How Bright the Night?
Light and Human Health

A reprint of the Illinois Coalition for Responsible Outdoor Lighting website page at http://www.illinoislighting.org/health2.html

Observers of nature have, for millennia, noted how the behavior and physiology of many living things pulse in tune with the 24-hour day/night cycle. Scientific investigation demonstrated that the timekeeping function within many organisms is regulated by the light/dark cycle of day and night -- nature's master clock for most earthly ecosystems. But from the dawning of the study of human physiology and behavior, right through most of the 20th Century, most physiology textbooks didn't discuss photosensitivity as a factor in human internal timekeeping; indeed, circadian (24-hour) rhythms in general were thought generally to be of secondary importance for our species.

This attitude is understandable; we had "conquered" the night with artificial lighting; man was no longer at the mercy of the Sun to declare when we could be active or not. We see no immediate effects when we expose ourselves to artificial light at night; we neither instinctively flee from it (as, for example, some species of bats do[1]), nor do we find ourselves circling light bulbs like insects at a streetlight. (On the other hand, it is frequently reported that humans "feel safer" in a lighted environment than in a dark one -- likely as much an instinctive response as that of the moths circling the streetlight.)

Discoveries made in just the past decade and a half have begun to shatter the notion that we humans are immune from the regulating effects which the light/dark cycle has over the behavior and physiology of most other living things. We are learning not only how light sensitivity is a core part of our beings -- part of a structural framework billions of years in the making -- but also how disrupting the natural light/dark cycle can create havoc throughout our inner workings.

We can begin the story with the discovery of melanopsin in 1997[2]; this light-sensitive pigment was isolated in the skin of the African Clawed Frog, where it serves to provide its host with simple information on whether the environment the frog is in is light or dark. In 1999, melanopsin was discovered in the retina of the human eye[3], residing in nerve cells which previously had not been known to be light sensitive. Further research has demonstrated that this photoreception pathway does not play a direct part in visual perception; rather, it is connected to the internal timekeeping "clock"; it is also shared by all classes of vertebrates[4].

The second part of the story is that of the circadian rhythm -- the 24-hour "pulse", geared to Earth's rotation, and the light-of-day/dark-of-night cycle. Where this cycle fits into the lives of other creatures is easy enough to understand. A tree will get sunshine during the day; it needs its physiology set to take advantage of that resource at the proper time, so it adjusts its internal water and nutrient flow accordingly, based on timing by internal clocks -- anticipating sunrise, rather than reacting to it. Some plants even turn their leaves during the pre-dawn hours to face the anticipated sunrise[5]. In animals, not only does behavior need to stay in sync with the day/night cycle, but so

does physiology; internal systems need to focus resources on functions related to physical activity during the waking part of the cycle, and on functions like growth and healing during the resting periods.

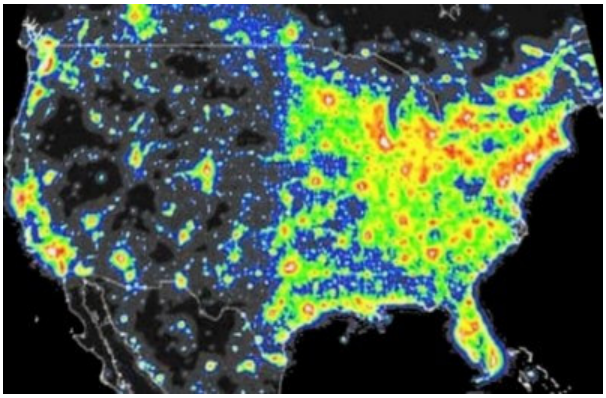
The circadian rhythm has been found to run deep and strong throughout our human physiology. Single-celled organisms display internal circadian timing; it seems probable that at least some of our trillions of individual cells do, too. But more obvious are the "clocks" within various human organs, which have the capability of expressing a circadian rhythm for at least some cycles without outside stimulation. Within humans (and likely most all mammals), these numerous and scattered clocks need a regular synchronizing stimulus to keep running; this stimulus signal is supplied by the suprachiasmatic nucleus[6.1], a small region located on the brain's midline, directly above the optic chiasm. The suprachiasmatic nucleus then connects to the melanopsin-containing cells in the retina; here we have the pathway by which the light/dark cycle of day/night ends up at the physiological, cellular level within our bodies[6.2].

Overall, daylight's effect on our physiology is a positive thing. Just like those of our fellow organisms, our bodies are complex machines, with scores of different processes going on which need to be inter-regulated to be successfully carried out. Our minds need to be saying "be awake" when we need to be awake; our organs need to support each other's activity when it is time to rest, heal, or grow. The central clock within the suprachiasmatic nucleus provides for this. Overall, it is an amazing regulatory system, tried and true from eons of evolutionary testing. But during the last split-second of geologic time, we have begun to throw a monkey wrench into the system, by creating an explosion of artificial light in what had, up to that point, always been the dark of night.

To take a side journey, we need to address this issue of the recent changes in the use of manmade light at night, before continuing our look at its potential effects on our health. It is likely that, to some extent, for more than a half-million years our ancestors created light at night -- fires have illuminated campsites, caves and dwellings during portions of the nights. But the levels of nocturnal illumination that we will experience tonight are many orders of magnitude above those of even just a few decades ago. The numbers of artificial light

sources have certainly increased, as have the hours of their use (as in: all night long, as opposed to a few hours in the evening); but most notably, technological changes have made our lights much brighter than they were even one generation ago.

