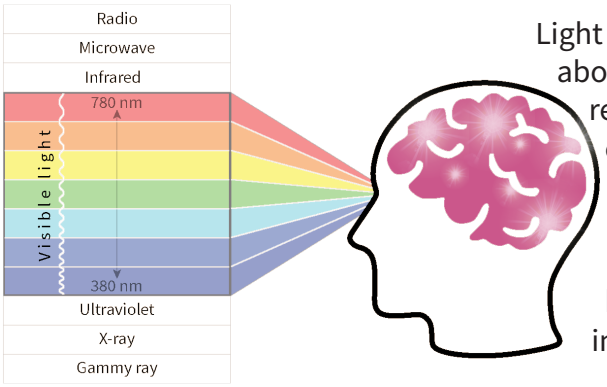
Light & the Circadian System

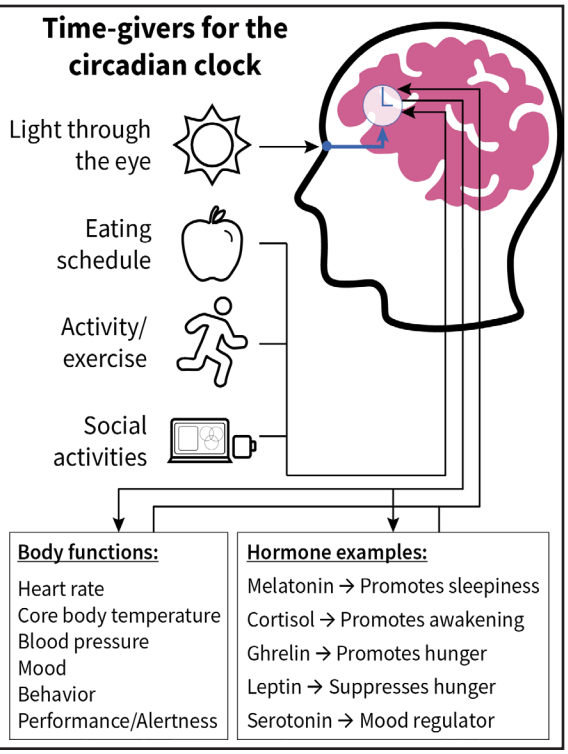
What is light?



Light is the portion of the electromagnetic spectrum between about 380 and 780 nanometers (nm) that evokes a visual response in humans. But light isn't just for vision; patterns of light and dark also provide timing cues that synchronize the circadian systems of Earth's innumerable organisms. Also, light makes us feel alert, at any time of day or night. Alertness is a short-term (<24 hours, "acute") effect that is largely independent of the circadian system [1].

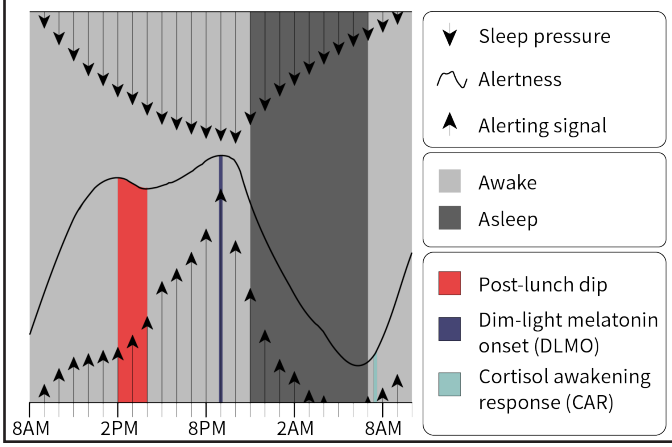
Circadian system's time-givers

All of the cycles of the body are controlled by the master clock in the brain, formally known as the circadian clock. The human circadian system (circa = "about," dies = "day") operates naturally on a ~24.2-hour cycle, so relies on external cues to synchronize with the 24-hour solar day. The circadian clock is responsible for regulating hormonal cycles and body functions that should occur at certain times in the day and night. If the biological clock is not synchronized to the solar day, it will be on a free-running schedule, regulated by social demands and sleep pressure. This causes the disruption and desynchronization of hormones. For example, excessive light at night (LAN) can delay the release of melatonin (a hormone released at night). Disruption to the proper cycles and amount of the hormones can cause negative impacts in the short and long term. These include sleep disorders, social jet lag, decreased performance and alertness, bad mood/behavior, and increased risk of cardiovascular disease, diabetes, obesity [6], cancer [7], and depression [8].



