy of Sleep Medicine classification of sleep stages, this is called NREM-1 (Silber et al., 2008).

In one of his 15,000 research participants, William Dement (1999) observed the moment the brain's perceptual window to the outside world slammed shut. Dement asked this sleep-deprived young man, lying on his back with eyelids taped open, to press a button every time a strobe light flashed in his eyes (about every 6 seconds). After a few minutes the young man missed one. Asked why, he said, "Because there was no flash." But there was a flash. He missed it because (as his brain activity revealed) he had fallen asleep for 2 seconds, missing not only the flash 6 inches from his nose but also the awareness of the abrupt moment of entry into sleep.

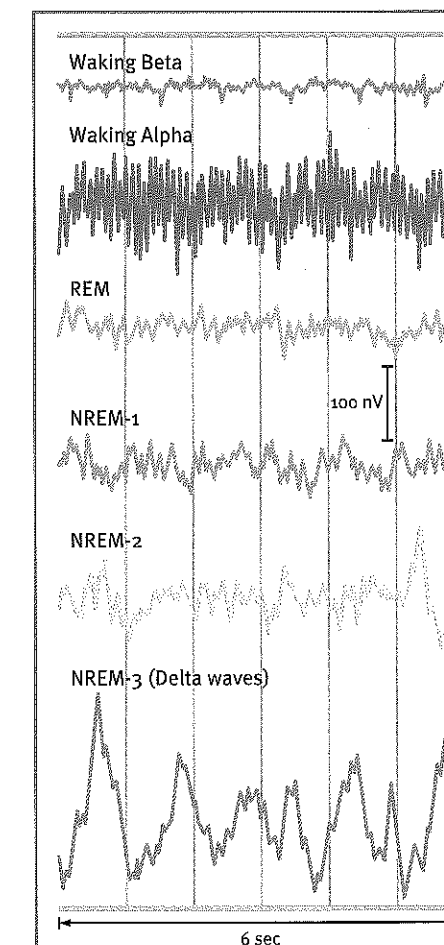


Figure 23.2

Brain waves and sleep stages The beta waves of an alert, waking state and the regular alpha waves of an awake, relaxed state differ from the slower, larger delta waves of deep NREM-3 sleep. Although the rapid REM sleep waves resemble the near-waking NREM-1 sleep waves, the body is more aroused during REM sleep than during NREM sleep.

Rebecca Spencer/University of Massachusetts, assisted with this figure.

alpha waves the relatively slow brain waves of a relaxed, awake state.

sleep periodic, natural loss of consciousness—as distinct from unconsciousness resulting from a coma, general anesthesia, or hibernation. (Adapted from Dement, 1999.)

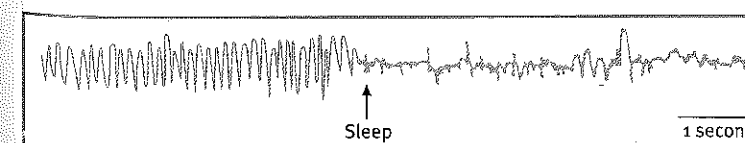


Figure 23.3

The moment of sleep We seem unaware of the moment we fall into sleep, but someone watching our brain waves could tell. (From Dement, 1999.)

hallucinations false sensory experiences, such as seeing something in the absence of an external visual stimulus.

delta waves the large, slow brain waves associated with deep sleep.

NREM sleep non-rapid eye movement sleep; encompasses all sleep stages except for REM sleep.

During this brief NREM-1 sleep you may experience fantastic images resembling **hallucinations**—sensory experiences that occur without a sensory stimulus. You may have a sensation of falling (at which moment your body may suddenly jerk) or of floating weightlessly. These *hypnagogic* sensations may later be incorporated into your memories. People who claim to have been abducted by aliens—often shortly after getting into bed—commonly recall being floated off of or pinned down on their beds (Clancy, 2005).

You then relax more deeply and begin about 20 minutes of NREM-2 sleep, with its periodic *sleep spindles*—bursts of rapid, rhythmic brain-wave activity (see Figure 23.2). Although you could still be awakened without too much difficulty, you are now clearly asleep.

