CHAPTER 1

# Normal Sleep

## CHAPTER OUTLINE



## LEARNING OBJECTIVES

1. Understand the importance of sleep and the significance of sleep deprivation
2. Understand why the human body and mind need sleep
3. Learn more about the circadian rhythm and its effects on our daily lives
4. Discover the differences between the sleep of humans and that of other animals
5. Discuss normal sleep patterns
6. Learn how the normal aging process affects sleep
7. Discuss the significance of specific changes in sleep patterns from the norm
8. Understand how certain drugs can affect sleep
9. Understand how pregnancy can affect sleep

## KEY TERMS

**sleep**
**sleep deprivation**
**chronic sleep deprivation**
**sleep debt**
**sleep hygiene**
**circadian rhythm**
**rapid eye movement (REM)**
**thermoregulation**
**thalamus**
**reticular activating system (RAS)**
**suprachiasmatic nucleus (SCN)**
**dopamine**
**acetylcholine**
**noradrenaline**
**histamine**
**glutamate**
**sleep state**
**nonrapid eye movement (NREM)**
**stage R**
**phasic REM**
**tonic REM**
**stage N1**
**stage N2**
**sleep spindles**
**stage N3**
**sleep architecture**
**stage W**
**wake after sleep onset (WASO)**
**sleep efficiency**
**histogram**
**hypnogram**
**sleep latency**
**sleep onset**
**excessive daytime sleepiness (EDS)**
**first night effect**
**total wake time (TWT)**
**stage R latency**
**stage R onset**
**rebound sleep**

## The Need for Sleep

Like food, water, or oxygen, the human body needs sleep to survive. **Sleep** is defined as "a natural and periodic state of rest during which consciousness of the world is suspended."[1] Sleep is a state during which the body and mind are allowed to rest and become restored. However, as we will discuss later in this chapter, many people do not get the sleep their body needs, or their sleep may be disrupted by any of several different causes.

When a person does not receive the length, consistency, or type of sleep necessary, that person may be suffering from **sleep deprivation**. Only 37% of American adults receive the eight hours of sleep they need every night for optimal performance and health.[2] Nearly 31% of Americans report sleeping less than 7 hours each night during the week.[2] This **chronic sleep deprivation**, or a consistent lack of necessary sleep over an extended period of time, can have drastic and sometimes deadly effects. As a person consistently fails to receive adequate sleep, **sleep debt** increases. Sleep debt refers to the amount of



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sleep a person has lost over a period of time compared with what they should receive. If an individual requires eight hours of sleep every night, but obtains only six hours in a night, then he or she has accumulated a sleep debt of two hours in just one night. If this pattern continues for four nights, he or she will have accumulated eight hours of sleep debt. According to Dr. William Dement, increased sleep debt is directly correlated with increased adverse effects, including daytime sleepiness, poor performance, lack of concentration, and multiple health problems.[3] Other potential results of increased sleep debt include difficulty awakening, irritability, morning headaches, and a lack of motivation.

Some of the most visible effects of sleep deprivation and sleep debt in the world today are in traffic accidents. The National Highway Traffic Safety Administration (NHTSA) estimates that 100,000 police-reported automobile accidents, resulting in over 1,500 fatalities and 71,000 injuries, are caused by drowsy drivers every year. These accidents alone result in an estimated $12.5 billion in lost property and productivity. According to the NHTSA, 49% of males and 26% of females have "nodded off" while driving.[4]

Truck drivers can be dangerous victims of sleep deprivation. In Salina, Kansas, in May 2005, a truck driver fell asleep at the wheel and crashed into an SUV, killing a mother and son and injuring two others. In October 2007, he was sentenced to six months in prison for two counts of vehicular homicide. Many states now recognize the gravity of drowsy driving. In August 2003, New Jersey became the first state to criminalize drowsy driving that leads to fatal accidents. Penalties can range as high as 10 years in prison and $100,000 in fines. In some states, drowsy driving can draw penalties as serious as driving while intoxicated.

Work-related accidents and loss of work productivity resulting from sleep deprivation and drowsiness also plague our world today. Fifty percent of adults ages 18–34 report that daytime sleepiness interferes with their daily work, resulting in approximately $15 billion in additional healthcare costs and $50 billion in lost productivity in the United States.[5] Among the most costly and devastating known work-related accidents that were at least somewhat attributable to sleep deprivation are the Three Mile Island nuclear meltdown in 1979; the gas leak in Bhopal, India, in 1984; the *Challenger* space shuttle disaster in 1986; the Chernobyl nuclear accident in 1986; and the Exxon *Valdez* oil spill in 1989.

The Three Mile Island Unit 2 nuclear power plant near Middleton, Pennsylvania, was the site of the most serious U.S. nuclear plant accident in history. The accident started at about 4:00 AM on March 28, 1979, when a cooler malfunctioned. It is believed that poor judgment by the sleepy workers led to the meltdown. Luckily, no known injuries or health problems occurred because of this accident.

On December 3, 1984, a storage tank in Bhopal, India, overheated, releasing large amounts of deadly gas. This accident also occurred in the early morning hours when the workers were drowsy and inattentive. As a result, 15,000 people died and approximately 600,000 people were injured.[6]

The United States was celebrating the "space race" as it prepared to send the first schoolteacher, Christa McAuliffe, along with a crew of six other astronauts, into space. The mission was highly publicized as the country anxiously gathered to watch the launch. The shuttle had several problems, and crews worked around the clock for days leading up to the launch to make the shuttle ready for its anticipated launch time. The managers who approved the launch reportedly slept very little the night before. As a result, on January 28, 1986, the *Challenger* space shuttle exploded just over a minute after its liftoff, killing the entire crew (see **Figure 1–1**).

