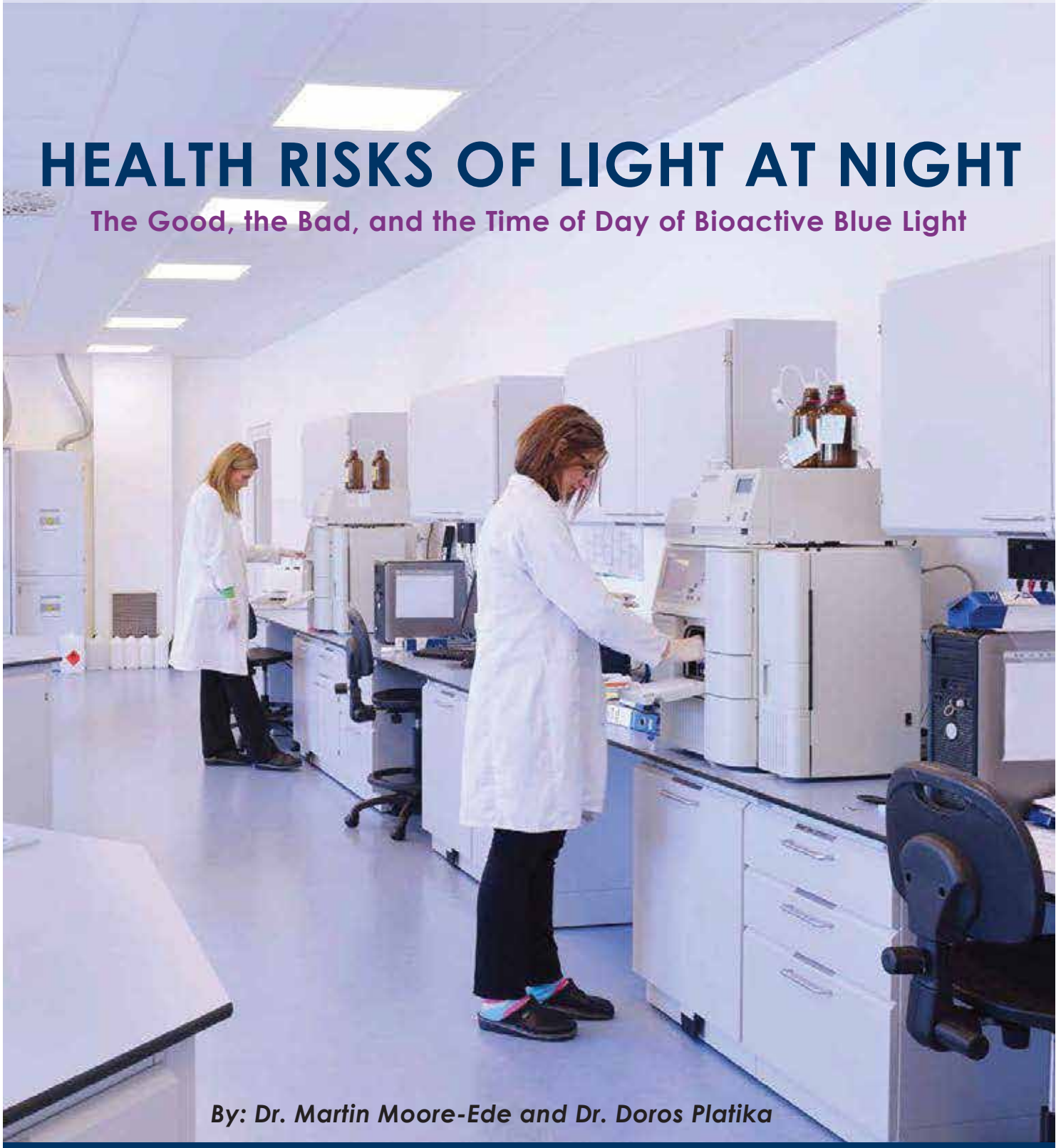
CIRCADIAN LIGHT

A CIRCADIAN® **WHITE PAPER**

HEALTH RISKS OF LIGHT AT NIGHT

The Good, the Bad, and the Time of Day of Bioactive Blue Light



By: Dr. Martin Moore-Ede and Dr. Doros Platika

Circadian Light / 2 Main St. Stoneham, MA 02180 / (781) 439-6333 / info@circadian.com / www.circadianlight.com

CIRCADIAN LIGHT

WHITE PAPER

Health Risks of Light at Night

The Good, the Bad, and the Time of Day of Bioactive Blue Light

By Martin Moore-Ede, M.D., Ph.D. and Doros Platika, M.D.

THE CHALLENGE

Edison's invention of the light bulb conquered the night, or so we thought. Now, the night seems to be striking back. On almost a regular basis, we see headlines extolling the harmful effects of arti ical light at night. "Your smartphone is making you fat!" says one headline. "Light at night is contributing to the diabetes epidemic and increases your chance of heart attacks!" says another. "Working at night increases your chance of getting breast or prostate cancer by over 50%, and if you do get a cancer, the wrong light will prevent the chemotherapy from working." A map of light at night exposure in Israel correlates with the map of increased rates of breast cancer in Israel.

To make matters worse, exposure to the wrong light at night can lead to depression and mood disorders. Individuals who work rotating shifts feel as though they exist in a state of permanent "jet lag." To add to the confusion, in areas where winters are long and dark, the lack of full spectrum bright light during daytime causes people to suffer Seasonal Affective Disorder (SAD) associated with depression and increased suicide rates.