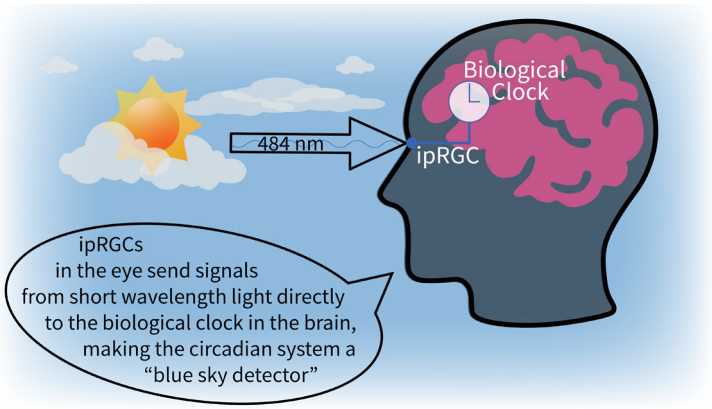
Sleep pressure & daily alertness

Sleep "debt" accumulates during our waking hours, and declines when we sleep. This tendency is counteracted to maintain daytime wakefulness by an alerting signal, regulated by the circadian system. Around 16–18 hours after the previous night's bedtime, many people experience a decline in alertness and performance known as the "post-lunch dip." At this time of day, the alerting signal is beginning to level off and decline. Meanwhile sleep debt is gathering momentum; sleep debt peaks about 8 hours later, triggering sleep. Melatonin hormone is produced in response to dim light during the evening. Melatonin prepares the body for sleep during an interval known as dim-light melatonin onset (DLMO) [34].

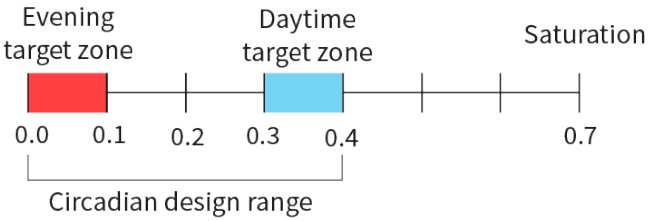


Circadian system's receptors

In the retina, intrinsically photosensitive retinal ganglion cells (ipRGCs) send light–dark neural signals to the biological clock to create a circadian system response. Only relatively recently discovered [53], the ipRGCs play a key—but not exclusive—role in circadian entrainment. These cells are particularly sensitive to blue (i.e., short wavelength) light. These non-visual cells are slower to respond than those contributing to vision (rods and cones).



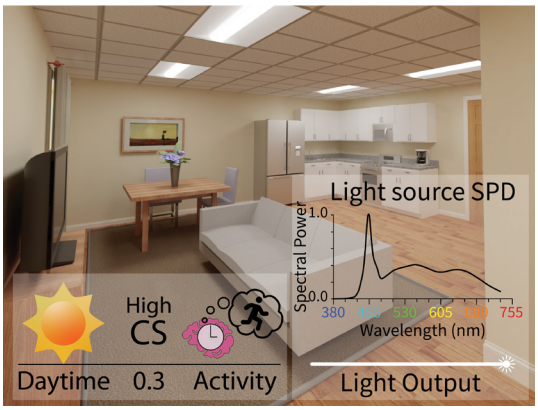
Circadian stimulus

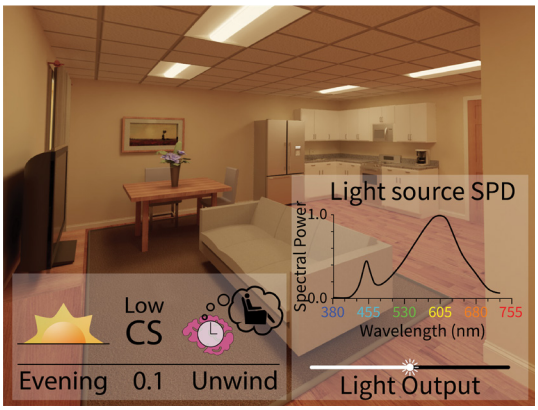


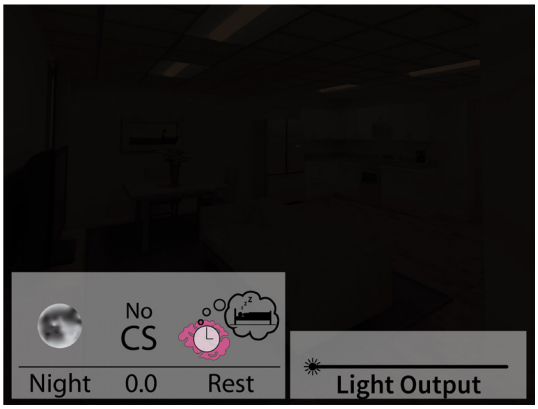
The circadian stimulus (CS) metric, developed by the LRC, is used to assess how eff ective a light source is in stimulating the circadian system [22, 41, 42]. CS calculations use circadian light ("CLA") based on amount and spectrum of light that reaches the eye. CS is calculated by transforming CLA into a relative scale, from approximately 0.1 (≈10%, the threshold for circadian system activation), to approximately 0.7 (≈70%, response saturation). CS is equivalent to nocturnal melatonin suppression (in percent) aft er a 1-h exposure to light.

To entrain the biological clock to the solar day, field and laboratory research [43, 44, 45, 46] suggests that a CS ≥0.3 should be provided for at least 2-3 hours in the morning; at least two hours before desired bedtime, CS should be reduced (< 0.1). Suggested CS schedules will vary based on the occupant(s). Changing CS values can be achieved primarly by changing light output, but also by using dynamic spectra (correlated color temperatures [CCT]), or a combination of both. Typically, white light sources with a "cooler" appearance (CCTs > 5000 K) will reach a CS of 0.3 at lower light levels compared to warmer "white" light sources (< 3500 K). In the first example below, a robust light/dark pattern is achieved; the second example shows a typical lighting scheme that is inadequate for stimulating the circadian system because CS is too low during the day.

Robust circadian- effective lighting design







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