Later the same year in the Ukraine, Reactor #4 at Chernobyl was to be shut down and tested at 1:00 AM. Several of the safety features were turned off by the sleepy crew, leading to a large steam explosion and fire. This caused at least 5% of the radioactive core to be released into the surrounding area. Twenty-eight people in the area died within four months from radioactive or thermal burns, and at least 75 deaths since that time are believed to have been caused by this accident.[7] Because of the nature of the accident, the exact number of injuries and casualties is impossible to determine.

On March 23, 1989, the Exxon oil tanker *Valdez* struck a large reef while maneuvering through a remote Alaskan coastline. Reports claim the crew was poorly rested, and many believe this to be one of the primary causes of the spill. The tanker spilled approximately 11 million gallons of oil, although exact amounts are difficult to determine. Hundreds of thousands of animals died instantly, and many more have died since. Massive lawsuits and large-scale economic and environmental consequences resulted.

**FIGURE 1–1** January 28, 1986: The space shuttle *Challenger* explodes shortly after liftoff. Many believe sleep deprivation may have played a role in the events leading up to this disaster.

Courtesy of NASA.

Despite the obvious negative consequences of sleep deprivation, Americans continue to increase their sleep debt. According to the National Sleep Foundation's 2002 "Sleep in America" poll, the average American slept 10 hours per night before the invention of the light bulb in 1879, but today sleeps an average of only 6.9 hours per night on weeknights and 7.5 hours per night on weekends. This is much less than the 8 hours of sleep per night recommended for adults. Modern day's busy lifestyle is undoubtedly one of the main causes for America's lack of sleep. According to Janet Hunsaker, mother of four, "Between my kids' band practices, football games, baseball games, getting dinner on the table and keeping the house clean, it's often difficult to get to bed before midnight. I then get up by 6:00 to get the kids up and ready for school. Eight hours of sleep in a night often is not an option for me. Even weekends can be difficult to find time to get enough sleep."[8]

For those who make time for and are able to get the amount and quality of sleep necessary, the benefits are well worth the effort. Those who are free of sleep disorders, get the recommended amount of sleep, and practice good **sleep hygiene** enjoy more energy, more motivation, greater health, increased levels of happiness, and less depression, and live longer lives than those who do not receive adequate sleep.[9]

## The Human Circadian Rhythm

In order to understand human sleep, we must first discuss the human **circadian rhythm**. A circadian rhythm is a daily cycle of biological activity influenced by variations in the environment, such as the alteration of day and night.[10] A circadian rhythm can include sleeping and waking in animals, tissue growth and differentiation in certain fungi, or the opening and closing of certain flowers. In humans, our circadian rhythm includes not only the 24-hour sleep/wake cycle, but also varying levels of alertness during wakefulness.

While we are awake, our circadian rhythm oscillates approximately every 90 minutes. People often note higher levels of alertness during the morning hours and a lower energy level after lunch in the early afternoon hours. Although this often varies according to the amount and quality of sleep a person receives, their daily activities and exercise, and the types of food they eat, it is also affected by our natural internal biological clock or pacemaker. Extensive research has shown that several factors can affect the circadian rhythm. Some of these factors include the following:

- *Light:* Light is considered to be the most dominant factor affecting the human pacemaker. Evidence of this can be seen in humans' tendency to be awake during the day and asleep at night. Further evidence is seen in studies involving bright light therapy to treat insomnia and certain circadian rhythm disorders.
- *Temperature:* Temperature has been shown to be another factor affecting circadian rhythm. Slightly increasing room temperature may cause a person to be drowsy, whereas decreasing the temperature may increase alertness for short periods of time. As a person enters **rapid eye movement (REM)** sleep, the core body temperature becomes unstable and drops.
- **Thermoregulation:** The body's ability to regulate its own temperature decreases during REM.
- *Food:* A lunch composed of fatty, greasy foods is often followed by periods of drowsiness, whereas eating healthier foods can encourage higher levels of alertness.
- *Drugs:* Stimulants, depressants, and other drugs can have profound effects on the circadian rhythm. Some of these effects may be short-term and others long-term. Certain drugs such as melatonin can aid in the quality of sleep by decreasing the amount of time needed to initiate sleep and decreasing the amount of wake time after sleep onset.[11] For more information on how different types of drugs affect our sleep, see the section "Drug Effects on Sleep" later in this chapter.
- *Activity:* Research has shown that exercise can increase our alertness and help us sleep better at night. However, sleep hygiene techniques instruct us to avoid strenuous exercise shortly before bedtime, because this can have a negative impact on our ability to initiate sleep.

Although countless factors can influence our circadian rhythms both when awake and when asleep, those listed are some of the most influential and common.

## Human Sleep

In order to understand normal human sleep, we must first discuss the functions of certain structures in the brain as they relate to sleep.

### Brain Structures Related to Sleep

The brain is made up of the brain stem, the diencephalons, the cerebrum, and the cerebellum. The brain stem consists of the pons, the midbrain, and the medulla oblongata. The diencephalons are made up of the hypothalamus, the thalamus, the epithalamus, and the pineal gland.

