

Brain Basics: Understanding Sleep

Introduction

Sleep is an important part of your daily routine—you spend about one-third of your time doing it. Quality sleep – and getting enough of it at the right times -- is as essential to survival as food and water. Without sleep you can't form or maintain the pathways in your brain that let you learn and create new memories, and it's harder to concentrate and respond quickly.

Sleep is important to a number of brain functions, including how nerve cells (neurons) communicate with each other. In fact, your brain and body stay remarkably active while you sleep. Recent findings suggest that sleep plays a housekeeping role that removes toxins in your brain that build up while you are awake.

Everyone needs sleep, but its biological purpose remains a mystery. Sleep affects almost every type of tissue and system in the body – from the brain, heart, and lungs to metabolism, immune function, mood, and disease resistance. Research shows that a chronic lack of sleep, or getting poor quality sleep, increases the risk of disorders including high blood pressure, cardiovascular disease, diabetes, depression, and obesity.

Sleep is a complex and dynamic process that affects how you function in ways scientists are now beginning to understand. This booklet describes how your need for sleep is regulated and what happens in the brain during sleep.

Anatomy of Sleep

Several structures within the brain are involved with sleep.

The **hypothalamus**, a peanut-sized structure deep inside the brain, contains groups of nerve cells that act as control centers affecting sleep and arousal. Within the hypothalamus is the **suprachiasmatic nucleus** (SCN) – clusters of thousands of cells that receive information about light exposure directly from the eyes and control your behavioral rhythm. Some people with damage to the SCN sleep erratically throughout the day because they are not able to match their circadian rhythms with the light-dark cycle. Most blind people maintain some ability to sense light and are able to modify their sleep/wake cycle.

The **brain stem**, at the base of the brain, communicates with the hypothalamus to control the transitions between wake and sleep. (The brain stem includes structures called the pons, medulla, and midbrain.) Sleep-promoting cells within the hypothalamus and the brain stem produce a brain chemical called *GABA*, which acts to reduce the activity of arousal centers in the hypothalamus and the brain stem. The brain stem (especially the pons and medulla) also plays a special role in REM sleep; it sends signals to relax muscles essential for body posture and limb movements, so that we don't act out our dreams.

The **thalamus** acts as a relay for information from the senses to the **cerebral cortex** (the covering of the brain that interprets and processes information from short- to long-term memory). During most stages of sleep, the thalamus becomes quiet, letting you tune out the external world. But during REM sleep, the thalamus is active, sending the cortex images, sounds, and other sensations that fill our dreams.

The **pineal gland**, located within the brain's two hemispheres, receives signals from the SCN and increases production of the hormone *melatonin*, which helps put you to sleep once the lights go down. People who have lost their sight and cannot coordinate their natural wake-sleep cycle using natural light can stabilize their sleep patterns by taking small amounts of melatonin at the same time each day. Scientists believe that peaks and valleys of melatonin over time are important for matching the body's circadian rhythm to the external cycle of light and darkness.

The **basal forebrain**, near the front and bottom of the brain, also promotes sleep and wakefulness, while part of the **midbrain** acts as an arousal system. Release of adenosine (a chemical by-product of cellular energy consumption) from cells in the basal forebrain and probably other regions supports your sleep drive. Caffeine counteracts sleepiness by blocking the actions of adenosine.

The **amygdala**, an almond-shaped structure involved in processing emotions, becomes increasingly active during REM sleep.

Sleep Stages

There are two basic types of sleep: rapid eye movement (REM) sleep and non-REM sleep (which has three different stages). Each is linked to specific brain waves and neuronal activity. You cycle through all stages of non-REM and REM sleep several times during a typical night, with increasingly longer, deeper REM periods occurring toward morning.

Stage 1 non-REM sleep is the changeover from wakefulness to sleep. During this short period (lasting several minutes) of relatively light sleep, your heartbeat, breathing, and eye movements slow, and your muscles relax with occasional twitches. Your brain waves begin to slow from their daytime wakefulness patterns.

