Artificial lighting and health

Text: Alexander Wunsch

New findings in photobiology show that we have to revise our understanding of the anatomical function of the human eye and brain. Human photo-endocrinology is much more complex than some scientific disciplines formerly expected and lighting engineers intend to acknowledge. Since R.G. Stevens put forward his melatonin hypothesis in 1987, an increasing number of scientists have been looking for a correlation between the use of artificial light sources and carcinogenesis. But the use of artificial light cannot only induce cancer development, there is also strong evidence for an involvement in the increase of cardiovascular disease in modern industrial societies. In this article we will put together the pieces that play their role in this dangerous outcome.

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www.international-light-association.org
www.lichtbiologie.de

Danger from artificial light

Light is essential for life on this planet. Evolution happened under very specific lighting conditions: the recurrent alternation of night and day has burned the circadian rhythms into the genes of all forms of life, which is highly adapted to the photonic conditions of the environment. The specific composition of sunlight as well as the properties of the atmospheric layers play important roles for the life-aiding qualities of natural light. Under today's viewpoint we have to suspect that every aberration from these properties make artificial lighting potentially dangerous for health.

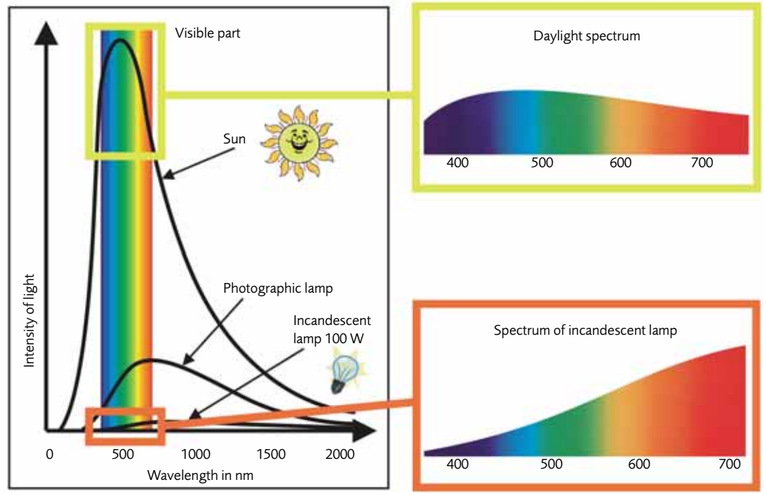
Sun physics

What are the aberrations we are talking about, and which sensory modules in our anatomical nature are responsible for detecting them? If we want to understand this, we first have to take a look at the subtle photonic consistency of sunlight itself. Astronomers tell us that it took around one million years to produce the photons we are receiving and consuming right now. There are myriads of occurrences like scattering and acts of collision until a photon reaches the surface of the sun after it has been generated in the sun's central regions by the well known fusion process, where hydrogen atoms amalgamate to helium and photonic energy. This deadly energy is transformed on its way from centre to periphery from inconceivably high frequencies into the range of optical radiation: more than 40 percent of the solar energy given off lies in the visible spectrum. While the radiation coming from the photosphere is really full spectrum light, the outer layer of our central star, the chromosphere, removes all element-related emission lines from the whole spectrum. We understand what this means if we use a spectroscope, so we can see the Fraunhofer lines: after perambulating the chromosphere, sunlight shows an absorption spectrum, which can be characterized as full spectrum minus elementary frequencies.

Colour temperature

Light and colour are the consequences of heat: if we increase the temperature of a metal filament, it will emit electromagnetic radiation. First we can feel the heat and then we can see the wire glowing in different colors: the red heat will turn into orange and yellow until we see white light. The distribution of the wavelengths radiating from a heated body is defined in physics as black body radiation. The solar radiation energy is distributed as we would expect from a black body at a temperature of 5700 K, which equals the sun´s surface heat, with one exception: a black body shows no Fraunhofer lines. For that reason it is already a simplification if we say that sunlight has a colour temperature of 5700 Kelvin, which ignores the inner spectral composition. (We will return to the term "colour temperature" when we look at some photometric definitions and measurements of artificial light sources later in this article.)