There are many structures of the brain that affect alertness, wakefulness, and sleepiness. The primary structures of the brain involved in the circadian rhythm and the sleep–wake process are as follows (see **Figure 1–2**)[12]:

Thalamus

Medulla oblongata

Hypothalamus

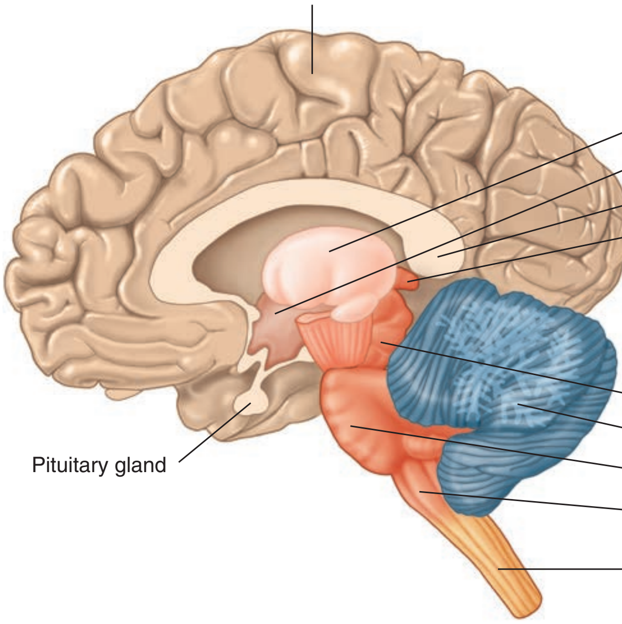


**FIGURE 1–2** The human brain.

Pons

Midbrain

Spinal cord

Raphe nuclei

Basal forebrain

Hippocampus

Suprachiasmatic nuclei

Reticular formation neurons

The **thalamus** constitutes the main part of the diencephalons, and is known to have multiple functions. Among other things, it is responsible for sending specific sensory data from the body to different areas of the brain, especially the cerebral cortex. As data between the thalamus and the cortex become blocked, awareness of external stimuli decreases, and consciousness is lost. This sensory blockage is caused by a deactivation of the **reticular activating system (RAS)**. The RAS consists of several neurons in the reticular formation, and is believed to be the center of arousal and motivation. Deactivation of the RAS leads to decreased alertness, and develops spindle activity in the thalamus seen in stage N2 (for more information on N2 and other stages of sleep, please see the "States and Stages of Sleep" section in this chapter). Reticular formation neurons stimulate other neurons through the thalamus to the cortex, which develops the cerebral activation that leads to wakefulness.

The **suprachiasmatic nucleus (SCN)** is a bilateral area of the brain located in the hypothalamus. It is strongly affected by light, and is responsible for controlling the circadian rhythm. The SCN is often referred to as the pacemaker for the circadian rhythm.

The primary chemicals involved in the circadian rhythm and the sleep–wake process include dopamine, acetylcholine, noradrenaline, histamine, and glutamate. The primary responsibility of **dopamine** is the arousal of the cortex, movement, and responsiveness. **Acetylcholine** activates the cortex. Acetylcholine levels are highest during wake and rapid eye movement sleep (stage R). **Noradrenaline** primarily maintains and enhances the activation of the cerebral cortex. **Histamine** also activates the cortex. **Glutamate** includes excitatory amino acids that progress to the cortex, forebrain, and brainstem. Glutamate is primarily responsible for central activation of the cortex.

## States and Stages of Sleep

Sleep is divided into two main **sleep states**: REM and **nonrapid eye movement (NREM)**. Just as there are varying levels of wakefulness and alertness in the circadian rhythm, there are also different levels or stages of sleep. Rather than being considered a state of unconsciousness, sleep is considered a state of altered or decreased consciousness.

**Stage R**, or REM sleep, is characterized by the presence of rapid eye movements during sleep. **Phasic REM** refers to periods of stage R in which the eyes move back and forth in rapid motions. **Tonic REM** refers to the occurrence of stage R without rapid eye movements. Sawtoothed electroencephalogram (EEG) waves, a characteristic waveform often seen in stage R, are mostly seen during phasic REM. The areas of the brain mostly responsible for causing stage R include the hippocampus, the pons, and the medulla oblongata. Other characteristics of stage R include muscle atonia; a low-voltage, mixed-frequency EEG pattern; a decrease in core body temperature; altered respiratory patterns; and penile erections in males. Stage R appears to be associated with memory, cognition, and feelings of restorative sleep.

NREM is divided into three stages: stage N1, stage N2, and stage N3. **Stage N1** is considered a transitional stage of sleep, which has characteristics of both wake and sleep. During stage N1, a subject may occasionally be able to hear and respond to external stimuli. Often a person may awaken from a brief period of N1 unaware that he or she was asleep. **Stage N2** is a slightly deeper stage of sleep in which **sleep spindles** first occur. Sleep spindles are unique EEG waveforms that indicate a blockage of external stimuli such as sounds. Therefore, in N2 we become much less aware of our surroundings than when we are in N1. **Stage N3**, formally called delta sleep, is considered to be the deepest stage of sleep because of the lack of responsiveness during this stage. N3 is typically the most difficult stage from which to awaken an individual. The primary structures in the brain playing roles in NREM sleep are the raphe nuclei, the forebrain, the thalamus, and the hypothalamus.

Periods of REM and NREM oscillate throughout the night in approximately 90-minute cycles, continuing the 90-minute circadian rhythm seen during wake.

