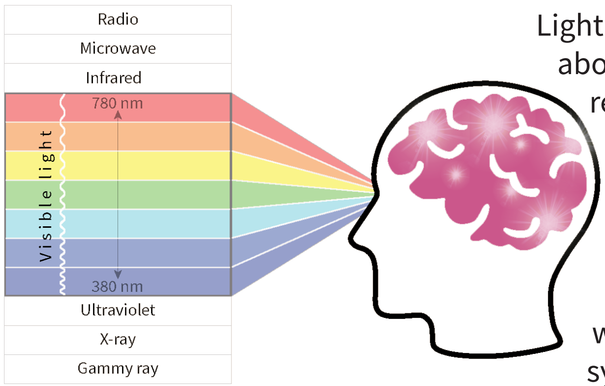
# Light & the Circadian System

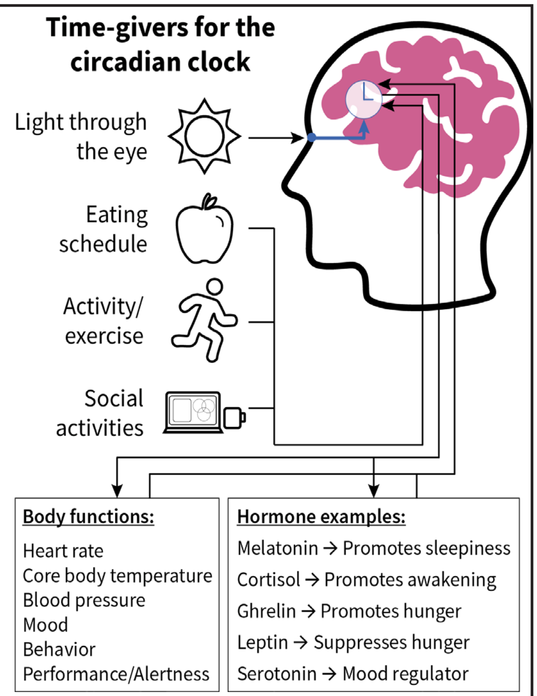
## What is light?




Light is the portion of the electromagnetic spectrum between about 380 and 780nano meters (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 innumerable organisms circadian systems to the local position on Earth's. Light can also makes us feel alert, at any time of day or night. Alertness is an "acute" effect that can be obtained without directly affecting the circadian system [1].

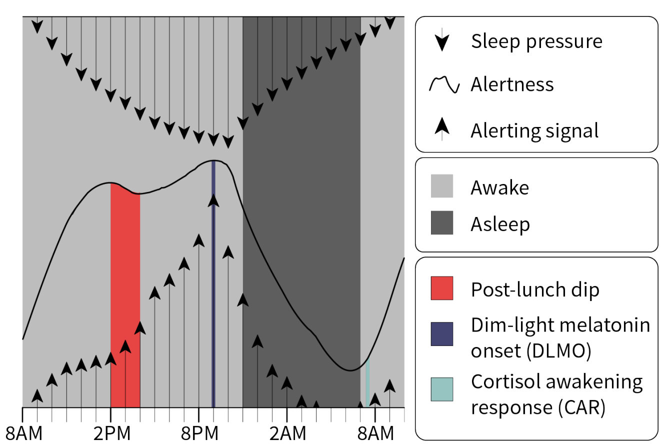

## Circadian system's time-givers

All body rhythms 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 it relies on external cues to synchronize it with the 24-hour solar day. The circadian clock generates and regulates hormonal cycles and body functions that are observed at different times in the day and night. If the circadian clock is not synchronized to the solar day, it will be disrupted and not perform the right things at the right times. For example, disruption circadian rhythms 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].



