DAYLIGHT
PHYSICAL HEALTH
Talking Points

PARTNERSHIP INITIATIVE
INTEGRATED DESIGN LAB
at the Center for Integrated Design

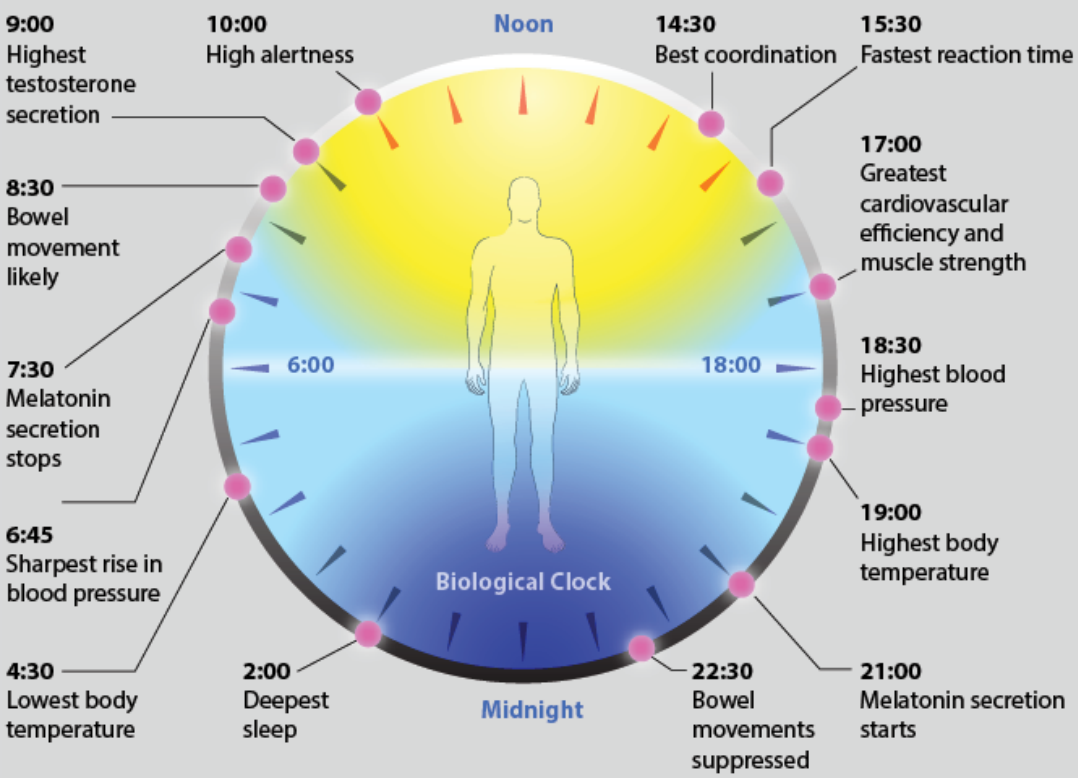

Figure 1:
Daily physiological effects of a typical circadian rhythm system. The inverse daylight-melatonin relationship is highlighted, with melatonin secretion stopping in the morning and resuming in the evening when the sun has set.

Source: https://cpapvictoria.com.au/blog/sleep-apnoea/circadian-rhythm-disorders/

Keywords:
daylight, physical health, circadian rhythm, melatonin, cortisol, physiological health, circadian disruption, sleep

CONTENT OVERVIEW

DAYLIGHT + PHYS. HEALTH SUMMARY

Daylight has many important physiological impacts on building occupants. These impacts predominantly manifest through light that enters the eye, though some come from light that is absorbed by the skin. In addition to contributing to eyestrain, daylight influences and properly sets the circadian rhythm, which has numerous impacts on physiology and physical health, both directly and indirectly.