Why should we think about these Fraunhofer lines at all? How can they matter, if we are unable to see them with the naked eye? The eye is definitely not the only receptive organ for light. Human skin is transparent to light. Even short wavelengths like UV radiation reach the capillary layers and the blood inside these delicate vessels. All the pigments and molecules with chromophoric groups in our body absorb and emit photons. Each single atom has the attribute we could call photonic metabolism. Photons are the language in which all matter communicates; every jump (change of energy level) of an electron is accompanied by photonic activity.



Spectrum of a glowing black body at the temperatures of a normal incandescent lamp, a photographer's lamp and the sun.

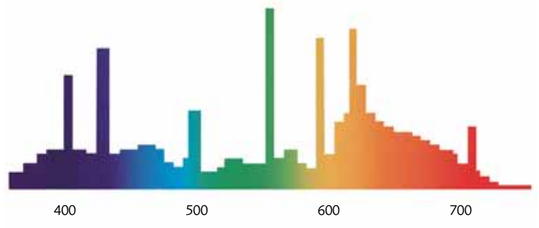
Let us now remember why Einstein received the Nobel Prize – it was not for his Theory of Relativity. It was for explaining the photoelectric effect. This effect occurs if a metal electrode is treated with photons, which liberate electrons if their quantum energy is high enough. In simple words, photons can make ions thicker or thinner, depending on absorption or emission activity. In the age of quantum theory we would be well advised if we extended the findings made with metal electrodes to effects which light can yield on biological membranes. Supposedly the Fraunhofer lines in sunlight act like photonic suction gaps influencing the molecular membrane passage in the capillary system of the skin, the largest organ for light reception, and in the ground substance outside the cells. This could give a deeper explanation why well-performed heliotherapy always creates a harmonizing balance, regardless if the patient's condition is characterized by hypo- or hyperactivity. We want to keep these considerations in mind when we later take a look at the mercury vapour lamps, better known as fluorescent lamps or so called full spectrum lights.

Incandescent light

There are many different types of light sources, so this article will only concentrate on three important ones: incandescent, fluorescent and LED light. If we approach this chronologically, we have to start with the incandescent lamps. This electrical light source was invented by German watchmaker Heinrich Goebel in 1854, six years after he had migrated to the USA, but he was not able to market it. So it took another 25 years before Edison succeeded in introducing the lamp to the market and developing a business out of it. But he was working with direct current, which cannot be transported over long distances. Before the world could be electrically enlightened, another genius, Nikola Tesla, had to invent alternating current technology. These two components, filament lamp and transportable electrical energy, were the keys to opening doors to our modern world. In the first decades of electrical lighting no one had a problem with the only disadvantage of incandescent light: its high energy consumption. Only five percent of investment in power comes back as light, the rest is transformed into heat, what makes this light comparable to a kind of tamed bonfire. The incandescent lamp is the only electrical light source which deserves the label "full spectrum," because it delivers all wavelengths without any gaps or energy peaks. When a filament bulb is operated with direct current, it produces a completely clean light, free from modulation frequencies and flicker.

Fluorescent light

Let us now take a look at mercury light sources, which entered the stage in the late thirties of the last century, when they lent a hand in demonstrating the advantages of modern technologies during the World Fair in New York. These fluorescent lamps contain mercury vapour that is charged up with electrical energy. During the subsequent discharging process the mercury atoms emit photons in specific wavelengths, which are able to excite other mercury atoms they meet in their path. Only excited atoms are prepared for chemical reactions. Fluorescent light shows mercury-specific energy peaks in its spectrum, a circumstance which John Ott regarded as a problem. We know today, that visible light enters the human system via the skin and reaches the fatty tissue without any problems; even the skull and brain are highly transparent to light. The fat is exactly the substance where we find the mercury that entered the body via food or dental amalgam fillings. Mercury is a toxic substance and hard to eliminate, so the body tries to deposit it in compartments with a low metabolic activity, so-called bradytrophic tissues. This is the reason why we find the mercury concentrated in the fat layers under the skin and in the neuronal myelin sheaths of the brain. Mercury light percolating through skin and bones counteracts the body's endeavours to detox this fatal substance. While sunlight with its Fraunhofer gaps induces a suction force for elementary wavelengths, the elementary spectral lines create a pressure, exactly the opposite. Sunlight has a calming effect on chemical elements; mercury light induces excitation of this poison.