In 2007 the World Health Organization's (WHO) International Agency for Research on Cancer identified night shift light exposure and circadian disruption as a probable carcinogen, especially with

SUMMARY

Most energy efficient lights in the workplace today, including fluorescents and especially LEDs, have a substantial downside health risk in 24/7 operations, which is now recognized by the World Health Organization (WHO), the American Medical Association (AMA), and the US National Institutes of Health (NIH). Because of their high bio-active blue wavelength content, these widely prevalent lights trigger newly discovered eye receptors and neural pathways to boost alertness and productivity during the day but at night cause a 35–65% increase in the risk of obesity, diabetes, heart disease, sleep disorders, and depression, as well as breast and prostate cancers. Fortunately, new energy-efficient CIRCADIAN® LED lights are becoming available, which provide good quality light 24/7 while intelligently controlling the blue dosage by time of day and season to boost alertness and productivity and avoid exposure to the harmful effects of blue light at night.

breast cancer in women. WHO stated that the finding was consistent with "experimental studies [which] show that reducing melatonin levels at night increases the incidence or growth of tumours." By 2012 sufficient data had accumulated for the American Medical Association (AMA) policy statement to go much further. The AMA confirmed that night time lighting exposure risks include "carcinogenic effects related to melatonin suppression, especially breast cancer." They further added that other diseases that are exacerbated by nighttime light "include obesity, diabetes, depression and mood disorders, and reproductive problems." In Europe, the continued accumulation of data on breast cancer risk has resulted in compensation payments from the Danish government to night shift workers who developed breast cancer.

POPULATION AT HIGHEST RISK

While we are all at risk of night light circadian disruption, night shift workers represent the population that is exposed to the greatest risk of circadian disruption and subsequent health effects. Night shifts make 24/7 productivity possible and in many fields such as nursing, are absolutely necessary. In the United States approximately 26.5 million people, or 17% of the employed population, work between the hours of 6 PM and 6 AM. In Canada it is approximately 2.3 million people at the highest risk. Worldwide over 100 million people work night shifts and the numbers are climbing as additional countries are industrialized.

Health risks are not the only result of night shift circadian disruption. Night shift workers have higher rates of accidents and absenteeism. They also have lower productivity. Due to these and other factors, each night shift worker costs the company on average $10,000 more per year when compared to day shift workers doing the same or similar job. It is a "tax" that each company pays to have a night shift, above and beyond any personal health penalty that a night shift employee may eventually pay. Globally this represents over $900 billion in excess cost associated with night shift work in 24/7 business operations.

The recent mass adoption of light emitting diodes (LEDs) in overhead lights has been fueled by government incentives and rebates that promote energy conservation. But this conversion to energy-efficient LED lights and the myriad of electronic devices that emit blue-rich light (smartphones, TVs, automobiles, tablets, e-readers, etc.) promises to make the problems associated with artificial light exposure at night much worse, risking a potential occupational health epidemic in the not-too-distant future. In March 2016 the United States Department of Health and Human Services organized a two-day conference and webinar on "Shift Work at Night, Artificial Light at Night and Circadian Disruption" to explore strategies to address this serious problem before it becomes an epidemic. We are faced with the age-old dilemma: Pay now with higher energy bills of less efficient lighting, or save money on energy now but pay much, much more later in health care costs and suffering. So what can we do, and is there a solution?

Night shift workers represent the population that is exposed to the greatest risk of circadian disruption and subsequent health effects.

Turning the lights off and returning to the dark ages is not a solution in our 24/7 society. Making our lights progressively dimmer and yellower as the day wears on is not realistic when safe and productive work at night requires good quality lighting. No one wants to be taken care of by perpetually "jet lagged" doctors and nurses working in dark, dingy conditions or nuclear power

plant operators trying to do their jobs when they cannot see properly in dim yellow or reddish light.

Fortunately, over the last 20 years, intense research at leading universities has elucidated the underlying mechanisms for the problems associated with the wrong light at night and has identified effective solutions. The result is a new generation of lighting products that can provide the energy efficiency this planet needs to conserve our climate, while providing safe, high quality light which increases employee productivity, alertness, health and a feeling of well-being.

THE KEY DISCOVERIES

Two major discoveries and a Nobel Prize-winning invention were critical to the understanding of the mechanism underlying the problems and to the creation of the solutions.

The **first** "eye-opening" discovery was that blue light—the color of the cloudless sky—regulates the timing of our biological ("circadian") clocks. While natural daylight, or artificial white light, is comprised of a rainbow color mix of multiple wavelengths, it is predominantly the blue wavelengths that keep our circadian rhythms and sleep-wake cycle in synch with the rising and setting of the sun. By shining lights with monochromatic single colors into people's eyes the unique sensitivity of circadian rhythms such as melatonin to blue wavelengths was discovered.

This blue wavelength sensitivity cannot be explained by the spectral sensitivity of the rods and cones in our eyes. For over a hundred years we have known that daytime color vision relies on cone receptors that provide color information to the brain. While the cones can respond to all colors in the visual spectrum, they are most sensitive to green light. Nighttime vision is dependent on rod receptors that can see even when light levels are very low. The pathways that carry visual images from the rods and cones to the brain have been well mapped and understood. But neither rods nor cones are highly sensitive to the blue wavelengths that reset circadian rhythms and suppress melatonin.

The **second** key discovery, which explained the blue light sensitivity, was the identification of special types of photoreceptor cells in the retina containing melanopsin, a photo pigment with a peak sensitivity to 460nm blue light. The melanopsin receptors are 25 times more responsive to light at this blue wavelength than to full spectrum white light. When activated by blue light, the melanopsin receptors send information via a special neuronal pathways directly to the suprachiasmatic nucleus (SCN) in the brain. These melanopsin pathways are quite separate from those that carry visual images to the brain. The SCN is the body's "master circadian biological clock." It thus became clear that, just like our ears have the two functions of hearing and balance, our eyes have the two functions of seeing visual images and regulating the brain's master circadian clock.