The sleep of hundreds of different species of mammals has been researched extensively. This research has provided us with further information regarding human evolution and our relationship as humans to these other mammals. Most of the research on mammalian sleep to date has determined that varying species of mammals may sleep anywhere from 3 to 19 hours every 24-hour period, with stages similar to our own, including REM and NREM sleep. The varied need for sleep in several species is represented in **Table 1–1**.[13]

As can be seen from **Table 1–1**, the need for sleep varies greatly among the species (see **Figure 1–3**). In addition to varying sleep lengths, some mammals sleep in different ways than others. For example, dolphins sleep with only half of their brain at once while the other half is still awake. This allows them to continue swimming and watching for predators while sleeping.

**TABLE 1–1** **Mammalian Sleep**

| Species | Sleep/Day (hours) | Stage R/Day (hours) |
|---|---|---|
| Armadillo | 17.0 | 3.0 |
| Baboon | 9.5 | 3.0 |
| Bat | 19.0 | 3.0 |
| Cat | 12.5 | 3.0 |
| Dolphin | 10.0 | ? |
| Echidna | 8.5 | ? |
| Elephant | 4.0 | ? |
| Ferret | 14.5 | 6.0 |
| Giraffe | 4.5 | 0.5 |
| Guinea pig | 9.5 | 1.5 |
| Hamster | 14.0 | 3.0 |
| Horse | 3.0 | 0.5 |
| Human | 8.0 | 2.0 |
| Koala | 14.5 | ? |
| Mole | 8.5 | 2.0 |
| Opossum | 18.0 | 5.0 |
| Platypus | 14.0 | 7.0 |
| Rat | 13.0 | 2.5 |
| Seal | 6.0 | 1.5 |

**FIGURE 1–3** The average housecat sleeps 12.5 hours per day.



## Sleep Architecture

**Sleep architecture** refers to the patterns of sleep stages through which we progress during our sleep period. In this section we will discuss the norms and averages of sleep patterns across normal, healthy adults. Changes to normal sleep architecture occur as a result of several different factors. Some of these factors may include age, internal and external stimuli, medical conditions, and psychological conditions, to name just a few. In order to discuss sleep architecture, we must further detail each of the sleep stages.

### Stage W (Wake)

During wake (**stage W**), muscle activity and cognitive responsiveness are high, and levels of alertness vary according to many different factors. Wake comprises two thirds of the 24-hour cycle in humans, or approximately 16 hours per day. EEGs can be difficult to read during wake because of frequent movement and muscle activity. However, EEGs during wake are typically high frequency with mixed voltages. When resting awake with the eyes closed, alpha waves are present in the occipital regions of the brain. Electromyogram (EMG) amplitudes are high, and airflow varies according to the activity levels. The average latency to sleep in normal, healthy adults is 10–20 minutes.

**Wake after sleep onset (WASO)** is the amount of wake time in minutes during the attempted sleeping period, after sleep onset has been achieved. WASO is often characterized by lower activity levels than wake periods during daytime hours. The average person is asleep at least 90% of the sleep period (from sleep onset to the final awakening). In other words, WASO should comprise less than 10% of the sleep period. The percentage of the night that a person spends asleep is called **sleep efficiency**. Sleep efficiency is calculated by dividing the total sleep time by the total time in bed. A sleep efficiency greater than 90% is considered normal and optimal.

### Stage N1

Stage N1 comprises approximately 5–10% of the sleep period. A person in stage N1 can sometimes detect and even respond to external stimuli. The EEGs in stage N1 present a relatively low voltage pattern with a mixed frequency. Most people enter sleep through stage N1, which is why it is often called a transitional stage. A person in stage N1 is often unaware that he or she is asleep.

### Stage N2

The EEGs during stage N2 are characterized by sleep spindles and K-complexes in the central areas of the brain. stage N2 comprises approximately 40–50% of the total sleep period in normal, healthy young adults. It is during stage N2 that the senses begin to be blocked from external stimuli.

### Stage N3

The EEGs in stage N3 present a moderate amount of low-frequency, high-amplitude activity. Stage N3 is considered to be a very deep stage of sleep because subjects are very difficult to awaken out of this stage; awakening from stage N3 often results in grogginess and disorientation. Stage N3 comprises approximately 20–25% of the sleep period in normal, healthy young adults, and is predominant during the first third of the night. Stage N3 tends to decrease dramatically with age. The human growth hormone (HGH) is released during stage N3, making stage N3 a restorative sleep for the body.

### Stage R

Stage R is characterized primarily by rapid eye movements; however, as mentioned in the previous section, periods of tonic REM are quite common, in which no rapid eye movements are seen. Stage R is often referred to as a paradoxical sleep because the brain activity resembles the activity during wakefulness, but the muscles are paralyzed. Muscle tone is at its lowest point of the circadian rhythm during stage R. Like stage N3, stage R comprises approximately 20–25% of the sleep period in normal, healthy young adults. This tends to decrease with many different sleep disorders. The patterns of stage R are the opposite of those in stage N3. Stage R periods are typically shorter in the beginning of the sleep period, and become longer as the sleep period progresses. Whereas stage N3 is restorative for the body, stage R is restorative for the mind. Research suggests that memory is diminished when stage R is deprived. The average latency to stage R is 90–120 minutes.