Spectrum of discharge lamps.

Light Emitting Diodes

LED light sources are luminescence radiators which are available in different colours. They are often called monochromatic light sources, but this is not really true. Depending on the wavelength or colour, they show a narrowband or broadband spectrum, but never emit real monochromatic light as a laser does. The advantage of LEDs lies in their low energy consumption while the handicap often is found in the type of electronic circuitry used for driving them. The so-called pulse width modulation (PWM), used for controlling the intensity, especially utilized in colour changing products, often operates on low frequencies (under 100 Hz).This leads to a flickering effect, which is only noticeable under certain conditions or by measurements. Flickering light can cause headache and discomfort and should be avoided in artificial lighting. LED technology is mentioned here because it can be used in treating SAD; using blue LED lights is much more effective for controlling the biological clock than white light for its deeper impact on melatonin inhibition.

Energetic pathways and the circadian clock

When light shines on a human being, it has a number of different effects:

We use light for orientation in time and space, as a source of energy as well as for information purposes. Our system has to know if it is day or night, summer or winter, dangerous or safe outside and so on. Since man lost his hairy coat, the body has had to change and improve the light processing mechanisms it applies – not only in unprotected skin, but also in the regions of the brain which are responsible for hormonal and vegetative homeostasis. The region of interest is the hypothalamus with the appending pituitary gland which is accountable for endocrine control and coordination. In recent decades another endocrine organ, the pineal gland, has also gained in importance. In the past five years we have been confronted with new scientific findings describing how the controlling mechanisms between light, the circadian clock and pineal gland really work. A new melanopsin pigment-containing receptor system was found in the retinal ganglion cell layers that is sensitive to blue light and connects to the hypothalamus, pituitary and pineal gland. The human eye seems to harbor a sensor system for the measurement of the color temperature for incoming light. Why do we need this and what are the consequences for artificial lighting?

Blue is different

Blue light plays an extraordinary role in the eye. Regarding the process of vision, blue light hampers the formation of a sharp image on the retina, therefore nature uses some optical tricks to enable focused vision: on the one hand, the macula lutea or yellow spot area of sharpest vision carries the yellow pigment for filtering out excrescent blue portions; on the other hand, the receptors for blue are relatively infrequent compared with the green and red ones. An average eye comprises about four million red receptors, two million green receptors and only one hundred thousand blue ones.

While blue tinted light reduces sharp vision, it has the highest impact on the energetic portion of the optic nerve by telling the organism that it must be quite sunny outside. But it is not really the blue our body clock is looking for: in nature bright blue light always comes together with ultraviolet radiation. The hypothalamus has to coordinate different hormone concentrations and adapt them to the environmental conditions. There is one very important hormone that is not excreted by a gland but produced directly in the skin under the influence of ultraviolet radiation with wavelengths between 290 and 320 nm: Vitamin D. As vitamins by definition are substances which the body cannot produce independently, the name Sun Hormone or Solitrol is a much better expression for this particular substance. Solitrol is antagonistic to melatonin and a number of other hormones, so it is essential for the system to foresee the dispersion of this sun hormone in the organism by extrapolating the amount of ultraviolet radiation outside. While the UV builds up solitrol in the capillary layers of the skin, other hormones like steroids are destroyed under the influence of this radiation. This light-driven endocrine cutback normally is compensated for by the activation of the retinohypothalamic tract with consecutive distribution of releasing factors and new hormone production.

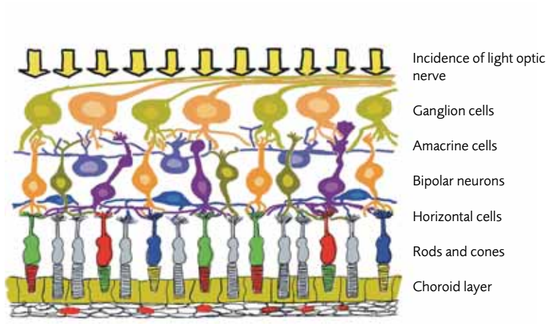
Table 1: Effect of sun light and artificial on the human body.