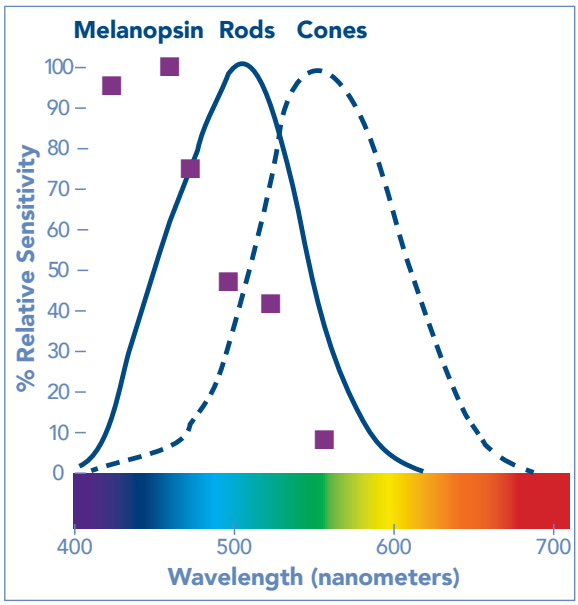


FIGURE 1. The relative color sensitivity of the newly discovered melanopsin photoreceptors which regulate circadian rhythms as compared to the color sensitivity of the rods and cones in the eye which are used in visual perception. *(from Thapan et al, J.Physiol.535:261-267, 2001)*

The **third** key invention, the Gallium Nitride (GaN) based LED, came out of the semiconductor industry in Japan and has revolutionized the world of lighting, with the inventors winning the 2014 Nobel Prize in Physics. The invention of LED light sources was a huge breakthrough in terms of the efficient conversion of electric power into light. Today's highly efficient LED lighting systems provide over 100 lumens per watt compared to only 10–15 lumens per watt from incandescent light bulbs. But this efficiency is achieved by using LED chips which primarily pump out blue light in the 440–470nm range. The LED dies are coated with phosphor materials to convert the GaN emitted blue light into a broader spectrum white light. The selection of the 440–470nm blue range is largely driven by lumens per watt and production cost efficiency.

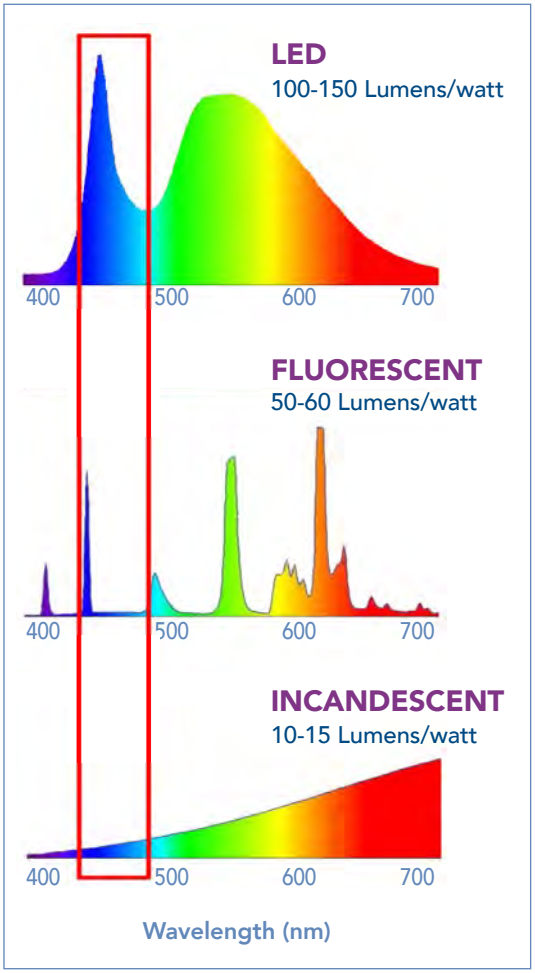


FIGURE 2. The color spectrum of Edison's incandescent light bulbs, fluorescent tube lights and conventional blue pump LED solid state lighting. The area of peak bioactive blue light sensitivity is indicated in each type of lighting.

The problem is that the 440-470nm blue light emission spike of these widely sold blue-pump LEDs causes maximum stimulation of the melanopsin retinal ganglion cell receptors and the non-visual pathways synchronizing our circadian clocks and the rhythms of the pineal and pituatory glands at the base of the brain. These endocrine glands are the master controllers of the human body's hormones. Because of their spectral characteristics, these conventional blue-pump LEDs are much more potent suppressors of pineal melatonin with its attendant disruptive health effects. With LED lighting projected to replace over 50% of the workplace lighting by the year 2020 we have an impending catastrophic collision between technological advance and human health and well-being.

BIOACTIVE BLUE LIGHT: The Good, The Bad and The Time of Day

Our master biological clock evolved to keep track of when the sun rises and the day begins and when the sun sets and the day ends. Recent studies of the few remaining pre-industrial societies of hunter-gatherers who still exist today, like the Hadza in Tanzania, the Kalahari San in Namibia, and the Tsimane in Bolivia all exhibit similar circadian and sleep patterns despite different ethnic backgrounds and living on different continents. They sleep six hours a night in the summer with one more hour of sleep in the winter, when there is less sunlight. They awake just before sunrise and go to sleep about 3.3 hours after sunset. The high content of bioactive blue light in morning sunlight when they awake sets and triggers the master biological clock to activate the human body to support peak efficiency during the day. In men it triggers testosterone, hunger, and bowel movements

and increases blood pressure. High bioactive blue light levels are critical to maintaining alertness, increased vigilance, improved mood, improved reaction time, increased muscle strength and coordination, cardiovascular efficiency, and increased work productivity during the day.

The productivity benefits to be gained from boosting the intensity of blue-rich light can also be seen in modern factories. Indeed, a recent AT Kearney study funded by the German Electrical Association projected a 12.8 billion euro gain in EU productivity if EU companies installed 1,000 lux plus blue-rich workplace lighting during the day shift.

Conversely, natural night after sunset is associated with the absence or very low levels of bioactive blue light content. The lack of blue light provides a night signal to the master clock and triggers a chain reaction that activates hormonal and other pathways critical to maintaining health and avoiding depression, diabetes, obesity, cardiovascular disease, and breast and prostate cancer. Around 9 PM melatonin secretion starts to climb and this a critical signal that circadian night has begun. Body temperature is lowered, and bowel movements are suppressed.

Melatonin secretion peaks around 2 AM, then starts to drop and terminates by 7 AM, signaling the start of a new day. Just as the **presence** of bioactive blue light is critical to maintaining circadian day functions, the **absence** of bioactive blue is critical to maintaining optimal circadian night functions.

Thus bioactive blue light is not intrinsically healthy or unhealthy. It is a very powerful regulator of the melanopsin receptors in the eye and of the biologic master circadian clock in the brain. Bioactive blue light content in ambient light needs to be tightly controlled and regulated like a drug so it can be boosted to peak levels in the morning to activate the master clock, can be maintained at a high level to maximize alertness and productivity during the day, and can be removed at night to maintain optimal circadian health.