I. General Physiological Impacts

i. Physiological effects through 2 mechanisms: falling on the skin or entering the eye.
   a. Daylight entering the eye influences a range of processes within the body.
   b. Daylight provides the best light for biological function because it has the richest spectral distribution of usable light, reducing stress on the eye.
   c. Most physiological effects of light are dependent on light directly entering the eye, not just reflected off of horizontal surfaces.

ii. The spectral characteristics of daylight are critical to the impact of light on health.
   a. Many biological functions are impacted by different wavelengths of light.
   b. Biological systems impacted include the nervous system, circadian system, endocrine system, and the pituitary and pineal gland.
   c. The optimal spectra for the visual system is different from the circadian system.

iii. The largest impact of daylight is related to the control of the circadian rhythms and hormone regulation through ligh-dark cycles.

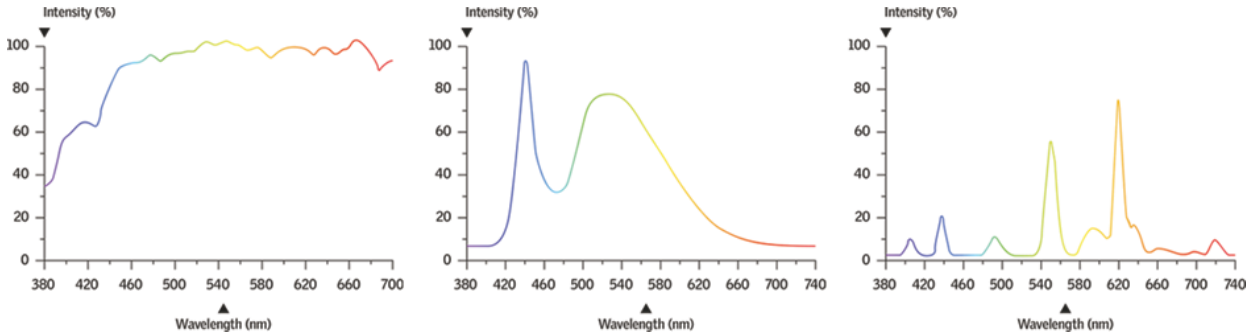

Figure 2: Comparison of spectral distribution of daylight, LED, and fluorescent light sources. Daylight provides a wider array of spectral diversity than artificial light sources, highlighting its importance in regulating health.
Source: https://www.velux.com/article/2016/daylight-natures-prescription

II. Pain + Healing

i. Exposure to daylight decreased pain levels in hospital patients.
   a. Daylight increases levels of serotonin, a neurotransmitter that inhibits pain pathways.
   b. Daylight reduced the use of hourly pain medication in patients recovering from surgery

ii. Daylight has been found to decrease the length of stay for hospital patients, both for mental health issues like depression and physiological health like heart attacks.
   a. Another study found daylight decreased mortality rates in heart attack patients.

III. Headaches, Eyestrain, Other Issues

i. Increased amount of time outside is associated with decreased levels of nearsightedness due to increased light intensity.

ii. Proper daylight in buildings reduces the incidences of headaches and migraines
   a. It may help by reducing the amount of flicker from electric lightings
   b. However, it may increase incidences due to high levels of contrast if not properly managed.

iii. For children in schools, daylight has been found to offer a number of benefits.
   a. Less cavities
   b. Improved eyesight
   c. Increased growth,
   d. Improved immune systems

iv. Workers in windowless factories were found to have higher rates of headaches, faintness and sickness compared to those in factories with windows.
   a. This suggests access to daylight has important impacts on health.

v. Eyestrain is the most direct physiological effect of daylight on the visual system.
   a. Caused by a range of issues, including too much light, too little light, too much glare, veiling reflections, shadows, and flicker (even when not perceptible)
   b. Daylight typically provides adequate light levels free of flicker, but can have issues with excessive illuminance and high contrast between outside and inside.
   c. Symptoms include inflammation of the eyes and lids, blurred or double vision, and headaches.
   d. Regular incidences of eyestrain negatively impact productivity due to decreased visual capabilities and the coping mechanisms employed by workers.
   e. In one study, those located near large proportions of daylight reported less incidents of eyestrain than those lacking daylight access.