Then you transition to the deep sleep of NREM-3. During this slow-wave sleep, which lasts for about 30 minutes, your brain emits large, slow **delta waves** and you are hard to awaken. Ever say to classmates, “That thunder was so loud last night,” only to have them respond, “What thunder?” Those who missed the storm may have been in delta sleep. (It is at the end of the deep, slow-wave NREM-3 sleep that children may wet the bed.)

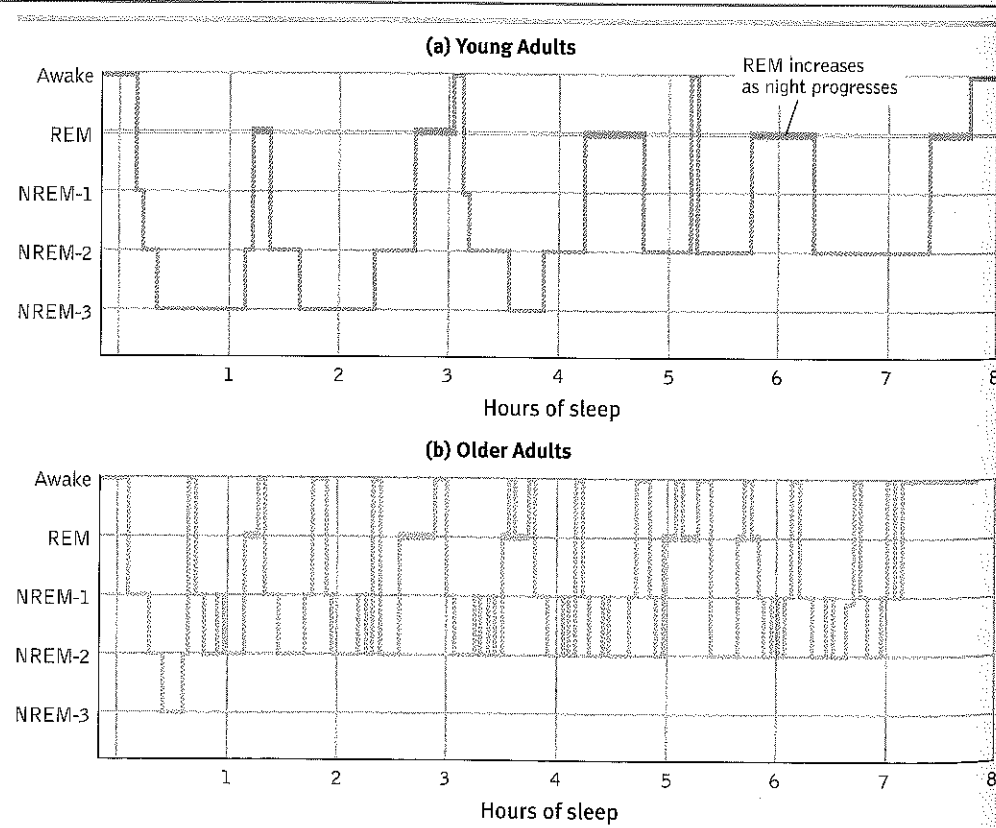
REM SLEEP

About an hour after you first fall asleep, a strange thing happens. You start to leave behind the stages known as **NREM sleep**. Rather than continuing in deep slumber, you ascend from your initial sleep dive. Returning through NREM-2 (where you spend about half your night), you enter the most intriguing sleep phase—REM sleep (**FIGURE 23.4**). For about 10 minutes, your brain waves become rapid and saw-toothed, more like those of the nearly awake NREM-1 sleep. But unlike NREM-1, during REM sleep your heart rate rises, your breathing becomes rapid and irregular, and every half-minute or so your eyes dart around in momentary bursts of activity behind closed lids. These eye movements announce the beginning of a dream—often emotional, usually story-like, and richly hallucinatory. Because anyone watching a sleeper’s eyes can notice these REM bursts, it is amazing that science was ignorant of REM sleep until 1952.



“Boy are my eyes tired! I had REM sleep all night long.”

