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The Effects of Circadian Rhythms on Human Sleep-Wake Cycles

by Elaine Tu

When the alarm clock rings in the morning, some of us wake up and feel an overwhelming urge to hit the snooze button and go back to sleep. Barely able to drag ourselves out of bed, we hear the cheerful "good mornings" of others, and secretly wonder how they can be alert and fully conscious at such an early hour. Conversely, there are those of us who love to begin each day by bouncing out of bed and throwing open the curtains, but cannot understand the people who merely cringe and retreat deeper into their blankets. The affinity of these early-rising "larks" and late-waking "owls" for either morning or evening is more than a matter of personal preference. The reason for such different behaviors is biological, caused by slight differences in the internal clock.

What is an Internal Clock?

An internal clock is a commonly used term that refers to the body's ability to maintain an inner rhythm. Physically, the clock is composed of two small, olive-shaped clusters located at the base of the brain, in the ventral hypothalamus region. This pair, each containing about 10,000 neurons, is referred to as the suprachiasmatic nucleus, or SCN (Koukkari and Sothern 2006). The SCN is primarily responsible for overseeing the body's circadian rhythms, which are biological processes that repeat every 24 hours (Dunlap 2004). Humans typically spend a 24-hour day in alternating periods of sleep and wakefulness. An important function of the clock is to maintain these daily sleep-wake cycles (Horne 2006). More specifically, the clock controls when feelings of alertness or sleepiness are most acute. Due to the internal clock, a person will experience a 24 hour rhythm of changing alertness levels, similar to that shown below:

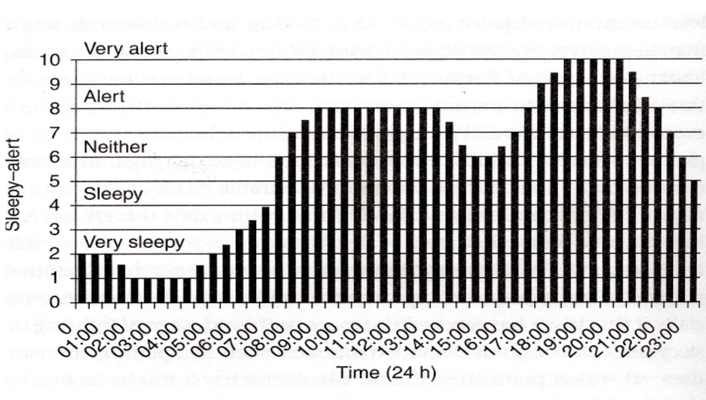


Figure 4 Alertness over the 24-hour day.

102 Courtesy of: Horne, Jim. 2006. Sleepfaring. Oxford: Oxford University Press.

Notice that there is a dip near mid-afternoon. The presence of this small decrease in alertness is a possible explanation of why some people feel the urge to nap after lunch. With the exception of the dip, the rest of the chart matches the expected human activities, with high levels of alertness corresponding to times spent awake and low levels of alertness corresponding to times spent sleeping.

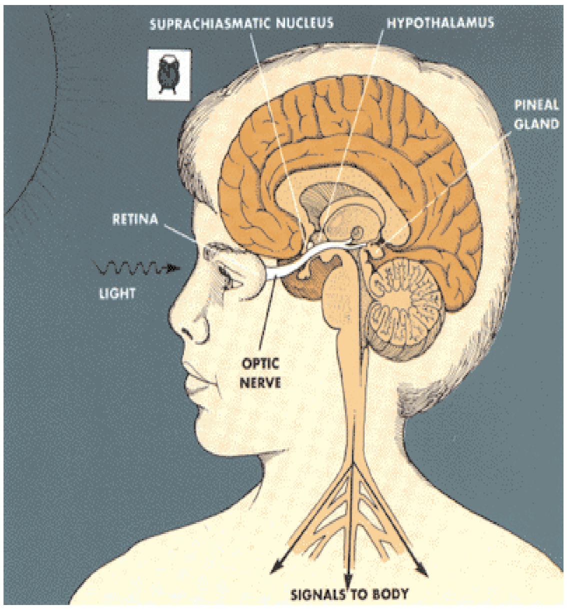
Experimental results have confirmed that, much like a mechanical clock, the internal clock can keep time by maintaining a rhythm independent of the environment.

Internal Timekeeping

To uphold a periodic sleep-wake cycle, the body must have a method of keeping time. Experimental results have confirmed that, much like a mechanical clock, the internal clock can keep time by maintaining a rhythm independent of the environment (Koukkari and Sothern 2006). In order to test the self-sustaining nature of the internal clock, scientists have developed a series of "free running" experiments, in which the body is allowed to run its natural rhythm without the presence of external time cues. One such study, conducted on 11 young men and 13 older subjects, showed that the period of the circadian oscillator was 24.18 hours (Czeisler, et al.). Indeed, although the exact times may differ, all free running experiments have produced results which suggest that circadian rhythms have an endogenous period that is slightly longer than 24 hours (Refinetti 1999).