Bioactive blue light content in ambient light needs to be tightly controlled and regulated like a drug.

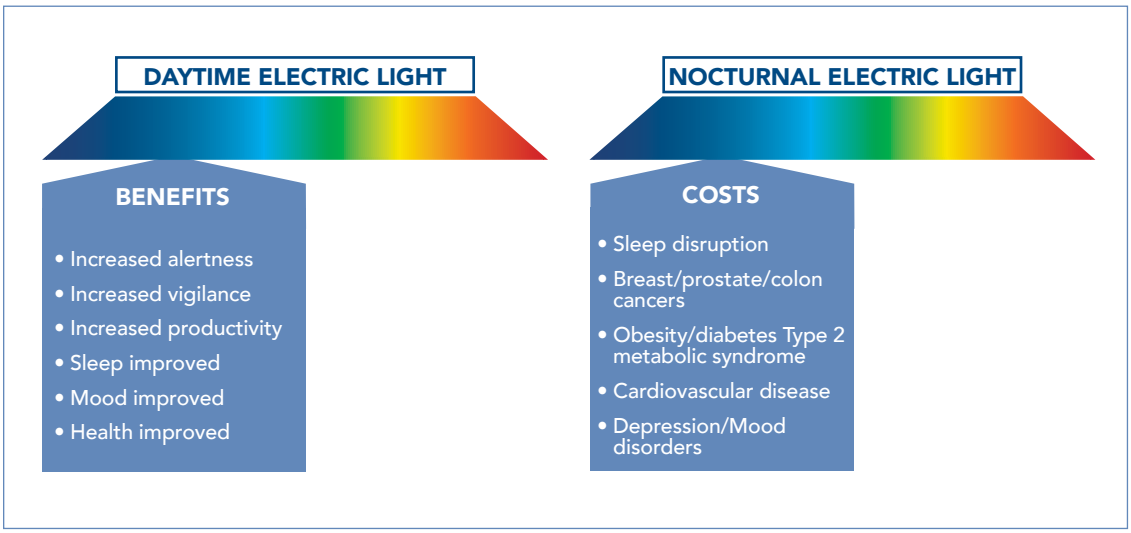


FIGURE 3: The same bioactive blue light wavelengths provide multiple benefits during daytime but have harmful effects at night.

BIOACTIVE BLUE LIGHT IMPACT: Melatonin and Other Markers of Circadian Health

Over the last 15 to 20 years researchers have been working diligently to trace the pathways by which blue-rich light exposure impacts human health and disease. It starts with the activation of melanopsin receptors in the eyes by bioactive blue light and the transmission of the signal to the SCN master circadian clock. Exposure to blue light when we wake in the morning provides a key signal to the SCN, which ensures the synchronization of our circadian rhythms and sleep-wake cycle with the natural day-night cycle. Continuing exposure to blue light during the day, just like when we live and work outdoors, simulates a healthy appetite and keeps us energetic and productive all day long.

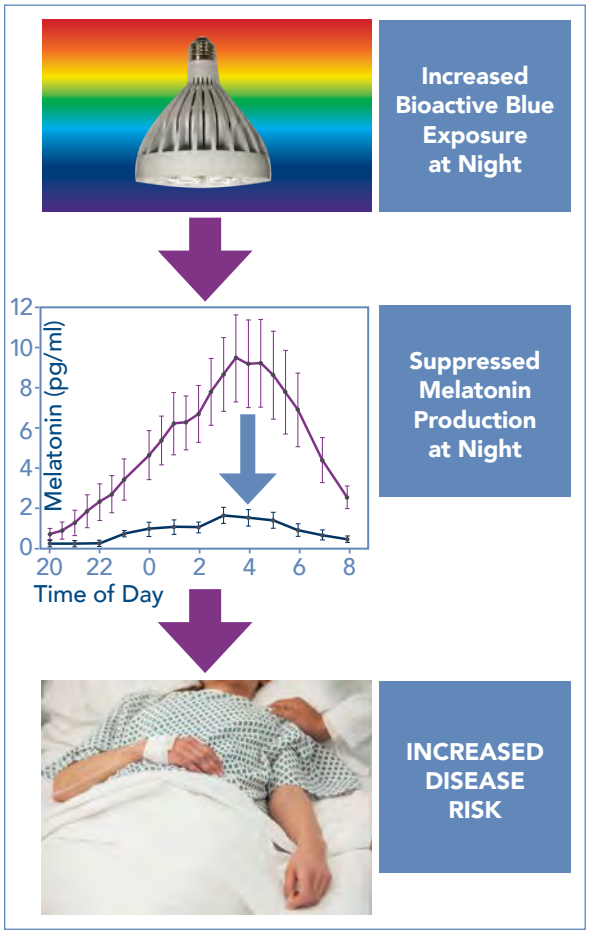


FIGURE 4: Regular blue-rich light exposure at night chronically suppresses the level of melatonin which is associated with an increased risk of a number of diseases.

But at night we are not designed to safely see blue light. Whether you are a time-zone crossing traveler confronted with sunlight when stepping off the plane in Tokyo or Paris during your biological night or a night shift worker exposed to blue-rich fluorescent or LED lighting, the timing of your master circadian clock is disrupted. From there, a cascade of effects spreads out through your body, disrupting the normal release of hormones such as melatonin and cortisol, impeding the expression of clock genes associated with cancer and diabetes risk, and removing the protective effects of nocturnal melatonin release.

The nightly release of melatonin is a vital protective mechanism that suppresses developing cancer cells in our body. Exposure to blue-rich light at night can suppress over 80% of the normal melatonin release, and this level of reduced melatonin is associated with a 65% increase in breast cancer risk. More than ten separate peer-reviewed epidemiological studies have shown increased breast cancer rates in people regularly exposed to workplace light at night, six such studies have shown increased risk of prostate cancer in men, and four have shown increased risk of colon-rectal cancer. The rapid acceleration of breast tumor growth is confirmed in laboratory animals exposed to light at night, and this can be reversed by infusing them with melatonin.

