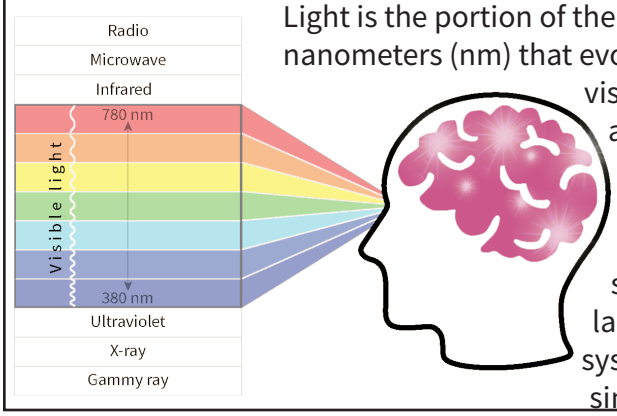
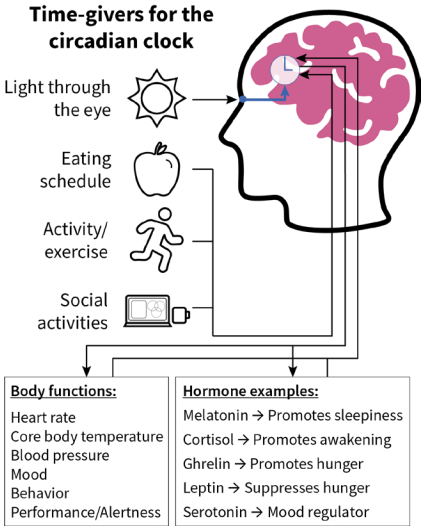
Light & the Circadian System

What is light?

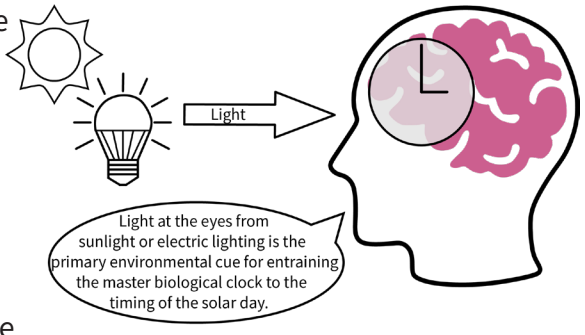


Light is the portion of the electromagnetic spectrum between about 380 and 780 nanometers (nm) that evokes a visual response in humans. But light isn't just for vision. The pattern of light and dark incident on the retinae also provides timing cues that inform and synchronize the circadian systems of Earth's innumerable organisms. In humans, light also evokes an acute alerting response any time of day or night. In this context, "acute" connotes a short-term (< 24 hours) effect that is largely independent of the circadian system [1] rather than an effect that is simply sudden, sharp, or severe.

Circadian system's time-givers

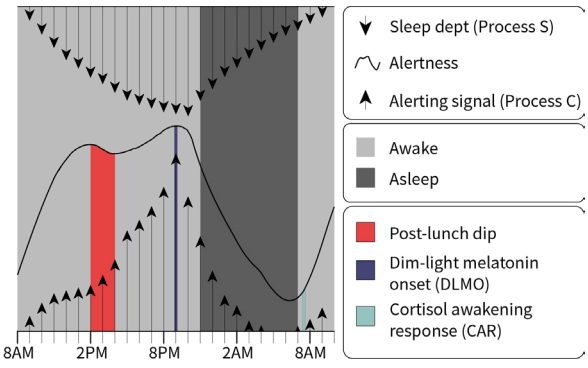


All of the cycles of the body are controlled by the master clock in the brain, formally known as the circadian clock. The human circadian system (circa = "about," dies = "day") opperates naturally on a ~24.2-hour cycle and relies on external cues to synchronize with the 24-hour solar day. The circadian 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, at the proper brightness and spectrum, light at night (LAN) can cause the release of melatonin (sleep hormone) to be delayed. Disruption to the proper cycles and amount of the hormones released can cause negative impacts in the short and long-term which include sleep disorders, depression [8], social jet lag, decreased performance and alertness, bad mood/behavior, and increased risk of cardiovascular disease, diabetes, obesity [6], and cancer [7].

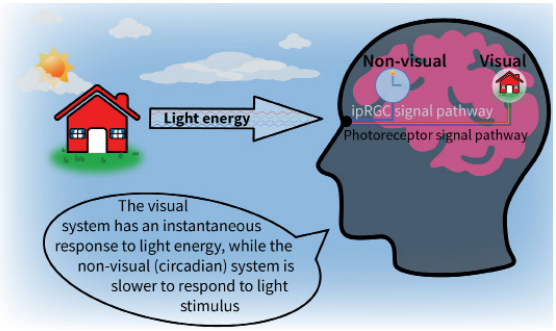


Sleep pressure & daily alertness

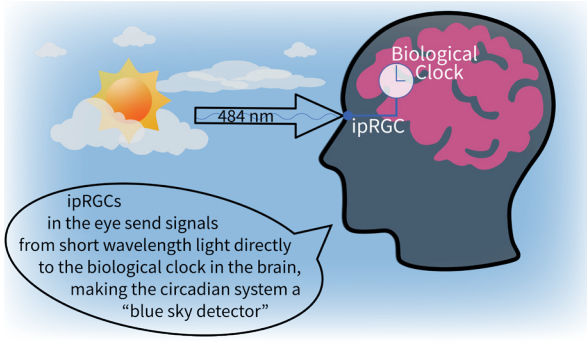
The regulation of sleep and waking has been broadly conceptualized as a two-process model, which involves the homeostatic process (Process S); sleep debt that accumulates during our waking hours and declines when we sleep. This tendency is counteracted to maintain daytime wakefulness by an alerting signal that is regulated by the circadian system (Process C). Around 2–4 PM, or 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, Process C is beginning to level off and decline while Process S is gathering momentum prior to it's abrupt peak and decline about 8 hours later, triggering sleep. Melatonin, a hormone released at night, is produced in response to dim light received at the eyes during the evening and prepares the body for sleep during an interval known as dim-light melatonin onset (DLMO) [34].