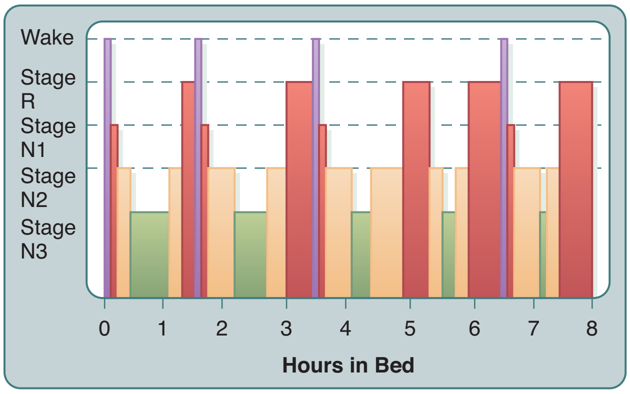


**FIGURE 1–4** Sleep staging histogram for a normal, healthy young adult.

### Typical Progression of Sleep

**Figure 1–4** shows a typical sleep **histogram** (or **hypnogram**) for a normal, healthy young adult. A histogram or hypnogram is a chart or graph showing sleep architecture throughout the night, and often includes other channels such as muscle tone, abnormal events, or oxygen level.

**Figure 1–4** shows a typical progression of sleep stages throughout the night for a normal, healthy young adult. Notice that the periods of stage N3 are longest during the first third of the night, and gradually decrease in length as the night progresses. Conversely, periods of stage R tend to be very brief at the beginning of the night and progressively become longer. Each sleep cycle is approximately 90 minutes in length, although this can certainly vary. Occasional unexplained awakenings are considered normal during the night, and may be evidence of an evolutionary defense mechanism. Sleep is typically entered through stage N1, and periods of this stage are usually very brief.

There are perhaps endless causes for changes to the normal sleep cycle and patterns, both internal and external. However, researchers believe that the normal aging process appears to have a more significant impact on sleep patterns than any other factor.

## Sleep and Aging

The effects of the normal aging process on sleep have been a major topic of discussion and research for the past several years. Much has been discovered about sleep and aging. This section will discuss a few of the findings on sleep changes that occur during the normal aging process.

As humans age, the number of EEG arousals and awakenings per hour of sleep, also known as the arousal index, tends to increase. The increased prevalence of arousals may be due to a number of factors including stress, medications, medical conditions, pain, respiratory events, limb movements, psychological conditions, or sensitivity to the environment. Stage N3 decreases significantly with age. Infants have very high percentages of slow-wave EEGs during sleep, whereas many older adults may not achieve any stage N3 during the night. This phenomenon may be due to the fact that EEGs decrease in amplitude with age. Because EEG slow waves have amplitude criteria, this may account for the decreased stage N3 typically seen in older adults.

Sleep efficiency decreases and complaints of insomnia increase with age. This is because our total time spent in bed increases with age, but our time spent asleep decreases. For many older adults, the average sleep efficiency may decrease to 70–80%, whereas young adults typically enjoy over 90% sleep efficiency.

The percentage of stage R to total sleep time appears to be fairly constant throughout adulthood; however, sleep problems during stage R such as obstructive sleep apnea typically worsen with age.

With stage N3 decreasing, the percentage of total sleep time spent in stages N1 and N2 increases with age. Because stages N1 and N2 are considered relatively light stages of sleep with increased awareness of external stimuli, this may contribute to increased complaints of insomnia with age.

There is evidence suggesting that with age comes a decreased need for sleep (see **Figure 1–5**); for example, infants may need over 12 hours of sleep per 24-hour period, whereas adolescents need 8–10 hours, young adults need 7–8 hours of sleep on average, and older adults may need less than 7 hours of sleep per night on average. Although this is true in general, individual differences are typically greater than age differences as a whole.

As we age, the prevalence of sleep disorders tends to increase. Although there are some sleep disorders that target specific age groups, such as narcolepsy developing primarily in young adulthood, the overall number and severity of sleep disorders typically increases with age. Again, this may be due to several different factors. With age, sleep problems can increase due to the presence of other medical conditions that may increase with age. For example, arthritis pains that increase with age can cause an individual to have difficulty initiating or maintaining sleep. Certain psychological factors that may increase with age, including fear, guilt, and anxiety, may also affect the ability to initiate or maintain sleep. Stressors that may change with age such as financial stress, marital stress, family pressures, or job changes, also can greatly affect a person's ability to sleep.

**FIGURE 1–5** Infants typically need 10–12 hours of sleep per 24-hour period whereas older adults often need less than 7 hours.



## Changes to Normal Sleep Architecture

As mentioned earlier, there are endless factors that can affect a person's sleep architecture. The sleep staging histogram in this chapter depicts the averages across all normal healthy young adults. It is important to remember that individual differences in sleep architecture are high, and a certain amount of variance from one person to the next may be of little to no significance. However, it is often possible to make certain deductions by comparing a person's sleep architecture to the norm. Following are a few important factors to pay attention to.