Stage 2 non-REM sleep is a period of light sleep before you enter deeper sleep. Your heartbeat and breathing slow, and muscles relax even further. Your body temperature drops and eye movements stop. Brain wave activity slows but is marked by brief bursts of electrical activity. You spend more of your repeated sleep cycles in stage 2 sleep than in other sleep stages.

Stage 3 non-REM sleep is the period of deep sleep that you need to feel refreshed in the morning. It occurs in longer periods during the first half of the night. Your heartbeat and breathing slow to their lowest levels during sleep. Your muscles are relaxed and it may be difficult to awaken you. Brain waves become even slower.

REM sleep first occurs about 90 minutes after falling asleep. Your eyes move rapidly from side to side behind closed eyelids. Mixed frequency brain wave activity becomes closer to that seen in wakefulness. Your breathing becomes faster and irregular, and your heart rate and blood pressure increase to near waking levels. Most of your dreaming occurs during REM sleep,

although some can also occur in non-REM sleep. Your arm and leg muscles become temporarily paralyzed, which prevents you from acting out your dreams. As you age, you sleep less of your time in REM sleep. Memory consolidation most likely requires both non-REM and REM sleep.

Sleep mechanisms

Two internal biological mechanisms—circadian rhythm and homeostasis—work together to regulate when you are awake and sleep.

Circadian rhythms direct a wide variety of functions from daily fluctuations in wakefulness to body temperature, metabolism, and the release of hormones. They control your timing of sleep and cause you to be sleepy at night and your tendency to wake in the morning without an alarm. Your body's biological clock, which is based on a roughly 24-hour day, controls most circadian rhythms. Circadian rhythms synchronize with environmental cues (light, temperature) about the actual time of day, but they continue even in the absence of cues.

Sleep-wake homeostasis keeps track of your need for sleep. The homeostatic sleep drive reminds the body to sleep after a certain time and regulates sleep intensity. This sleep drive gets stronger every hour you are awake and causes you to sleep longer and more deeply after a period of sleep deprivation.

Factors that influence your sleep-wake needs include medical conditions, medications, stress, sleep environment, and what you eat and drink. Perhaps the greatest influence is the exposure to light. Specialized cells in the retinas of your eyes process light and tell the brain whether it is day or night and can advance or delay our sleep-wake cycle. Exposure to light can make it difficult to fall asleep and return to sleep when awakened.

Night shift workers often have trouble falling asleep when they go to bed, and also have trouble staying awake at work because their natural circadian rhythm and sleep-wake cycle is disrupted. In the case of jet lag, circadian rhythms become out of sync with the time of day when people fly to a different time zone, creating a mismatch between their internal clock and the actual clock.

How Much Sleep Do You Need?

Your need for sleep and your sleep patterns change as you age, but this varies significantly across individuals of the same age. There is no magic “number of sleep hours” that works for everybody of the same age. Babies initially sleep as much as 16 to 18 hours per day, which may boost growth and development (especially of the brain). School-age children and teens on average need about 9.5 hours of sleep per night. Most adults need 7-9 hours of sleep a night, but after age 60, nighttime sleep tends to be shorter, lighter, and interrupted by multiple awakenings. Elderly people are also more likely to take medications that interfere with sleep.

In general, people are getting less sleep than they need due to longer work hours and the availability of round-the-clock entertainment and other activities.

Many people feel they can "catch up" on missed sleep during the weekend but, depending on how sleep-deprived they are, sleeping longer on the weekends may not be adequate.

Dreaming

Everyone dreams. You spend about 2 hours each night dreaming but may not remember most of your dreams. Its exact purpose isn't known, but dreaming may help you process your emotions. Events from the day often invade your thoughts during sleep, and people suffering from stress or anxiety are more likely to have frightening dreams. Dreams can be experienced in all stages of sleep but usually are most vivid in REM sleep. Some people dream in color, while others only recall dreams in black and white.