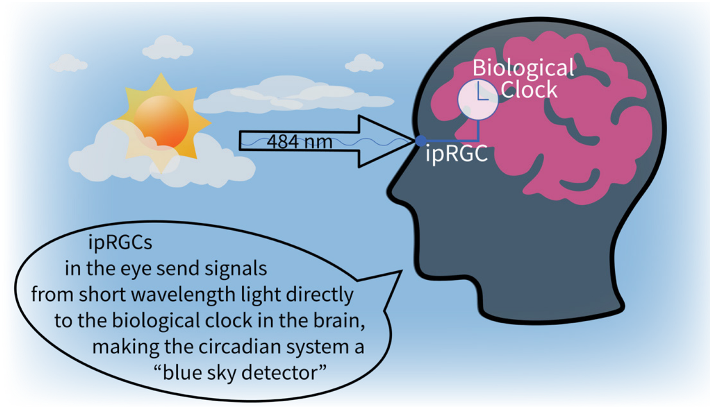

## Sleep pressure & daily alertness

Sleep "debt" accumulates during our waking hours, and declines when we sleep. During the day, this sleep tendency is counteracted by an alerting signal given by the circadian clock. 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 from the circadian clock is not strong enough to counteract the sleep pressure. Meanwhile sleep debt is gathering momentum; sleep debt peaks about 8 hours later, triggering sleep. Melatonin at night and under circadian darkness or dim light. Melatonin tells the body it is nighttime, which means it is time to prepare for sleep [34].

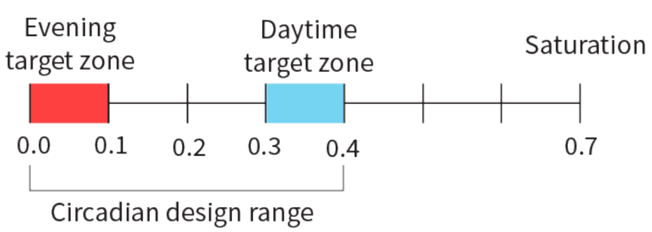


## Circadian system's receptors

In the retina, intrinsically photosensitive retinal ganglion cells (ipRGCs) combines signals from rods and cones and send them to the circadian clock. 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.



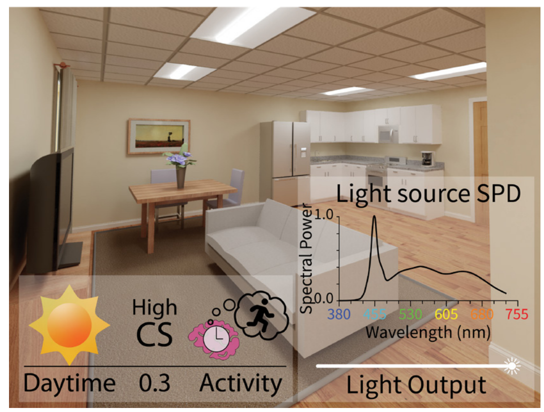

## Circadian stimulus

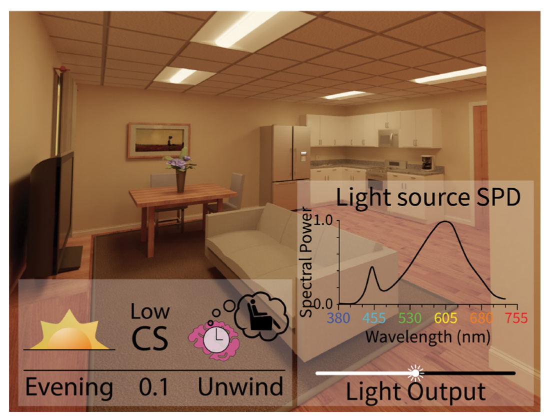


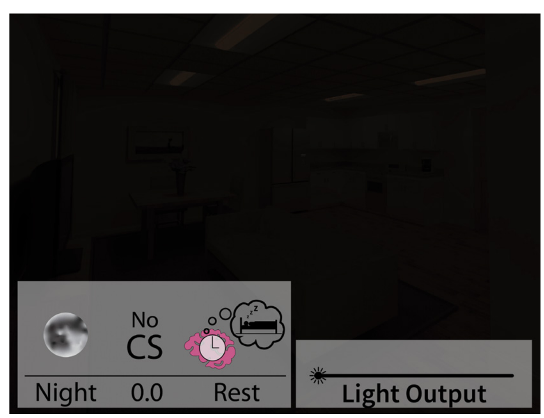

The circadian stimulus (CS) metric, developed by the Lighting Research Center (LRC), is used to assess how effective a light source (amount and spectrum) is in stimulating the circadian system [22, 41, 42]. CS calculations use circadian light ("$CL_A$") based on the spectral sensitivity of the circadian system response. CS is calculated by transforming $CL_A$ 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) after a 1-hour 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 primarily 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 example to the right, a robust light/dark pattern is achieved.

### Robust circadian- effective lighting design



## References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