We now know that the normal nightly release of melatonin plays a vital "oncostatic" role in suppressing the growth of cancer cells in the body. Total nocturnal melatonin production, measured most easily in an overnight urine collection, is strongly correlated with breast cancer risk, and the risk of a number of other chronic diseases including diabetes. As Figure 5 (on page 7) shows, suppressed melatonin production, such as would be caused by frequent exposure to light on the night shift, can result in a substantial (35-65%) increase in disease risk.

Diabetes is also associated with suppressed melatonin levels and increased secretion of the stress hormone, cortisol. Light exposure at night activates the pituitary and the adrenal gland and the elevation in cortisol causes insulin resistance and diabetic symptoms. Cortisol is also a key regulator of inflammation and immune function. Repeated exposure to light at night over the years of a shift work lifestyle not only elevates diabetes risk by 50%, but also lowers immunity and increases susceptibility to infections.

These effects cannot be simply explained by lack of sleep. Melatonin in the absence of blue light rises at night whether you are awake or asleep. Furthermore, normal levels of melatonin do not make you sleepy (although excess doses can be soporific). Contrary to common belief, melatonin is not the sleep hormone. It is actually the hormone that signals that it is dark outside.

The key mechanism that accounts for the pathological effects of blue light is the disruption of the circadian clocks in the body. We are finely timed machines, and we rely on all the cellular processes in our bodies operating in sync. We suffer the malaise symptoms of jet-lag whether we travel or work irregular or rotating schedules. We are at our healthiest when we are exposed to 50,000 lux of sunlight during the day and sleep in darkness at night. But that is not the world we live in. We spend most of our time indoors in relatively dim light of less than 200 lux and are exposed to similar levels of light at night, so we have lost the natural rhythms of day and night which kept us in good health and well-being.

BIOACTIVE BLUE LIGHT DILEMMA: Energy Efficiency OR Health?

Concerns about climate change and energy conservation have swung the pendulum to promoting energy efficient

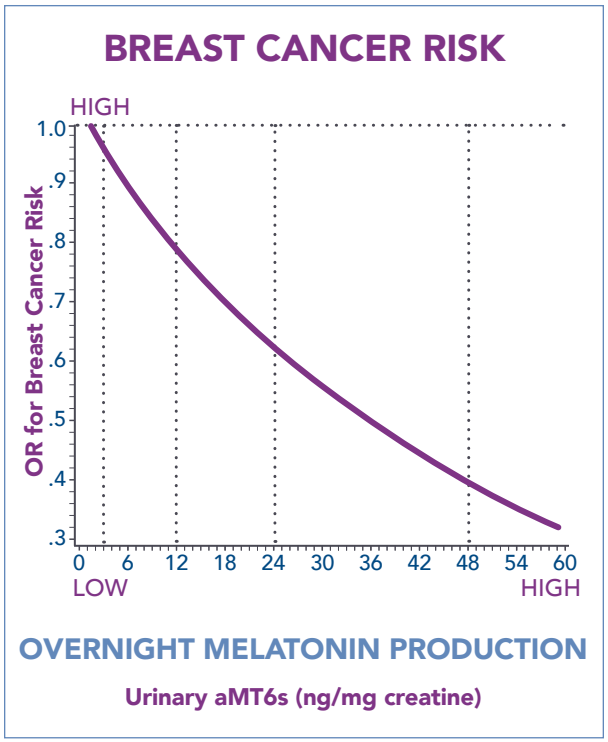
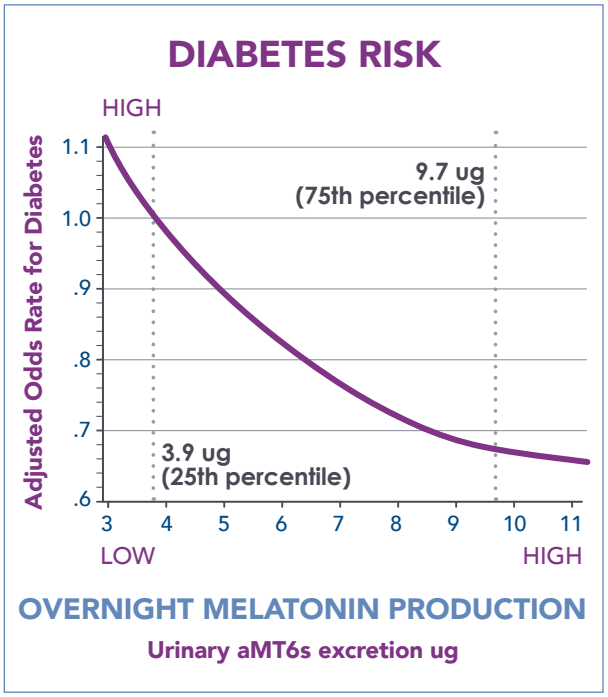


FIGURE 5: A strong quantitative relationship exists between total overnight melatonin production and the risk of breast cancer (above) and diabetes (below) and other diseases *(from Schernhammer & Hankinson, Cancer Epidemiol. Biomarkers Prev. 18:74-79, 2009 and Obayashi et al. Chronobiol. Int. 31:394-400, 2014)*



light, without attention to the health impact. It is no longer possible to buy incandescent or halogen light bulbs because government policy is backing the widespread installation of energy efficient LEDs. And the competitively priced LEDs on the market pump out bioactive blue light whenever they are switched on.

But it doesn't have to be a choice between energy efficiency and health. You can have both thanks to a recent breakthrough in LED lighting technology.

Simply filtering out or dimming blue light wavelengths creates an unpleasant yellowish colored light which is unattractive and makes it hard to see clearly. While that might be acceptable when you are winding down and getting ready to go to bed, it is not an acceptable solution for the night shift or for anyone else who has to do critical work in the evening or at night. In a similar manner, producers of electronic device like Apple created the "night shift" function in the latest IOS version for their smart phones, which also dimmed and yellowed the light emitted by the screen later in the day. Unfortunately, many of these adjustments, despite the best intentions, do not remove sufficient bioactive blue light content to avoid circadian disruption and many do not eliminate the potential impact on productivity and health.

Fortunately, a new LED lighting technology has emerged, which can provide bright white light 24/7 where the only thing that changes across the day and night is the bio-active blue dosage. Advanced research has developed white light with biologically-tuned wavelengths delivering blue-rich light during the day and blue-depleted light at night, controlled by smart timing systems that track day and night, season of the year and latitude & longitude. They ensure that healthy bioactive blue dosages are delivered at the right time across day and night.