IV. Light on the Skin

i. At the most basic level, sunlight on the skin causes skin tanning and sunburns.

ii. Daylight on the skin is also essential for the production of Vitamin D
   a. Vitamin D is needed for the absorption of calcium
   b. Helps decrease levels of tooth decay
   c. Helps recovery of broken bones

V. Impact on Sleep

i. Exposure to daylight during the day has been shown to impact sleep later in the evening
   a. Workers with greater daylight exposure slept an average of 46 more minutes a night than those with less exposure.

ii. Lack of sleep quality and quantity has a number of negative health outcomes
   a. These include short-term issues such as memory loss, slower reflexes, and diminished attention.
   b. This has also been associated with issues affecting weight management through hormones controlling appetite, metabolism, and cortisol.
   c. It's also been associated with higher BMIs (body mass index)
   d. Has performance impacts as well though increased fatigue and decreased concentration, leading to greater errors and risk for injury.

VI. Hormone Response

i. Hormone regulation is one of the key ways daylight impacts physiological health
   a. Melatonin
      1. Melatonin is the most important hormone regulated by daylight.
      2. Daylight suppresses the production of melatonin
      3. Melatonin plays an important role in determining a person's activity and energy level.
      4. High levels of melatonin cause drowsiness while low levels correspond with periods of alertness
      5. Melatonin is involved in a variety of diseases such as cancer, insomnia, depression, dementia, hypertension, and diabetes.
      6. More specifically, melatonin impacts sleep, mood, body temperature, puberty onset, and tumor development.
      7. Melatonin is a central component of the circadian system.
   b. Cortisol
      1. Daylight stimulates the production of cortisol.
      2. Cortisol plays an important roll in governing alertness.
      3. It also stimulates the immune and nervous systems, preparing the body for the day.

VI. Hormone Response cont.

c. Serotonin
   1. Serotonin is a neurotransmitter that inhibits pain pathways
   2. Daylight exposure and intensity increases serotonin levels

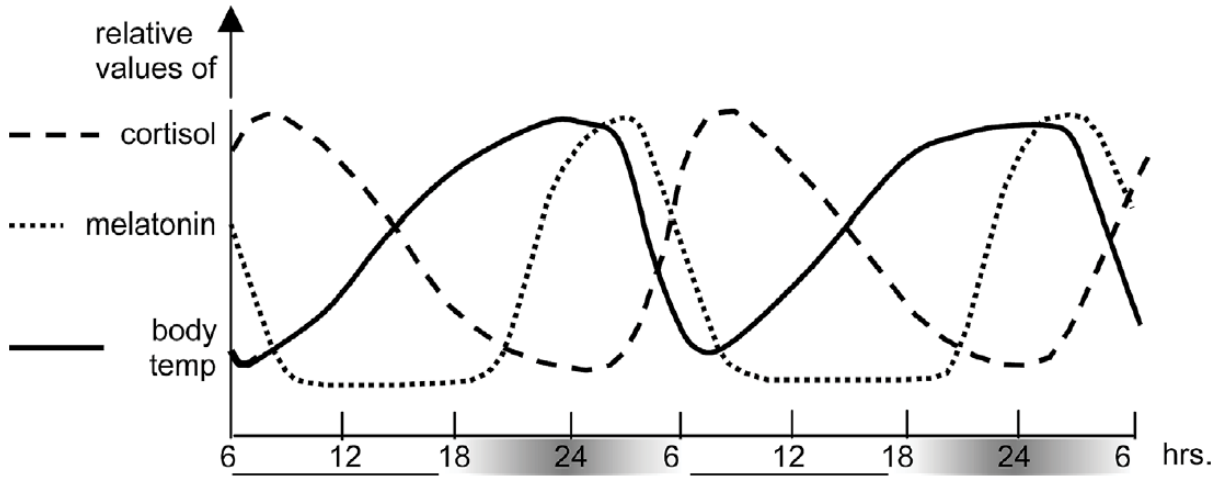

Figure 3: The cyclical pattern of melatonin, cortisol, and body temperature over the course of two days.
Source: van Bommel 2004