### Sleep Latency

**Sleep latency** is the amount of time, in minutes, it takes a person to fall asleep. The measurement of sleep latency on a polysomnogram, or sleep study, begins at "Lights Out," when the lights are turned off and the patient attempts to fall asleep, and ends at **sleep onset**. Sleep onset is defined as the first 30-second epoch of sleep on a polysomnogram, which is usually stage N1. A sleep latency of 10–20 minutes is considered normal. A decreased sleep latency may indicate **excessive daytime sleepiness (EDS)**. A person who is excessively sleepy will usually fall asleep quicker than a person who is not sleepy. This excessive daytime sleepiness may be caused by a number of reasons, but can often indicate that a person's sleep is being interrupted by upper airway obstructions or periodic limb movements. A decreased sleep latency may indicate that a person has difficulty staying awake and therefore may be dangerous behind the wheel of a motor vehicle. A sleep latency longer than 20 minutes may indicate that a person is having difficulty initiating sleep. This could be due to a **first night effect** while being tested, problems with insomnia, or getting too much sleep the previous night. First night effect refers to the stresses and other factors that a patient feels during the first night of testing in a sleep lab, which may affect his or her ability to initiate and maintain sleep.

### Sleep Efficiency

As mentioned earlier, normal sleep efficiency for a healthy young adult is 90% or higher. A decreased sleep efficiency, by definition, indicates increased **total wake time (TWT)**. Increased total wake time may indicate a disruption during sleep due to any number of factors including leg movements, apneas, pain, insomnia, and so on. A very high sleep efficiency may be indicative of **rebound sleep**. An example of rebound sleep is a patient with obstructive sleep apnea who is sleeping with continuous positive airway pressure (CPAP) for the first time. Rebound sleep can also lead to increases in stage N3 and stage R.

### Total Stage N1 Time

Normal sleep architecture tells us that a person should spend approximately 5–10% of the night in stage N1 sleep. Because stage N1 is a transitional stage, an increase in stage N1 often indicates increased wakefulness or disruptions to sleep, such as those mentioned earlier. A decrease in stage N1 often indicates decreased disruptions to sleep.

### Total Stage N2 Time

Stage N2 comprises approximately 40–50% of the total sleep time. Increases or decreases in stage N2 are usually associated with increases or decreases in stage N3 or stage R sleep, which may be better indicators of significant problems during sleep.

### Total Stage N3 Time

Stage N3 comprises approximately 20–25% of the total sleep time. This naturally decreases with age, and is often absent in older adults. Decreases to stage N3 in young adults may indicate a disruption to sleep, perhaps caused by too much sleep during the night prior to testing or anxiety resulting from first night effect. Stage N3 may be increased due to rebound sleep or by taking certain medications such as sedatives or alcohol.

### Total Stage R Time

Stage R typically comprises 20–25% of the total sleep time. Increases are often found during rebound sleep. Decreases to stage R are often caused by disruptive sleep, often due to apneas, periodic limb movements, pain, or external factors.

#### *Stage R Latency*

**Stage R latency** is defined as the amount of time, in minutes, from sleep onset to **stage R onset**. Stage R onset is the first 30-second epoch of Stage R. The normal latency to stage R is 90–120 minutes. A decreased stage R latency may indicate excessive daytime sleepiness (EDS) or rebound sleep. An increased stage R latency may indicate problems with insomnia, disruptive sleep, or too much sleep the previous night.

#### *Stage R Periods*

The length of individual periods of stage R can provide insight into the causes of abnormal sleep architecture. Although a patient's total stage R time in a night may be consistent with the norm, he or she may start the night with very short or absent stage R periods and end the night with excessively long stage R periods. This is often seen during a PAP titration, when the pressures at the beginning of the night may not be sufficient to allow the patient to remain in stage R, but the increased air pressure at the end of the night may allow the patient to experience a long stage R rebound.

## Drug Effects on Sleep

Much research has been performed on the effects of various drugs and medications on sleep. It is not uncommon to see a television advertisement for a new drug specifying insomnia or other changes in sleep as common side effects. In this section, we will discuss some of the effects on sleep that can be caused by certain classes of drugs.

### Sedative Hypnotics

Hypnotics is a class of psychoactive drugs whose primary function is to help initiate sleep. Common hypnotics include barbiturates, benzodiazepines, and nonbenzodiazepines. Barbiturates are central nervous system (CNS) depressants that can produce any reaction from mild sedation to total anesthesia. They used to be prescribed commonly for insomnia, but have for the most part been replaced by benzodiazepines because barbiturates are more dangerous in the case of an overdose. Benzodiazepines can work as a sedative, a hypnotic, an anti-anxiety medication, or a muscle relaxant. They are commonly used to treat insomnia. Nonbenzodiazepines are a class of drugs that are chemically different from benzodiazepines, but have similar effects, both positive and negative. Antihistamines also work as hypnotics. Antihistamines block the release of histamine, which is an inflammation-producing substance produced from white blood cells that occurs with an injury or an allergic reaction.

### Antidepressants

Antidepressants are medications designed to treat depression. Occasionally, a physician will prescribe an antidepressant to help initiate sleep. There are three uniquely different agents that are used to treat depression: tricyclic antidepressants (TCAs), selective serotonin reuptake inhibitors (SSRIs), and monoamine oxidase inhibitors (MAOIs). Tricyclics work by inhibiting the reuptake of norepinephrine and serotonin. SSRIs act specifically to maintain higher levels of serotonin in the brain. When serotonin is increased, mood is elevated. SSRIs have fewer side effects than TCAs and MAOIs. MAOIs differ from TCAs and SSRIs by their side effects, and are typically reserved for patients who do not respond well to either TCAs or SSRIs.

