

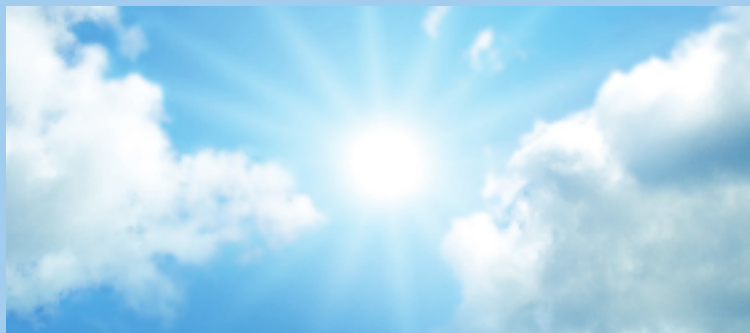
further experiments using electroencephalography, blue wavelengths suppressed sleep-associated delta brainwaves and boosted the alpha wavelengths, which are related to alertness. “This means you might be able to use short [blue] wavelengths as a sleepiness countermeasure,” Lockley says.

Hattar says no previous experiment has determined whether the ill effects of shift work are due to light stimulation at the wrong time of day, to the circadian clock's being out of phase, or to a combination of the two. However, he adds, even as activating melanopsin photopigment during the day is believed to be beneficial, it could be bad to activate it at night.

The investigators who study bright light to tame mood disorders would agree. Lewy, now director of the Sleep and Mood Disorders Laboratory at Oregon Health & Science University, succeeded in suppressing melatonin in humans by applying bright light of 2,500 lux. This is much brighter than indoor lighting, but much less so than a cloudy day. Similar experiments had succeeded in animals, but had failed in humans. That was probably because in both cases only tepid illumination was used, Lewy reasoned; the success in animals probably resulted from laboratory animals' lack of exposure to the bright outdoors.

That suggested to Lewy that “humans might have seasonal rhythms cued to natural photoperiod,” which he says would be insensitive to indoor lighting. And that led to treating seasonal affective disorder with bright light. The literature on the efficacy of blue light for treating this disorder is just now beginning to develop, and Brainard says much more work needed to confirm whether blue light is more potent than broad-spectrum white light.

Investigations of treatment of other mood-related maladies with bright light followed. Daniel Kripke, an emeritus professor of psychiatry at the University of California, San Diego, thinks bright light, particularly blue wavelengths, may also prove useful for treating premenstrual depression and bulimia, and he says there is preliminary evidence it might be useful for anxiety. And researchers at Case Western Reserve University, led by Patricia Higgins, an associate professor of nursing, are testing bright blue lights in a long-term care facility for patients with dementia. Very



Why blue? Blue's power to reset circadian rhythms is not intrinsic to the color. A photoreceptor for any color could have evolved to signal daylight to the suprachiasmatic nucleus. But the blues more easily penetrate the surface of the oceans—where life (and photoreceptors) likely first evolved—than do other visible wavelengths. The color balance of the sky may have helped to preserve blue's clock-setting role throughout evolutionary history.



preliminary results “show promise in raising activity levels during daytime hours and increasing sleep at nighttime,” she says.

But blue's benefit, and its detriment, are both a matter of timing. In one experiment, Kunz showed that exposing healthy subjects to 30 minutes of 500 lux polychromatic blue light an hour before bedtime, in their natural home environment, delayed the onset of rapid eye movement sleep by 30 minutes. The implications of that finding have yet to be determined, says Kunz. But the melanopsin receptors are particularly sensitive during the evening and nighttime hours, so “I'm pretty sure that at least many of the sleep disorders we are facing epidemically are related to evening or nighttime light,” he says. According to the National Center on Sleep Disorders Research, sleep-related problems affect 50–70 million U.S. men and women of all ages.

Kunz and others also suspect that outdoor artificial night lighting aggravates circadian disruption, although he says there is a dearth of human data on the subject. [For more information about artificial light at night, see “Missing the Dark: Health Effects of Light Pollution,” *EHP* 117:A20–A27 (2009).]

Kunz believes rapidly increasing knowledge concerning the circadian timing system

and the coordination of physiologic and psychologic processes on the one hand as well as the increasing understanding of the mechanisms of circadian entrainment will induce a substantial change in our daily living. “The major aim will have to be to strengthen the circadian timing system which can be achieved by increasing the blue portion in artificial light during daytime and by reducing the same blue portion of artificial light during the night and evening hours,” he says. “Increasing the blue portion of artificial light may improve performance and learning ability in school kids and employees working indoors, and health will be improved in patients staying at nursing homes or hospitals.” On the other hand, he adds, a reduction of the blue portion in artificial light during nighttime hours could protect shift workers against disorders such as cancer and cardiovascular disorders as well as reduce sleep disturbances and their consequences among the general population.

Coming Full Circle

The irony of blue as an environmental agent is that before the industrial age, it was merely a color. The unnatural lighting conditions we created turned it into both a potential hazard and a treatment for the ailments it brought about. In addition to the traditional architectural values of visual comfort, aesthetics, and energy efficiency, Brainard says architectural lighting must be redesigned to account for its biological and behavioral impact on humans. “Ultimately that should improve people's health and well-being in the built environment,” he says.

“Some people consider the progress in the field of light and health over the last couple of years as the most important light induced innovation since the invention of the light bulb,” says Kunz. “Fascinating times are ahead of light industry, clinical chronobiologists, and architects, to mention just a few. By optimizing lighting regimes we will be able to improve health, save energy, and improve learning and performance.”

David C. Holzman writes on science, medicine, energy, economics, and cars from Lexington and Wellfleet, Massachusetts. His work has appeared in *Smithsonian*, *The Atlantic Monthly*, and the *Journal of the National Cancer Institute*.