VII. Circadian Rhythm

i. What is circadian rhythm?
   a. Circadian rhythm is the collection of daily biological processes in the body that cycle approximately every 24 hours in response to daylight.
   b. The period is not exactly 24 hours, and relies on daylight to properly entrain to the day.
   c. Light exposure late at night can shift the circadian rhythms forward if while exposure in the afternoon and early night can delay them.
   d. Nearly all physiological processes exhibit circadian rhythms
   e. Physiological effects are influenced both directly through light reaching the eye and indirectly by the influence of the circadian rhythm system.
   f. The most visible manifestation of the circadian system is the sleep-wake cycle through the secretion of melatonin.
   g. Though a critical competent of regulating physiological systems, it's important to note that the impact of light on health is not exclusively through the circadian system.

VII. Circadian Rhythm cont.

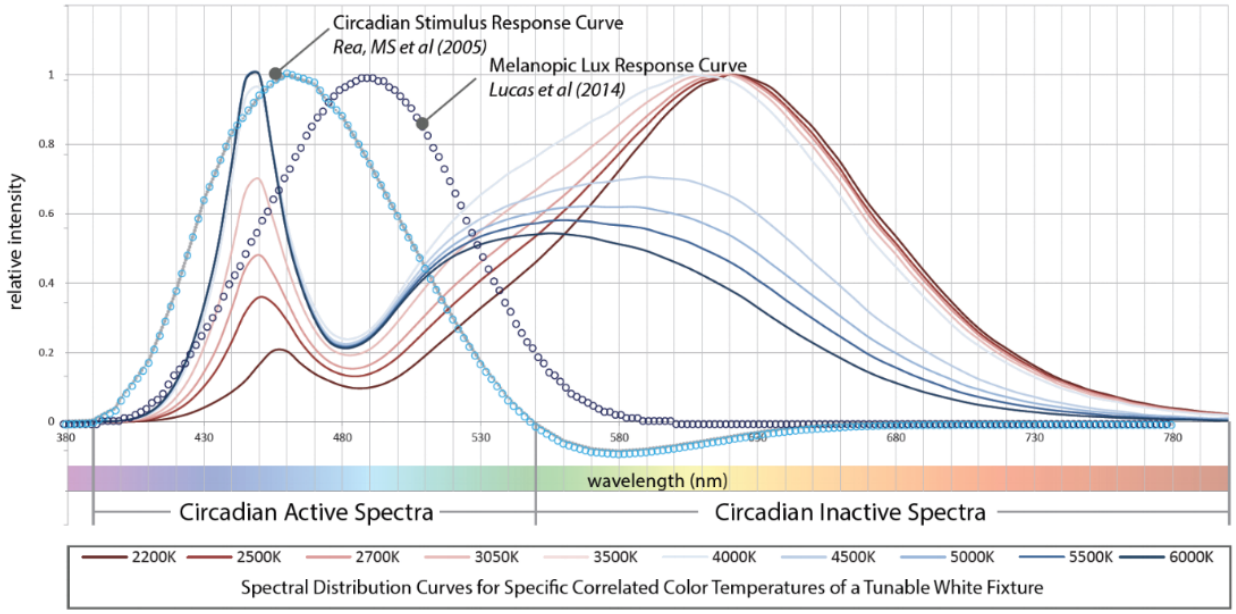

Figure 4: Circadian spectral sensitivity compared to typical spectral distribution of color temperature light fixtures.
Source: https://www.circa-dies.com/circadian-impactful-design/

ii. Spectral Sensitivity

a. The circadian system responds to a different spectrum (colors/wavelengths) of light than the visual system.
    1. Maximum visual sensitivity lies in the yellow/green range.
    2. Maximum circadian sensitivity lies in the blue range.
    3. The blue light of the morning has an alerting affect while the red sky of the evening has a relaxing effect.

iii. Quantity of Light

a. The precise amount of light needed is not known, and thresholds are still being debated.
    1. Hard to say exactly because it depends on multiple factors such as the amount of light, the spectral quality, and the duration.
    2. One's photic history is also a factor because it influences the circadian system's overall sensitivity to light.
    3. Light levels of 100 lux to 350 lux at the eye (not the work plane) have been shown to suppress melatonin levels
    4. Exposure to just 100 lux in the evening may be enough to delay melatonin production.