Sunlight (5700K)			
Location of effect	ACTH	Stereoids	Vitamin D
CNS	↑	↑	-
Skin	↓	↓	↑
Artificial light (5700K)			
Location of effect	ACTH	Steroids	Vitamin D
CNS	↑	↑	-
Skin	-	-	-

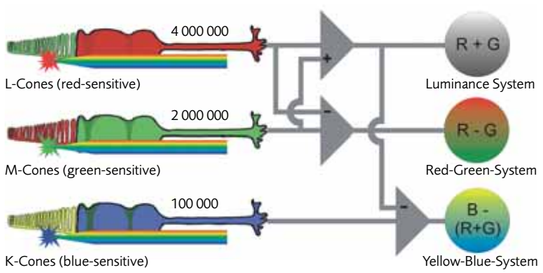
ACTH = Adrenocorticotropic hormone (Stress hormone cocktail),
CNS = Central nervous system

Table 2: Properties of artificial light sources.

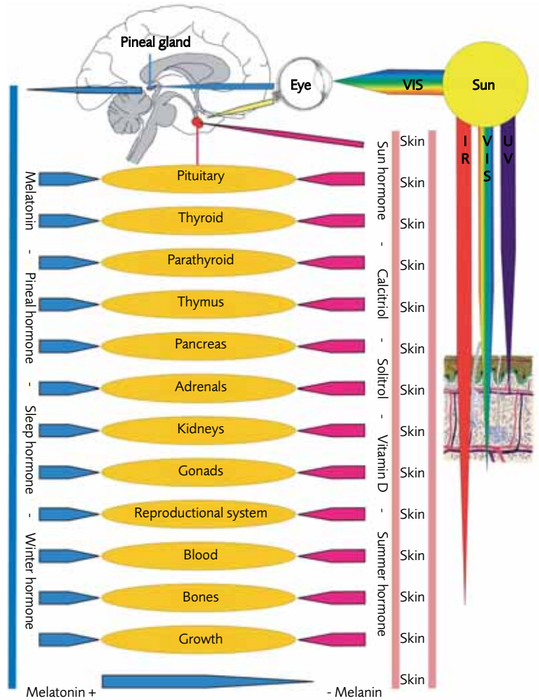
Properties of artificial light sources			
Light source	**Colour temperature in Kelvin**	**True temperature in Celsius**	**Chronobiological effect**
Red LED	1000	< 100	---
Orange LED	1500	< 100	--
Yellow LED	2000	< 100	-
Candle	1500	1.230	-
Incandescent lamp	2000 - 2600	1730 - 2330	0
Halogen lamp	2600 - 3300	2330 - 3030	+
Fluorescent lamp	2700 - 4000	< 100	++
Full spectrum lamp	4000 - 6000	< 100	+++
White LED	4500 - 10 000	< 100	++++
Blue LED	> 12 000	< 100	+++++



Light-processing layers of the retina.



Principle behind the switching of colour-sensitive receptors in the human retina.



The effect of light on human skin, the human eye and the human hormone system.

Energy fools the brain

The problem that occurs is that when we use artificial light sources with high colour temperatures that tell the energetic pathway through the eye that there is a high amount of UV outside. The organism starts producing new stress hormones and waiting for solitrol – but solitrol is not forthcoming, and existing stress and sex hormones are not destroyed because there is no UV in the light and the skin is covered by clothes. The result is an increase of stress and sex hormones with typical consequences for health (under long term conditions): cardiovasculatory diseases and hormone-dependent cancers.

Salutary light

The positive thing is that we do not have to wait for tomorrow's inventions: we can start right now in improving the artificial lighting conditions, if we respect the chronobiologic effectiveness of the different lamp types. Chronobiologically effective does not always mean healthy. Depending on the intended purpose it might often be less detrimental to use the chronobiologically neutral light sources. Avoiding mercury-based light sources and white LED lights (both have high colour temperatures) may be a rough rule of thumb. Another indication of unnatural light is the difference between colour temperature and true temperature.

Let there be healthy light!