The graphic on the left below shows an estimate of the relative sky brightness over the continental United States, generated by data from meteorological satellites which imaged the ground during nights in 1994[7]. We don't have that satellite data from earlier decades, but using actual measurements of sky brightness from earlier years, we can estimate what that graphic would have looked like at an earlier time; the picture on the right shows such an estimate for the early 1960s[8]. In just a few decades, we see an explosion in the amount of light shining outward and upward, primarily from outdoor lighting sources; this certainly also correlates to a similar increase in general ambient outdoor light throughout these areas, and likely to some increases in interior light levels, which also occurred because of changing technology & nocturnal habits over the period. And this explosive increase in the generation of light continues to the present day.



If exposure to artificial light during the nighttime hours disrupted the human circadian rhythm, what effects would we see? As mentioned above, the circadian rhythm reaches deep into the functioning of our bodies. An obvious part of the rhythm is our sleep/wake cycle; our bodies have to go through a number of physiological and behavioral changes to "shut down" for sleep. A disrupted circadian rhythm would disturb this ability to move into sleep mode, or trigger the sleep mode at the wrong time, and sleep disorders would result. Studies suggest that a substantial percentage of the adult U.S. population suffer from various sleep disorders[9], and research substantiates a connection between such disorders and circadian rhythm disruption[10].

Metabolism is also strongly tied to the circadian rhythm, which influences not only the level of our hunger, but various stages of the digestive process and how nutrients and calories are ultimately handled by the body[11]. Research provides strong evidence that disruption of the circadian rhythm can be a substantial causal factor of metabolic problems such as obesity[12,13,14] and possibly even diabetes[15].

Our moods, and how we perceive and interact with the world, can strongly vary with our mental state, which is also affected by our hormones and our internal clocks. While this is a relatively new area for research, studies are finding ties between circadian disruption and a variety of mood disorders[16,17].

Hardly any of the human body's functions, nor any of its abilities to combat disease, are removed from the influences of the circadian cycle. For example, it appears that disruption of the circadian cycle reduces the body's ability to resist a number of forms of cancer. Evidence is mounting for the whole chain of causality -- exposure to light at night, leading to reduced production of the hormone melatonin, leading to an increased rate of cancer[18-26].

There are many variable factors which contribute to how light affects an organism, including timing, length and intensity of exposure(s), spectral (color) properties of the light, and prior light exposure. We will need much more research before we can begin to predict each of the precise effects that exposure to artificial light at night will have on each individual human. But we are already have a rapidly growing volume of evidence that the issue of exposure to light at night is a serious one, as far as our health is concerned (see also reference items 27-36, below). No doubt we are exposed to quite a bit of nocturnal light from illumination within our workplaces and dwellings; we will need to learn to manage that light exposure in terms of its effects on our health.

But as the sky brightness charts illustrate above, in many places, our nighttime environments are increasingly being flooded with light. Is this an issue of concern? In the paper *"Does the modern urbanized sleeping habitat pose a breast cancer risk?"*[19], Kloog, et al., suggest the precautions of "the installation of window blinds in the bedroom, and also by the use of eye covers while sleeping", to reduce the impact of ambient outdoor artificial light on the sleeper. Others have suggested that melatonin, the hormone "messenger" for the circadian rhythm, could be administered artificially (on a very specific schedule) to make up for reduced natural production caused by interfering light at night.

Do these "fixes" make sense, in the long run? We do not believe so. Firstly, environmental disruption (in this case, widespread dumping of stray light into the nocturnal environment) should be addressed at its sources, not dealt with by its victims. Secondly, our fellow citizens should have the ability to enjoy the nighttime environment (on their own properties, and in parks and other areas) without being assaulted by excessive, potentially hazardous stray light. And thirdly, the very biological mechanisms which make excess light at night a physical hazard for humans also exist in many other organisms -- a whole biota of living things which cannot put on eye shades, draw blackout curtains, nor administer medications to alleviate the health problems caused by

stray manmade light.

The real "fixes" will be two-fold. First, we need a more detailed understanding of the light/health connection for humans. For instance, some research indicates that the level of brightness of light we're exposed to during the day affects how sensitive we are to disruption by light at night; if we get lots of sun during the day, we might be less affected by dim light at night, but if we spend our days within dimmer indoor settings, we might be more subject to circadian disruption by low levels of light at night. Changing our lifestyles based on that principle could help reduce health side-effects, as would changes to our lighting methods, based on a better understanding of how the spectral quality of the light we use for various purposes affects our health.

The second fix will be to drastically reduce the amount of stray manmade light in our outdoor environments. There is nothing unrealistic about that goal; we simply need to set good standards for the use of artificial light outdoors, and then apply them. We need to engineer lighting installations so the light only goes where it is needed, and illuminates those areas only to the level needed for the prescribed activity there. We need to shut off lights when they are not needed. We need to look at outdoor lighting from a cost-effectiveness standard, and the cost side of the balance sheet needs to include the environmental costs of lighting up the night. We install much of our outdoor lighting in the name of "public safety", but if that same lighting is creating serious health issues within our citizenry, then the cost effectiveness balance sheet will often look considerably different when negative health impacts are factored in.

Natural laws present us with some truths that we may not want to hear or believe. We cannot use our lands, air and water as unlimited dumping grounds for our wastes, without eventually suffering negative consequences. We cannot harvest unlimited fish from the sea, or fossil fuels from the ground, and have the supplies of those commodities last forever. And our bodies are built to operate on specific chronological cycles, which are moderated by the exposure to light during the day and darkness at night. Humanity has achieved amazing things over the centuries, but none of those accomplishments involve breaking the laws of nature; if we are to survive a successful species, it would do us well to remember that in nature, "night" equals "darkness", period.

Bibliography & Additional Resources:

Three good general papers on light and human health:

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(Web links to these resources are available from the webpage version of this article at http://www.illinoislighting.org/health2.html)