VII. Circadian Rhythm cont.

5. Blue-shifted light seems to require less intensity, with levels as low as 40 lux at they eye impacting melatonin.
6. Additionally, intermittent exposure has been shown to be more effective than continuous exposure.
7. Also worth noting that illuminance levels (lux) aren't recommended for measuring circadian light, but that no standard metrics have been adopted.
8. Some metrics used include Equivalent Melanopic Lux (eml) , Circadian Stimulus (CS), and Circadian Lux (CL)
9. This is an area undergoing current research, and will likely evolve as research expands.

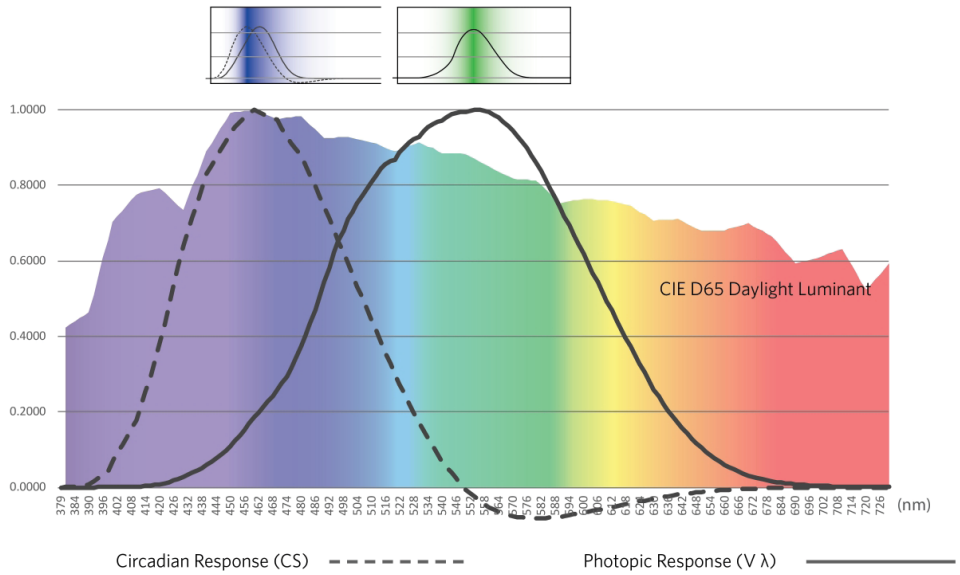

Figure 5: Circadian and visual spectral sensitivity compared to spectral distribution of sunlight.
Source: http://www.metropolismag.com/interiors/healthcare-interiors/why-light-matters-designing-with-circadian-health-in-mind/

iv. Role of Daylight

a. As seen in Figure 5, daylight provides an effective spectral range needed to entrain the circadian system, especially compared to artificial sources, as shown in figure 4.
b. Daylight also tends to deliver higher illuminance values at the eye than artificial light.
c. Artificial light can impact the circadian system, but the lighting levels will be lower than the metrics typically used by lighting designers measuring light on the work plane.