Figure 23.4
The stages in a typical night’s sleep. People pass through a multistage sleep cycle several times each night, with the periods of deep sleep diminishing and REM sleep periods increasing in duration. As people age, sleep becomes more fragile, with awakenings common among older adults (Kamel et al., 2006; Neubauer, 1999).



AP® Exam Tip
Study this cycle of sleep carefully. One common mistake that students make is to believe that REM sleep comes directly after deep NREM-3 sleep. As you can see, it does not. Generally, NREM-2 follows NREM-3. Then comes REM.

Except during very scary dreams, your genitals become aroused during REM sleep. You have an erection or increased vaginal lubrication, regardless of whether the dream’s content is sexual (Karacan et al., 1966). Men’s common “morning erection” stems from the night’s last REM period, often just before waking.

Your brain’s motor cortex is active during REM sleep, but your brainstem blocks its messages. This leaves your muscles relaxed, so much so that, except for an occasional finger, toe, or facial twitch, you are essentially paralyzed. Moreover, you cannot easily be awakened. (This immobility may occasionally linger as you awaken from REM sleep, producing a disturbing experience of *sleep paralysis* [Santomauro & French, 2009].) REM sleep is thus sometimes called *paradoxical* sleep: The body is internally aroused, with waking-like brain activity, yet asleep and externally calm.

The sleep cycle repeats itself about every 90 minutes. As the night wears on, deep NREM-3 sleep grows shorter and disappears. The REM and NREM-2 sleep periods get longer (see Figure 23.4). By morning, we have spent 20 to 25 percent of an average night’s sleep—some 100 minutes—in REM sleep. Thirty-seven percent of people report rarely or never having dreams “that you can remember the next morning” (Moore, 2004). Yet even they will, more than 80 percent of the time, recall a dream after being awakened during REM sleep. We spend about 600 hours a year experiencing some 1500 dreams, or more than 100,000 dreams over a typical lifetime—dreams swallowed by the night but not acted out, thanks to REM’s protective paralysis.



FYI
People rarely snore during dreams. When REM starts, snoring stops.

FYI
Horses, which spend 92 percent of each day standing and can sleep standing, must lie down for REM sleep (Morrison, 2003).

Safety in numbers? Why would communal sleeping provide added protection for those whose safety depends upon vigilance, such as these soldiers?

ANSWER: With each soldier cycling through the sleep stages independently, it is very likely that at any given time at least one of them will be awake or easily awakened in the event of a threat.

What Affects Our Sleep Patterns?

23-3 How do biology and environment interact in our sleep patterns?

The idea that “everyone needs 8 hours of sleep” is untrue. Newborns often sleep two-thirds of their day, most adults no more than one-third. Still, there is more to our sleep differences than age. Some of us thrive with fewer than 6 hours per night; others regularly rack up 9 hours or more. Such sleep patterns are genetically influenced (Hor & Tafti, 2009). In studies of fraternal and identical twins, only the identical twins had strikingly similar sleep patterns and durations (Webb & Campbell, 1983). Today’s researchers are discovering the genes that regulate sleep in humans and animals (Donlea et al., 2009; He et al., 2009).

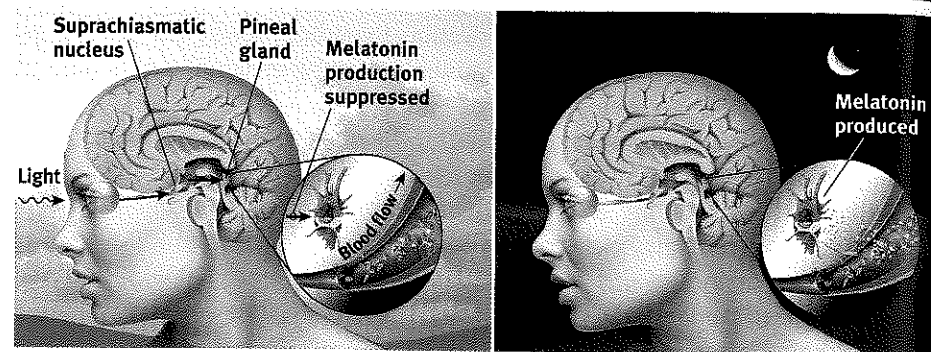
Sleep patterns are also culturally influenced. In the United States and Canada, adults average 7 to 8 hours per night (Hurst, 2008; National Sleep Foundation, 2010; Robinson & Martin, 2009). (The weeknight sleep of many students and workers falls short of this average [NSF, 2008].) North Americans are nevertheless sleeping less than their counterparts a century ago. Thanks to modern lighting, shift work, and social media and other diversions, those who would have gone to bed at 9:00 P.M. are now up until 11:00 P.M. or later. With sleep, as with waking behavior, biology and environment interact.