THE SOLUTION: Energy Efficiency with Productivity and Improved Health

The ideal lighting fixture would know the location and season where it is located. It would also produce crisp white light 24/7 that would permit optimal working conditions and productivity while varying bioactive blue light content based on time of day. The ideal lighting fixture would boost bioactive blue light component in the morning to set the circadian clock and maintain preferred levels during the rest of the day to maximize productivity. At night, the bioactive blue light content ideally should be as close to zero as possible, while still maintaining a white light with a similar color temperature to that of the day. If it can be achieved, this light fixture during the night would increase productivity, decrease errors, and maintain a normal circadian rhythm that results in improved health. Such light fixtures will have the potential to significantly decrease the risk of disorders exacerbated by circadian disruption, including obesity, diabetes, depression and mood disorders, reproductive problems, as well as breast and prostate cancer by up to 50% to 65%.

Light fixtures will have the potential to significantly decrease the risk of disorders exacerbated by circadian disruption, including obesity, diabetes, depression and mood disorders, reproductive problems, as well as breast and prostate cancer by up to 50% to 65%.

For more than a decade, many LED companies have tried to develop an effective solution but have failed because of technological barriers and incorrect interpretation of published biological data. The major technological barrier was the challenge of

creating white light, while at the same time removing the blue content. As noted previously, removing blue light results in a light fixture that is emitting reddish yellow light that creates a visually challenging environment. It was only after the creation of new LEDs using innovative dies and phosphor combinations and extensive trials to balance the polychromatic white spectrum that a solution was finally created that permitted removing bioactive blue component while maintaining crisp white light. The proprietary solution balances blue, violet, green, and other spectral colors to avoid any risks from bioactive blue or ultraviolet light and to maximize the health productivity and efficiency of the final product.

A key question was how much of the blue biologically-active wavelengths had to be removed to achieve the beneficial targets? Finding the answer to this issue was complicated by the fact that the early research on the melanopsic sensitivity curve was misleading.

To expedite studies and to maintain controls, many experimenters limited the time of exposure to full spectrum light and manipulated the subjects. The subjects had their pupils dilated and were asked to stare into a light box, as when having their eyes examined by an ophthalmologist. Because they could only tolerate sitting like this for an hour or so, the only thing examined was their responses to short exposures of monochromatic lights of different colors. These laboratory studies produced misleading data regarding the sensitivity of melatonin secretion to violet, blue, and green wavelengths that has confused both researchers and producers of circadian lighting technologies.

In the real-world, evening and night shift workers are exposed to broad spectrum white light for much longer periods of time. When people are working for 8 or 12 hours overnight, under normal freely moving conditions illuminated by polychromatic white light, the spectral sensitivity curve of the circadian system turns out to be significantly different than was first assumed.

It was only by conducting 24/7 studies under normal working conditions that the normal melanopsic sensitivity curve could be defined. The determination of the true melanopsic sensitivity curve enabled the creation of proprietary, patented, high-quality white LED lights that control the bioactive blue dosage, while maintaining crisp white light.

This major research breakthrough, partially supported by SBIR Phase I and Phase II Grants from the United States National Institutes of Health, permitted the creation of LED lighting utilizing various GaN LED chip substrates as well as with tunable and other lighting systems. Contrary to prior assumptions, this solution does not require a variation in color temperature. At color temperatures between 3000–4000K these chips either emit white light rich in blue (Day LED) or depleted of blue (Night LED).

The contrast in the protective effect on melatonin provided by the Night LED compared to the highly suppressive effect of blue-rich conventional LEDs can be seen in Figure 6 (below). This represents a more than fivefold difference in melatonin output and the consequent enhancement of its protective effects.

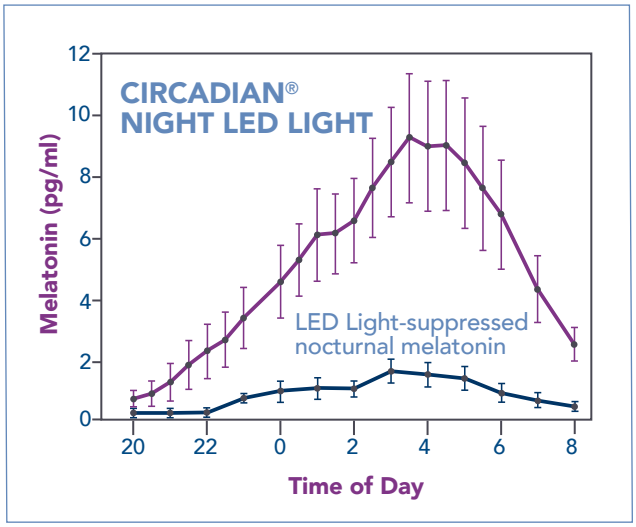


FIGURE 6: In contrast to other LED lights in the market today CIRCADIAN® LED Lights restore melatonin, stabilize the circadian clock, and provide the critically needed lighting for the 24/7 workplace.

To ensure that this solution is effective under real-world conditions, workplace studies in hospitals and nuclear power plants have been conducted to validate the effectiveness of this strategy. The studies have shown that removal of the specific bio-active blue wavelengths improves night time performance, reduces errors, increases memory, and counteracts the dip in mood that occurs on the night shift. This because the circadian timing system of the body is no longer being disrupted by the light seen at night. The study with nuclear power plant operators was featured in the 2011 Gemini award winning Canadian TV documentary, "Acquainted with the Night."

A series of studies in peer-reviewed publications in major scientific journals have documented the effectiveness of removing bioactive blue light at night. These studies showed that besides the restoration of melatonin the level of alertness and performance was boosted in the early hours of the morning when shift workers normally have the greatest challenge staying awake and keeping vigilant. Errors during the night shift were reduced.

Accuracy on performance tests stayed at a high level. Instead of falling from 120 to 80 correct responses per minute over the course of the night shift under normal spectrum white light, with the bioactive blue light removed, performance improved to 130 correct responses per minute, an improvement of greater than 50%.