VII. Circadian Rhythm cont.

d. Similar to night-time levels of light, lack of daylight exposure during the day can disturb circadian rhythms and the sleep-wake cycle.

e. Exposure to higher levels of light during the day decrease the circadian system's sensitivity to light later at night, helping prevent circadian disruption.

f. Intermittent exposure to light, that naturally occurs with daylight over the course of a day, has been shown to provide better circadian entrainment than continuous exposure.

v. Manifestations of the Circadian System

a. The sleep-wake cycle is the most visible manifestation of the circadian system.

b. It is also seen in cycles of body temperature, urine production, cortex activity, and alertness as well.

c. Overall, most of the endocrine system is impacted because they are essential parts of physiological timekeeping.

d. The immune system is also highly regulated by the circadian system.

e. Circadian disruption can lead to the endocrine system disruption, with major health consequences.

f. Inflammatory diseases such as asthma and rheumatoid arthritis have been connected to circadian rhythms due to the daily fluctuations in severity,

g. Weight regulation also appears to be impacted by the circadian system

1. Low melatonin secretion at night has been associated with increased risks of developing type 2 diabetes.
2. Higher exposure to light during the day has also been associated with lower BMI
3. Melatonin disruptions impact metabolism through altering metabolic hormones

h. The strongest connection between circadian rhythm and disease has been shown with increased cancer risk

1. This connection is supported by extensive epidemiological, clinical, and basic research.
2. A primary concern is exposure to light at night, with higher incidences of cancer when nightly melatonin is suppressed for extended periods of time.
3. Melatonin-depleted blood has been shown to speed the growth rates of breast cancer tumors.
4. However, because daylight decreases light sensitivity later at night, daylight should help mitigate these effects.

VIII. KEY REFERENCES

Review Articles

- Aries, Mbc, Mpj Aarts, and J. Van Hoof. "Daylight and Health: A Review of the Evidence and Consequences for the Built Environment." Lighting Research & Technology 47, no. 1 (2015): 6-27.
- Boyce, P., Hunter, C. and Howlett, O. (2003) The Benefits of Daylight through Windows. Rensselaer Polytechnic Institute, Troy.
- Edwards, L., & Torcellini, P. (2002). Literature Review of the Effects of Natural Light on Building Occupants
- Joseph, A. (2006). The impact of light on outcomes in healthcare settings (No. Issue Paper #2). Concord, CA: The Center for Health Design.
- Ulrich, Roger, Craig Zimring, Xiaobo Quan, Anjali Joseph, Ruchi Choudhary. "The Role of the Physical Environment in the Hospital of the 21st Century: A Once-In-A-Lifetime Opportunity." The Center for Health Design. (2004).
- Ulrich, Roger S, Craig Zimring, Xuemei Zhu, Jennifer DuBose, Hyun-Bo Seo, Young-Seon Choi, Xiaobo Quan, and Anjali Joseph. "A Review of the Research Literature on Evidence-Based Healthcare Design." HERD: Health Environments Research & Design Journal 1, no. 3 (2008): 61-125.
- Van Bommel, Wout J.M. "Non-visual Biological Effect of Lighting and the Practical Meaning for Lighting for Work." Applied Ergonomics 37, no. 4 (2006): 461-66.

Primary Research

- Bedrosian, T.A., Fonken, L.K. & Nelson, R.J. Endocrine effects of circadian disruption. Annu. Rev. Physiol. 78, 109–131 (2016).
- Boubekri, M, Cheung, I, Reid, K, Wang, C, Zee, P. Impact of windows and daylight exposure on overall health and sleep quality of office workers: A case-control pilot study. Journal of Clinical Sleep Medicine 2013; 10: 603–61
- Lucas RJ, Peirson SN, Berson DM, Brown TM, Cooper HM, Czeisler CA, Figueiro MG, Gamlin PD, Lockley SW, O'Hagan JB, Price LL, Provencio I, Skene DJ, Brainard GC. (2014). Measuring and using light in the melanopsin age. Trends Neurosci. 2014;37:1–9

Popular Press

- "A Greener, more healthful place to work" - *New York Times*
- "Your new office lightbulbs may be hacking your circadian rhythms" - *Quartz*
- "Quantifying Circadian Light and Its Impact" - *Architectural Lighting*
- "Why Ligh Matters: Designing with Circadian Health in Mind" - *Metropolis Magazine*
- "The Benefits of Natural Light" - *Architectural Lighting*
- "Daylight: Nature's Prescription for Health, Productivity, and Sleep" - *Velux*