Bright morning light tweaks the circadian clock by activating light-sensitive retinal proteins. These proteins control the circadian clock by triggering signals to the brain’s **suprachiasmatic nucleus (SCN)**—a pair of grain-of-rice-sized, 10,000-cell clusters in the hypothalamus (Wirz-Justice, 2009). The SCN does its job in part by causing the brain’s pineal gland to decrease its production of the sleep-inducing hormone *melatonin* in the morning and to increase it in the evening (**FIGURE 23.5** on the next page).

suprachiasmatic nucleus (SCN) a pair of cell clusters in the hypothalamus that controls circadian rhythm. In response to light, the SCN causes the pineal gland to adjust melatonin production, thus modifying our feelings of sleepiness.

Figure 23.5

The biological clock Light striking the retina signals the suprachiasmatic nucleus (SCN) to suppress the pineal gland's production of the sleep hormone melatonin. At night, the SCN quiets down, allowing the pineal gland to release melatonin into the bloodstream.



Try This

If our natural circadian rhythm were attuned to a 23-hour cycle, would we instead need to discipline ourselves to stay up later at night and sleep in longer in the morning?

FYI

A circadian disadvantage: One study of a decade's 24,121 Major League Baseball games found that teams who had crossed three time zones before playing a multiday series had nearly a 60 percent chance of losing their first game (Winter et al., 2009).

"Sleep faster, we need the pillows." -YIDDISH PROVERB

Figure 23.6

Animal sleep time Would you rather be a brown bat and sleep 20 hours a day or a giraffe and sleep 2 hours daily (data from NIH, 2010)? Kruglov, Orda/Shutterstock; Courtesy of Andrew D. Myers; Utekhina, Anna/Shutterstock; Steffen Foerster Photography/Shutterstock; The Agency Collection/Punchstock; Eric Isselée/Shutterstock; pandapaw/Shutterstock



Being bathed in light disrupts our 24-hour biological clock (Czeisler et al., 1999; Dement, 1999). Curiously—given that our ancestors' body clocks were attuned to the rising and setting Sun of the 24-hour day—many of today's young adults adopt something closer to a 25-hour day, by staying up too late to get 8 hours of sleep. For this, we can thank (or blame) Thomas Edison, inventor of the light bulb. This helps explain why, until our later years, we must discipline ourselves to go to bed and force ourselves to get up. Most animals, too, when placed under unnatural constant illumination will exceed a 24-hour day. Artificial light delays sleep.

Sleep often eludes those who stay up late and sleep in on weekends, and then go to bed earlier on Sunday evening in preparation for the new school week (Oren & Terman, 1998). They are like New Yorkers whose biology is on California time. For North Americans who fly to Europe and need to be up when their circadian rhythm cries "SLEEP," bright light (spending the next day outdoors) helps reset the biological clock (Czeisler et al., 1986, 1989; Eastman et al., 1995).

Sleep Theories

23-4 What are sleep's functions?

So, our sleep patterns differ from person to person and from culture to culture. But why do we have this need for sleep?

Psychologists believe sleep may have evolved for five reasons.