### Cardiovascular Drugs

Cardiovascular drugs are some of the most widely prescribed medications today, and are used to treat cardiovascular diseases. Because of the documented association between obstructive sleep apnea and cardiovascular diseases, many patients in the sleep lab take various cardiovascular drugs. Antihypertensives are commonly prescribed cardiovascular drugs designed to decrease blood pressure. Common antihypertensives include ACE inhibitors, which reduce salt/water retention and inhibit vascular constriction; beta blockers, which reduce cardiac output; calcium channel blockers, which relax the blood vessels; and diuretics, which decrease fluid volume. Antihyperlipidemics are also commonly prescribed cardiovascular drugs that are intended to decrease cholesterol levels.

### Stimulants

Stimulants are a class of psychoactives that produce enhanced alertness, wakefulness, and locomotion. Common stimulants include caffeine, nicotine, and amphetamines. Depending on the dosage and the time of day taken, they can prolong sleep latency and decrease the quality of sleep.

### Over-the-Counter Sleep Aids

In recent years, over-the-counter (OTC) sleep medications have become very popular and effective in initiating sleep. Common ingredients include melatonin, valerian, and tryptophan. Misuse and abuse of these drugs is common. Withdrawal from these medications can result in difficulty initiating and maintaining sleep.

**Table 1–2** shows some commonly used drugs and their effects on sleep.[14] **Table 1–3** shows some commonly used medication stems and their meanings.

## Pregnancy and Sleep

Pregnancy can cause significant changes in a woman's body, many of which can affect sleep. One of the most important changes that can affect sleep during pregnancy is weight gain. Additional weight caused by pregnancy, specifically in the abdominal and thoracic areas, can greatly increase the likelihood of obstructive respiratory events, including apneas, hypopneas, and snoring.[15] The comorbidities of obstructive sleep apnea syndrome—such as morning headaches, decreased stage R, increased EEG arousals and awakenings, increased limb movements, increased blood pressure, and many others—are often increased in frequency and severity during pregnancy. Incidences of obstructive sleep apnea during pregnancy can also lead to excessive daytime sleepiness, fatigue, drowsiness, falling asleep unintentionally, decreased sleep efficiency, and an increased desire to take naps.

It is also common for pregnancy-related morning sickness to interrupt sleep. As mentioned earlier in this chapter, periods of stage R are longest in the early morning hours. If morning sickness associated with pregnancy occurs early enough, it can disrupt the amount of stage R a pregnant woman obtains.

Pain and discomfort related to pregnancy can also have profound effects on the amount and quality of sleep obtained. Particularly in the third trimester of pregnancy, discomfort increases, often causing the subject to

**TABLE 1–2 Drug Effects on Sleep**

| | Benzodiazepines | Nonbenzodiazepines | Tricyclics | SSRIs | SNRIs* | Antihistamines |
|---|---|---|---|---|---|---|
| Sleep latency | – | – | | – | + | – |
| Total sleep time | + | + | + | – | – | + |
| Sleep efficiency | + | + | | – | – | |
| Wake after sleep onset | – | – | – | + | + | |
| Stage N1 | + | – | | | + | + |
| Stage N2 | + | + | + | | | + |
| Stage N3 | – | – | + | – | | + |
| Stage R | – | – | – | – | – | – |
| Arousals | – | | | + | | |
| Restless legs | | + | + | + | | |
| Periodic limb movements | | | + | + | + | |
| Daytime sleepiness | + | | + | + | + | |
| Eye movements in NREM | | | | + | | |
| REM behavior disorder | | | | + | | |
| Obstructive sleep apnea | + | | | | | |

*SNRIs refers to Serotonin-norepinephrine reuptake inhibitors.

**TABLE 1–3 Common Medication Stems and Syllables**

| Stem or Syllable | Drug Class |
|---|---|
| -andr- | Androgens |
| -ase | Enzymes |
| -azepam | Antianxiety |
| -bactam | Beta-lactamase inhibitors |
| -bamate | Tranquilizers/Antiepileptics |
| -barb | Barbituric acids |
| -butazone | Anti-inflammatory analgesics |
| -caine | Local Inalgesics |
| -cillin | Penicillins |
| -conazole | Antifungals |
| -cort | Cortisones |
| -curium | Neuromuscular blocking agents |
| -cycline | Tetracycline antibiotics |
| -dralazine | Antihypertensives |
| -estr- | Estrogens |
| -fibrate | Antihyperlipidemics |
| -flurane | Inhalation anesthetics |
| -gest- | Progesterins |
| -ipine | Calcium channel blockers |
| -ipramine | Antidepressants |
| -irudin | Anticoagulants |
| -lol | Beta blockers |
| -mycin | Antibiotics |
| -olone | Steroids |
| -oxacin | Antibiotics |
| -pamil | Coronary vasodilators |
| -parin | Heparin derivatives |
| -peridol | Antipsychotics |
| -pred | Prednisone derivatives |
| -pril | Antihypertensives (ACE inhibitors) |
| -profen | Anti-inflammatories |
| -setron | Serotonin receptor antagonists |
| -statin | Antihyperlipidemics |
| -terol | Bronchodilators |
| -thiazide | Diuretics |
| -tocin | Oxytocin derivatives |
| -trexate | Antimetabolites |
| -triptyline | Antidepressants |
| -zosin | Alpha blockers |

experience increased difficulty initiating sleep, increased sleep latencies, increased awakenings after sleep onset, and decreased sleep efficiency.

Leg movements, both periodic limb movements in sleep (PLMS) and the occurrence of restless legs syndrome (RLS), are increased during pregnancy, possibly related to hormonal changes.[16] The occurrence of RLS can increase sleep latency, and PLMS can increase nocturnal awakenings and EEG arousals, and decrease sleep efficiency.