In nurses working rotating 12-hour 2-3-2 shift schedules in a major city hospital, sleepiness during the night shift was significantly decreased, and reaction times, memory lapses, and mood were greatly improved ($p < 0.01$) once the bio-active blue wavelengths were removed. Polysomnography sleep studies with EEG, electrooculography (EOG), and electromyography (EMG), and respiratory monitoring showed that after night shifts during which blue light content was removed, all phases of sleep were longer and better including: sleep onset latency (SOL); total sleep time (TST); sleep efficiency (SE); wakefulness after sleep onset (WASO); duration of each NREM sleep stage; duration of REM sleep; REM latency; absolute number of arousals in the total sleep episode; and absolute number of stage shifts.

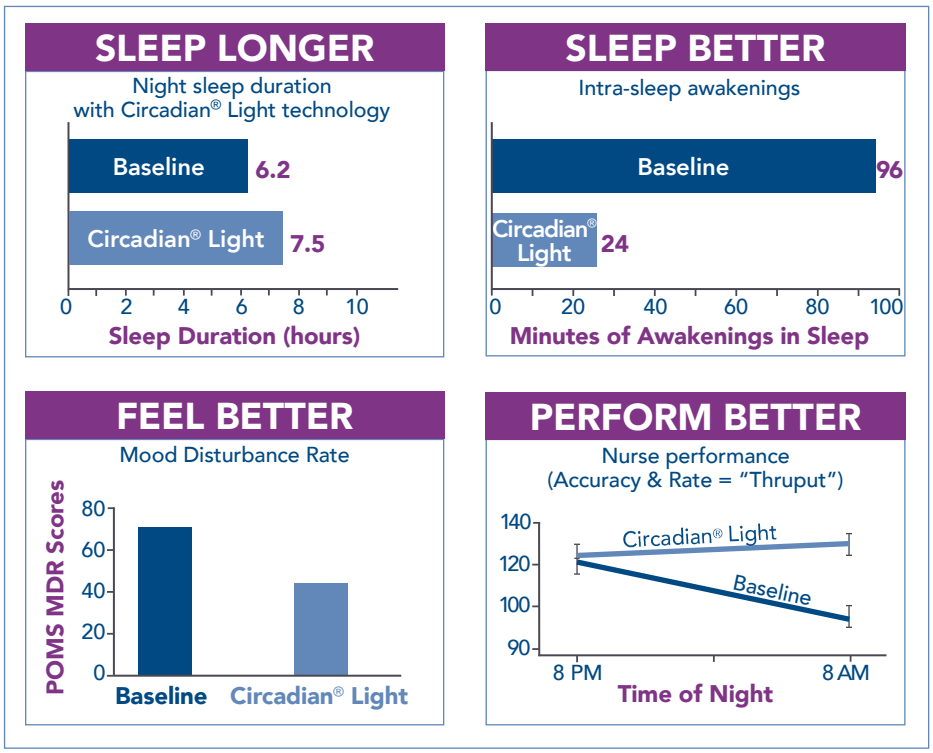


FIGURE 7:
When bioactive blue light was removed during night shifts sleep, performance, and mood were improved in hospital nurses. *(personal communication S. Rahman and R. Casper, University of Toronto, 2011)*

In both workplace studies, the employees reported major improvements in feeling better and decreased depressive symptoms. Their families noted major improvements in mood and family interactions within the first couple of days of the study. The improved feeling of "well-being" made them resistant to going back to the usual lighting condition.

This work has culminated in the creation of intelligent lighting systems that can determine location, seasonality, time of day, and other critical parameters to vary the dosage of bioactive blue content to maximize productivity during day and night, eliminate circadian disruption, optimize health, and maintain efficiency to qualify energy rebates. Just optimizing light during the day shift is projected to result in productivity gains of 12.8 billion euros ($14.5 billion USD), and much more benefit can be achieved by also providing appropriate lighting during the night shift when productivity gains are enhanced by greater health benefits. The combined overall gains are anticipated to greatly accelerate the return on investment (ROI) in CIRCADIAN® Lighting.

CIRCADIAN LIGHT

FIGURE 8: CIRCADIAN® Light fixtures for workplaces which provide high quality light 24/7 while varying the bioactive blue wavelength dosage to enhance productivity and prevent circadian disruption.

THE DAWN OF CIRCADIAN® Light

CIRCADIAN® Light products are available in multiple high quality SKUs that can address various ceiling heights and work place environments. While they meet or exceed all applicable lighting standards, additional available features of CIRCADIAN Light include the ability to use the sensors in the lighting fixtures to monitor worker productivity, incidents, errors, accidents, injuries, absenteeism, worker turnover, health costs, and other risk/cost analytics.

We are now entering an era in which workplace lighting will become an integral informatics hub of time and attendance, payroll cost management, duty/shift scheduling, planning, and staffing level systems. Using these proprietary and patented additional data analytics features has been demonstrated to effectively monitor fatigue and human error risks and when combined with modified scheduling, can reduce accident costs by up to 75%.

CIRCADIAN® LED lighting fixtures comprised of Day and Night LEDs can now be used to provide precisely regulated bioactive blue light dosage and to provide the health, productivity, AND energy efficiency we should expect from workplace lighting. They represent a complete lighting solution that will improve the bottom line by optimizing the balance between energy efficiency, productivity, and health.

CIRCADIAN LIGHT

ABOUT THE AUTHORS

MARTIN MOORE-EDE, M.D., Ph.D.

For over 30 years, Dr. Moore-Ede has been a leading expert on circadian clocks and managing the risks of human fatigue in transportation and industrial businesses that operate 24/7. After experiencing the challenges of fatigue as a surgeon-in-training required to work 36-hour shifts, Dr. Moore-Ede was one of the first to define the challenges of living, working, and sleeping in a 24-hours-a-day, 7-days-a-week world. As a professor at Harvard Medical School (1975–1998), he led the team that located the suprachiasmatic nucleus, the biological clock in the human brain that controls the timing of sleep and wake, and pioneered research on how the human body can safely adapt to working around the clock and sustain optimum physical and mental performance.

Since 1983, Dr. Moore-Ede has guided the growth of the international network of "CIRCADIAN®" companies which now provides products and services to over half of the Fortune 500 companies for optimizing 24/7 workforce productivity, health, and safety.