1. **Sleep protects.** When darkness shut down the day's hunting, food gathering, and travel, our distant ancestors were better off asleep in a cave, out of harm's way. Those who didn't try to navigate around rocks and cliffs at night were more likely to leave descendants. This fits a broader principle: A species' sleep pattern tends to suit its ecological niche (Siegel, 2009). Animals with the greatest need to graze and the least ability to hide tend to sleep less. (For a sampling of animal sleep times, see **FIGURE 23.6**.)
2. **Sleep helps us recuperate.** It helps restore and repair brain tissue. Bats and other animals with high waking metabolism burn a lot of calories, producing a lot of *free radicals*, molecules that are toxic to neurons. Sleeping a lot gives resting neurons time to repair themselves, while pruning or weakening unused connections (Gilestro et al., 2009; Siegel, 2003; Vyazovskiy et al., 2008). Think of it this way: When consciousness leaves your house, brain construction workers come in for a makeover.

3. **Sleep helps restore and rebuild our fading memories of the day's experiences.** Sleep consolidates our memories—it strengthens and stabilizes neural memory traces (Racsmány et al., 2010; Rasch & Born, 2008). People trained to perform tasks therefore recall them better after a night's sleep, or even after a short nap, than after several hours awake (Stickgold & Ellenbogen, 2008). Among older adults, more sleep leads to better memory of recently learned material (Drummond, 2010). After sleeping well, seniors remember more. And in both humans and rats, neural activity during slow-wave sleep re-enacts and promotes recall of prior novel experiences (Peigneux et al., 2004; Ribeiro et al., 2004). Sleep, it seems, strengthens memories in a way that being awake does not.
4. **Sleep feeds creative thinking.** On occasion, dreams have inspired noteworthy literary, artistic, and scientific achievements, such as the dream that clued chemist August Kekulé to the structure of benzene (Ross, 2006). More commonplace is the boost that a complete night's sleep gives to our thinking and learning. After working on a task, then sleeping on it, people solve problems more insightfully than do those who stay awake (Wagner et al., 2004). They also are better at spotting connections among novel pieces of information (Ellenbogen et al., 2007). To think smart and see connections, it often pays to sleep on it.
5. **Sleep supports growth.** During deep sleep, the pituitary gland releases a growth hormone. This hormone is necessary for muscle development. A regular full night's sleep can also "dramatically improve your athletic ability," report James Maas and Rebecca Robbins (see Close-up: Sleep and Athletic Performance). As we age, we release less of this hormone and spend less time in deep sleep (Pekkanen, 1982).

Given all the benefits of sleep, it's no wonder that sleep loss hits us so hard.

"Corduroy pillows make headlines." -ANONYMOUS

Close-up

Sleep and Athletic Performance

Exercise improves sleep. What's not as widely known, report James Maas and Rebecca Robbins (2010), is that sleep improves athletic performance. Well-rested athletes have faster reaction times, more energy, and greater endurance, and teams that build 8 to 10 hours of daily sleep into their training show improved performance. Top violinists also report sleeping 8.5 hours a day on average, and rate practice and sleep as the two most important improvement-fostering activities (Ericsson et al., 1993).

Slow-wave sleep, which occurs mostly in the first half of a night's sleep, produces the human growth hormone necessary for muscle development. REM sleep and NREM-2 sleep, which occur mostly in the final hours of a long night's sleep, help strengthen the neural connections that build enduring memories, including the "muscle memories" learned while practicing tennis or shooting baskets.

The optimal exercise time is late afternoon or early evening, Maas and Robbins advise,

when the body's natural cooling is most efficient. Early morning workouts are ill-advised, because they increase the risk of injury and rob athletes of valuable sleep. Heavy workouts within three hours of bedtime should also be avoided because the arousal disrupts falling asleep. Precision muscle training, such as shooting free throws, may, however, benefit when followed by sleep.

Maas has been a sleep consultant for college and professional athletes and teams. On Maas' advice, the Orlando Magic cut early morning practices. He also advised one young woman, Sarah Hughes, who felt stymied in her efforts to excel in figure-skating competition. "Cut the early morning practice," he instructed, as part of the recommended sleep regimen. Soon thereafter, Hughes' performance scores increased, ultimately culminating in her 2002 Olympic gold medal.

AP Photo/Lionel Cironneau

Ample sleep supports skill learning and high performance. This was the experience of Olympic gold medalist Sarah Hughes.