The National Sleep Foundation's 2007 "Sleep in America" poll focused on sleep in women. A large section of the report focused on the sleep of pregnant women. The poll showed that although 82% of women reported sleeping well before they were pregnant, only 60% reported sleeping well during their pregnancy.[17] This dropped to 54% in women during the third trimester of pregnancy. Among the top factors reported to have the largest negative effects on sleep in pregnant women were getting up to go to the bathroom, pain, dreams, heartburn, nasal congestion, and leg cramps.

## Chapter Summary

Sleep is one of the most important functions the human body performs. This is especially evident when the body is deprived of sleep. Sleep deprivation can have profoundly negative effects, including daytime sleepiness, poor performance, lack of concentration, memory loss, and multiple health problems. Sleep debt refers to the amount of sleep we have lost over a period of time, compared with what we should have received. In addition to countless automobile and work-related accidents, many large-scale disasters may be related to sleep deprivation. Some of these include the Three Mile Island nuclear meltdown in 1979; the gas leak in Bhopal, India, in 1984; the *Challenger* space shuttle disaster in 1986; the Chernobyl nuclear accident in 1986; and the Exxon *Valdez* oil spill in 1989. Although the exact events leading to these disasters may never be fully known, it is believed that sleep deprivation may have played an important role in each of them.

The circadian rhythm affects not only our alertness during the daytime, but also our sleep patterns at night. Many factors can affect our circadian rhythm, including light, temperature, food, drugs, and activity levels.

Many different parts of the brain affect our circadian rhythm and our sleep. The main parts of the brain involved in sleep include the thalamus, medulla oblongata, hypothalamus, pons, midbrain, spinal cord, raphe nuclei, basal forebrain, hippocampus, suprachiasmatic nuclei, and reticular formation neurons.

Mammalian sleep can vary greatly among species. Among the most interesting is the dolphin, which can sleep with half of its brain at a time, allowing it to stay alert at all times and avoid predators.

Human sleep architecture consists of stages W, N1, N2, N3, and R (rapid eye movement) sleep. Stage N1 is a transitional stage from wake to sleep, and comprises approximately 5–10% of the total sleep time. Stage N2 is characterized by sleep spindles and K-complexes in the EEGs, and comprises approximately 40–50% of the total sleep time. Stage N3 is the stage in which the body's tissues and muscles are restored, and comprises approximately 20–25% of the night. Stage R is characterized by rapid eye movements and a decreased amplitude in the chin EMG, and comprises approximately 20–25% of the night. Deprivation from stage R has been shown to lead to memory loss and a lack of concentration. Normal sleep architecture shows a decrease in stage N3 as the night progresses, and longer periods of stage R.

Many changes to our sleep come naturally with age. Among the most significant are a decrease or even complete loss of stage N3, a decreased sleep efficiency, and increased complaints of insomnia. Drugs can also have profound effects on sleep, depending largely on the amount taken. Alcohol, for example, can increase slow wave sleep; however, it also tends to decrease sleep efficiency and increase daytime sleepiness.

Pregnancy can also greatly affect sleep in women. Additional weight from pregnancy can increase the likelihood of obstructive sleep apnea and primary snoring, and certain hormonal changes may play a role in the increase of leg movements during pregnancy. Other factors such as pain, discomfort, and increased urination can also negatively impact the sleep of pregnant women.

## Chapter 1 Questions

Please consider the following questions as they relate to the material in this chapter.

1. What is sleep debt? How can an increased sleep debt impact our daily lives?
2. How is our cycle of alertness during the day related to our sleep patterns at night?
3. How does human sleep differ from the sleep of other animals?
4. What are the stages of sleep, and how are they normally distributed during the night?
5. How does the normal aging process affect our sleep?
6. What is the significance of a decreased sleep latency? A decreased sleep efficiency?
7. What are some of the major effects that drugs can have on our sleep?
8. How can pregnancy affect sleep?

## FOOTNOTES


1. Sleep. (23 Oct. 2007). *WordNet 3.0*. Princeton University.
2. National Sleep Foundation. (2002). Sleep in America Poll.
3. Dement, W. C. (1999). *The Promise of Sleep*.
4. National Highway Traffic Safety Administration. National Survey of Distracted and Drowsy Driving Attitudes and Behavior: 2002.
5. Long, T. (2008). Dec. 3, 1984: Bhopal, 'Worst Industrial Accident in History'. *Wired.* Accessed at http://www.wired.com/science/discoveries/news/2008/12/dayintech_1203.
6. United States Nuclear Regulatory Commission. (2013). Backgrounder on Chernobyl Nuclear Power Plant Accident. Accessed at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/chernobyl-bg.html.
7. National Geographic New, 24 Feb. 2005.
8. Personal account with the author.
9. Dement, W. C. (1999). *The Promise of Sleep*.
10. Circadian Rhythm. (29 Oct. 2007). *American Heritage Science Dictionary*. Houghton-Mifflin.
11. Butkov. (2007). *Fundamentals of Sleep Technology*.
12. Sleep Management Services. (2002) *Principles of Polysomnography*.
13. *Principles and Practice of Sleep Medicine*, 3rd ed.
14. Sleep Management Services. (2002). *Principles of Polysomnography*.
15. Butkov. (2007). *Fundamentals of Sleep Technology*.
16. Suzuki, K., et al., (2003). Sleep. 26(6).
17. National Sleep Foundation. (2007). Sleep in America Poll.