In addition to the period of the SCN as a whole, rhythmicity also exists at the cellular level. By cutting away a rat's SCN and observing it in a laboratory dish, researchers found that individual SCN cells retained a rhythm with a period different from that of the entire SCN. In one experiment, the scientists concluded that the mean circadian period was about 24.2 hours, while the period of each cell ranged from 20 to 28.3 hours (Honma et al.). The ability of the SCN and individual SCN neurons to keep time independently implies that the period is genetically determined, and will continue in the absence of external time factors (Koukkari and Sothern 2006). Even so, *The primary responsibility of the SCN is to oversee the body's circadian rhythms, biological processes that repeat every 24 hours.*

because the outside world is not without time cues, the internal clock must adjust accordingly to these everyday parameters.



Courtesy of: http://www.sfn.org/skins/main/images/brainbriefings/bio_clocks_illus.gif.

The physical location of the SCN, otherwise known as the internal clock.

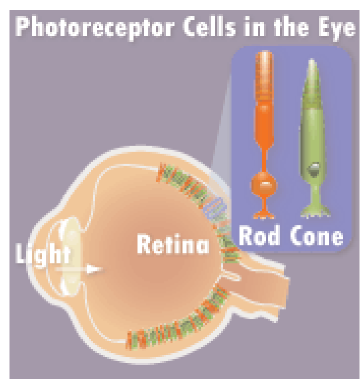
External Time Cues

In a typical day, an individual will encounter a variety of elements that can potentially synchronize the internal clock through a process called entrainment. Such external motivators are known as "zeitgebers" from the German term "time givers," and can include any type of regular activity, such as habitual mealtimes, physical exercise, and social interactions (Refinetti 1999). Since circadian rhythms are based upon alternating intervals of light and darkness, light is the main factor that entrains the period of the internal clock to match the pattern of a 24-hour day (Duffy and Wright 2005). Light detecting proteins, called photoreceptors, are required to sense changes in the light-darkness cycle. For mammals, photoreceptors are located in the eyes (Foster and Kreitzman 2004).

The Eyes—Beyond Vision

In addition to providing visual information, the eyes also serve as windows to the circadian system. Early studies of rats revealed that the SCN is connected to the eyes by a pathway named the retinohypothalamic tract (RHT). By means of the RHT, the SCN receives information concerning light levels from photoreceptors located in the eye (Moore and Lenn 1972). For many years, rods and cones were the only identified photoreceptors (von Schantz, Provencio, and Foster 2000). However, studies of blind people have suggested that one or more additional photoreceptors exist in the inner layers of the retina (von Schantz, Provencio, and Foster 2000). One of these photoreceptors was recently identified as melanopsin, a protein which, like rods and cones, can also convey information to the SCN (Hankins, Peirson, and Foster 2008).

Using the data provided by the photoreceptors, the SCN can adjust the timing of the circadian system to match that of the outside environment. One method of entrainment is through the release of melatonin. During the day, melatonin levels are fairly low, but as a response to darkness, the SCN sends a signal to the pineal gland through a multi-synaptic pathway to produce melatonin (Lubkin, Beizai, and Sadun 2002). As light levels decrease, melatonin levels increase, reach a peak at 2-4 a.m., and gradually level off during the remaining part of the night (Brzezinski 2008). The changing melatonin levels in the bloodstream act as a biological time cue for the rest of the body. Induced by the regular rising and setting of the sun, these time indicators usually vary periodically and only deviate from the established pattern if a change in environment occurs.



Light, sensed by rods and cones located at the back of the eye, serves to entrain the circadian system.

Courtesy of: http://learn.genetics.utah.edu/features/clockgenes

Lagging Behind

Travelers flying across multiple time zones often have trouble sleeping at night, feel tired and drowsy during the day, and may experience increased irritability. These symptoms, along with others, are collectively known as "jet lag," and occur when a person's internal sense of time and the local time become desynchronized (Dunlap 2004). While the circadian clock will eventually adjust itself to the new environment, the traveler will have a few uncomfortable days until then. Such drastic changes and resulting discomfort can draw attention to the importance of circadian rhythms, which might otherwise be taken for granted.

The internal clock is such an engrained part of daily life that its presence often goes unnoticed. The daily pattern of waking and sleeping occurs with such regularity that people often cease to think about it at all. Many like to believe that they are in complete control of their lives, but closer examination reveals that the SCN, a mere fraction of the billions of cells in the brain, dictates when and how much of a day should be spent in wakefulness and sleep. Some of us naturally have internal clocks which make us early-rising larks, while others possess clocks which make them "owls." Regardless of "lark," "owl," or anything in between the extremes, awareness of circadian rhythms can be extremely advantageous. With the knowledge that there are optimum times for each of our bodies, we can adjust our daily activities accordingly, or at the very least have a better understanding of why others are so grumpy or cheery in the mornings.

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