The Role of Genes and Neurotransmitters

Chemical signals to sleep

Clusters of sleep-promoting neurons in many parts of the brain become more active as we get ready for bed. Nerve-signaling chemicals called neurotransmitters can “switch off” or dampen the activity of cells that signal arousal or relaxation. GABA is associated with sleep, muscle relaxation, and sedation. Norepinephrine and orexin (also called hypocretin) keep some parts of the brain active while we are awake. Other neurotransmitters that shape sleep and wakefulness include acetylcholine, histamine, adrenaline, cortisol, and serotonin.

Genes and sleep

Genes may play a significant role in how much sleep we need. Scientists have identified several genes involved with sleep and sleep disorders, including genes that control the excitability of neurons, and "clock" genes such as *Per*, *tim*, and *Cry* that influence our circadian rhythms and the timing of sleep. Genome-wide association studies have identified sites on various chromosomes that increase our susceptibility to sleep disorders. Also, different genes have been identified with such sleep disorders as familial advanced sleep-phase disorder, narcolepsy, and restless legs syndrome. Some of the genes expressed in the cerebral cortex and other brain areas change their level of expression between sleep and wake. Several genetic models—including the worm, fruit fly, and zebrafish—are helping scientists to identify molecular mechanisms and genetic variants involved in normal sleep and sleep disorders. Additional research will provide better understand of inherited sleep patterns and risks of circadian and sleep disorders.

Sleep studies

Your health care provider may recommend a polysomnogram or other test to diagnose a sleep disorder. A polysomnogram typically involves spending the night at a sleep lab or sleep center. It records your breathing, oxygen levels, eye and limb movements, heart rate, and brain waves throughout the night. Your sleep is also video and audio recorded. The data can help a sleep specialist determine if you are reaching and proceeding properly through the various sleep stages. Results may be used to develop a treatment plan or determine if further tests are needed.

Tracking Sleep Through Smart Technology

Millions of people are using smartphone apps, bedside monitors, and wearable items (including bracelets, smart watches, and headbands) to informally collect and analyze data about their sleep. Smart technology can record sounds and movement during sleep, journal hours slept, and monitor heart beat and respiration. Using a companion app, data from some devices can be synced to a smartphone or tablet, or uploaded to a PC. Other apps and devices make white noise, produce light that stimulates melatonin production, and use gentle vibrations to help us sleep and wake.

Tips for Getting a Good Night's Sleep

Getting enough sleep is good for your health. Here are a few tips to improve your sleep:

Set a schedule – go to bed and wake up at the same time each day.

Exercise 20 to 30 minutes a day but no later than a few hours before going to bed.

Avoid caffeine and nicotine late in the day and alcoholic drinks before bed.

Relax before bed – try a warm bath, reading, or another relaxing routine.

Create a room for sleep – avoid bright lights and loud sounds, keep the room at a comfortable temperature, and don't watch TV or have a computer in your bedroom.

Don't lie in bed awake. If you can't get to sleep, do something else, like reading or listening to music, until you feel tired.

See a doctor if you have a problem sleeping or if you feel unusually tired during the day. Most sleep disorders can be treated effectively.

Hope Through Research

Scientists continue to learn about the function and regulation of sleep. A key focus of research is to understand the risks involved with being chronically sleep deprived and the relationship between sleep and disease. People who are chronically sleep deprived are more likely to be overweight, have strokes and cardiovascular disease, infections, and certain types of cancer than those who get enough sleep. Sleep disturbances are common among people with age-related neurological disorders such as Alzheimer's disease and Parkinson's disease. Many mysteries remain about the association between sleep and these health problems. Does the lack of sleep lead to certain disorders, or do certain diseases cause a lack of sleep? These, and many other questions about sleep, represent the frontier of sleep research.

Where Can I Get More Information?

For information on other neurological disorders or research programs funded by the National Institute of Neurological Disorders and Stroke, contact the Institute's Brain Resources and Information Network (BRAIN) at:

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P.O. Box 5801
Bethesda, MD 20824
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