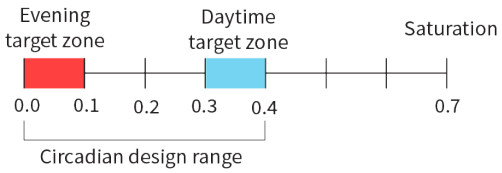
Circadian system's receptors



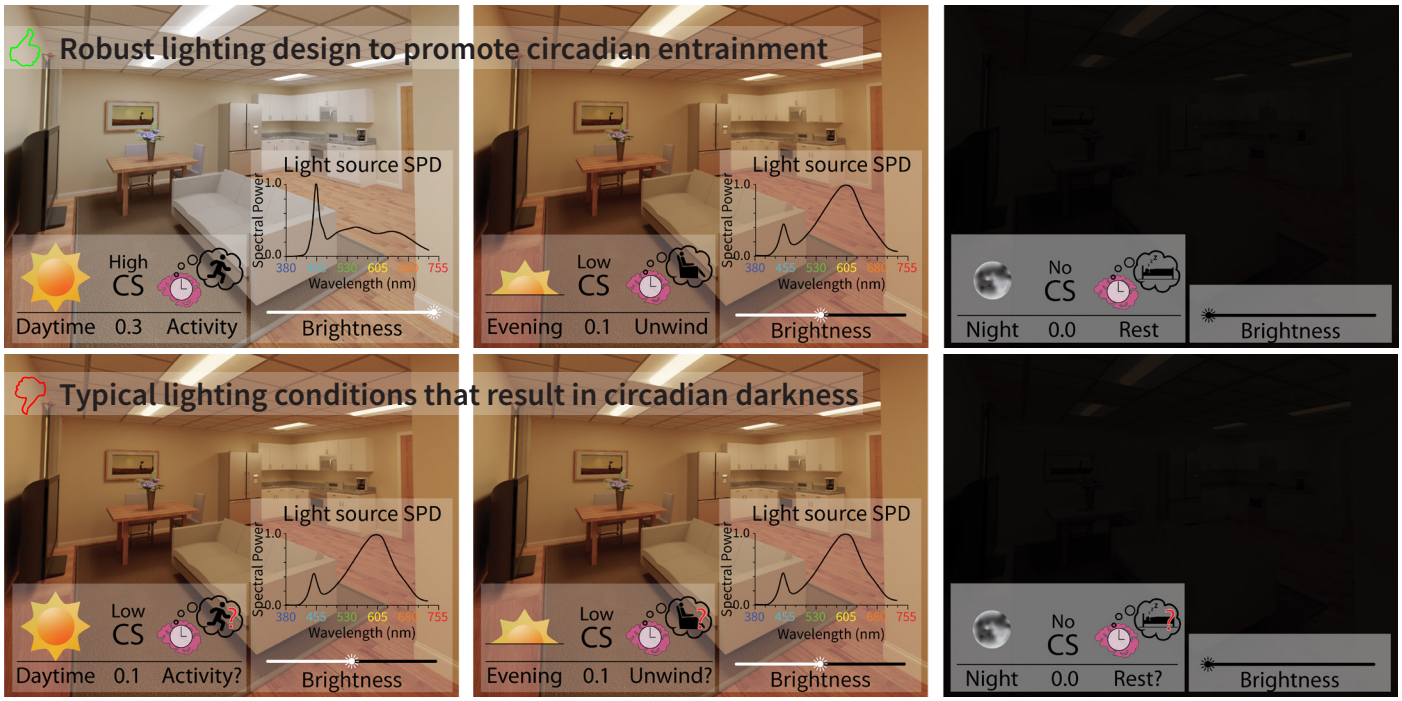
In addition to relaying image-forming ("visual") signals processed by the eye's photoreceptors, a unique class of retinal ganglion cells known as intrinsically photosensitive retinal ganglion cells (ipRGCs) send light–dark neural signals to the biological clock to create a circadian system response. Only relatively recently discovered [54], the ipRGCs play a key—but not exclusive—role in circadian entrainment.



Circadian stimulus



The circadian stimulus (CS) metric, developed by the LRC, is used to assess how effective a light source is in stimulating the circadian system [22,41,42]. CS is a transformation of circadian light, or CLA (based on brightness and spectrum of light that reaches the eye), into a relative scale from approximately 0.1 (≈ 10%), the threshold for circadian system activation, to approximately 0.7 (≈ 70%), response saturation, and is equivalent to nocturnal melatonin suppression in percent after 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, reducing to a CS < 0.1 in the evening hours, at least two hours before desired bedtime. Suggested CS schedules will vary based on the occupent(s). Changing CS values can be achieved by using dynamic spectra (correlated color temperatures [CCT]), brightness, or a combination of both. Typically, cooler white light sources, with CCTs > 5000 K, will reach a CS of 0.3 at lower light levels compared to warmer white light sources (< 3500 K). Below are two examples; one where a robust light/dark pattern is achieved, and one depicting a typical lighting scheme that is inadequate for stimulating the circadian system. Whether you want to have a regulated sleep schedule, healthier diet, exercise routine, more energy, better sleep and mood, or reduced risk of disease, proper circadian entrainment is the origin to which these initiatives can be achieved.



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