Since 1983, Dr. Moore-Ede has guided the growth of the international network of "CIRCADIAN®" companies which now provides products and services to over half of the Fortune 500 companies for optimizing 24/7 workforce productivity, health, and safety. In 2014, CIRCADIAN established Circadian ZircLight Inc., which develops CIRCADIAN LED lighting systems based on a comprehensive proprietary IP portfolio. The CIRCADIAN Light products provide both the energy-saving and technology advantages of LED lighting and improved productivity, health, and safety without the considerable downside risks of dosing large populations of people with blue wavelengths at night.

Dr. Moore-Ede graduated with a First Class Honors degree in physiology from the University of London and received his medical degrees from Guy's Hospital Medical School and his Ph.D. in physiology from Harvard University. He has published 10 books and more than 145 scientific papers on human fatigue, errors, and accidents and the physiology of sleep deprivation and circadian rhythms. Dr. Moore-Ede holds multiple patents on tools for assessing and mitigating fatigue risk including the Circadian Alertness Simulator (CAS), a scientifically validated fatigue risk model. He has served on multiple national and international committees and has received numerous awards including the Bowditch Lectureship of the American Physiological Society. He is a frequent guest on television (CNN, Today Show, Good Morning America, 20:20, Dateline, Oprah Winfrey, Nova, BBC), radio (NPR Fresh Air, Connection), and print media (Wall Street Journal, New York Times, Washington Post, Time and Newsweek). He has testified before Congressional committees on multiple occasions and advised government agencies on the health and safety of the 24/7 workforce in the US, Canada, and Europe.

CIRCADIAN LIGHT

ABOUT THE AUTHORS

DOROS PLATIKA, M.D.

As executive chairman of CIRCADIAN ZircLight Inc., Dr. Platika brings over 30 years of expertise in optimizing neuro-endocrine function to maximize health and longevity. While on the faculties of Harvard Medical School and Albert Einstein College of Medicine, he pioneered cutting edge regenerative medicine strategies to restore normal physiological function.

Dr. Platika, an expert in bringing medical devices to commercialization and FDA approval, has helped create more than 40 companies that have brought to market approved novel cancer therapeutics, diabetic therapies, surgical devices, and adhesives.

Dr. Platika, an expert in bringing medical devices to commercialization and FDA approval, has helped create more than 40 companies that have brought to market approved novel cancer therapeutics, diabetic therapies, surgical devices, and adhesives. The companies led by Dr. Platika have been listed on NASDAQ and have also been acquired by major pharmaceutical and medical device companies. In the process, he has helped raise over $750 million dollars to develop and commercialize the medical products. The most recent surgical device products have been among the first products chosen by the FDA to undergo “fast track” approval.

Dr. Doros Platika is a Phi Beta Kappa graduate of Reed College in biology and psychology. He graduated with honors from the Stony Brook School of Medicine where he was a Health and Public Affairs Scholar and in 2004 received the University’s Distinguished Alumni Award. He completed post-doctoral research training at the Whitehead Institute for Biomedical Research at Massachusetts Institute of Technology and at Harvard Medical School. He completed clinical training in Internal Medicine and Neurology at the Massachusetts General Hospital where he served as Chief Resident in Neurology and received the Physician Scientist Award from the National Institute of Health (NIH).

He has contributed chapters in books and has published in peer reviewed journals, such as Nature and Proceedings of National Academy of Sciences. He has organized and chaired numerous biomedical seminars and conferences in the United States, Canada, Europe, and Asia and conducted Grand Rounds at leading medical institutions in Canada, Europe, and the United States, including the Mayo Clinic and Massachusetts General Hospital. He has been a guest on television (CNN, MSNBC, NBC, PBS, and Nova), including two Nova features on the regenerative medicine work that resulted in the creation of Curis, Inc. (CRIS) and the generation of revolutionary non-toxic anti-cancer therapies.

FURTHER READING

1. Council on Science and Public Health Report 4. Light pollution: Adverse health effects of nighttime lighting. Chicago, IL: American Medical Association House of Delegates Annual Meeting; 2012.

2. Stevens RG, Brainard GC, Blask DE, Lockley SW, Motta ME. Adverse health effects of nighttime lighting: Comments on American Medical Association policy statement. *Am J Prev Med.* 2013; 45(3): 343–346.

3. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Painting, ire ighting, and shiftwork. France: 2010. Report No.: 98.

4. Straif K, Baan R, Grosse Y, Secretan B, El Ghissassi F, V B, Altieri A, Benbrahim-Tallaa L, V C. Carcinogenicity of shift-work, painting, and ire- ighting. *The Lancet Oncology.* 2007; 8: 1065–1066.

5. Hill SM, Belancio VP, Dauchy RT, Xiang S, Brimer S, Mao L, Hauch A, Lundberg PW, Summers W, Yuan L, Frasch T, Blask DE. Melatonin: An inhibitor of breast cancer. *Endocr Relat Cancer.* 2015; 22(3): R183–204.

6. Najjar R, Wolf L, Taillard J, Schlangen L, Salam A, Cajochen C, Gron ierC. Chronic Arti icial Blue-Enriched White Light Is an Effective Countermeasure to Delayed Circadian Phase and Neurobehavioral Decrements. PLoS ONE 9: e102827, 2014.

7. Human Centric Lighting: Going beyond energy ef iciency" by ZVEI, Lighting Europe and A.T. Kearney. Source: A.T. Kearney

8. Fonken L, Nelson R. Illuminating the deleterious effects of light at night. F1000 Reports Medicine 3: 18–25, 2011

9. Czeisler C. Casting light on sleep de iciency. Nature 497: S13 , 2013.

10. Leproult R., Holmback U, Van Cauter E. Circadian Misalignment Augments Markers of Insulin Resistance and In lammation, Independently of Sleep Loss. Diabetes 63: 1860–1869, 2014.

CIRCADIAN LIGHT

THE 24-HOUR SPECTRUM OF HEALTH

Health Risks of Light at Night

The Good, the Bad, and the Time of Day of Bioactive Blue Light

By: Dr. Martin Moore-Ede and Dr. Doros Platika