


Artificial Lighting and the Blue Light Hazard

(The Facts About Lighting and Vision)

by

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Macular Degeneration Support

Contents

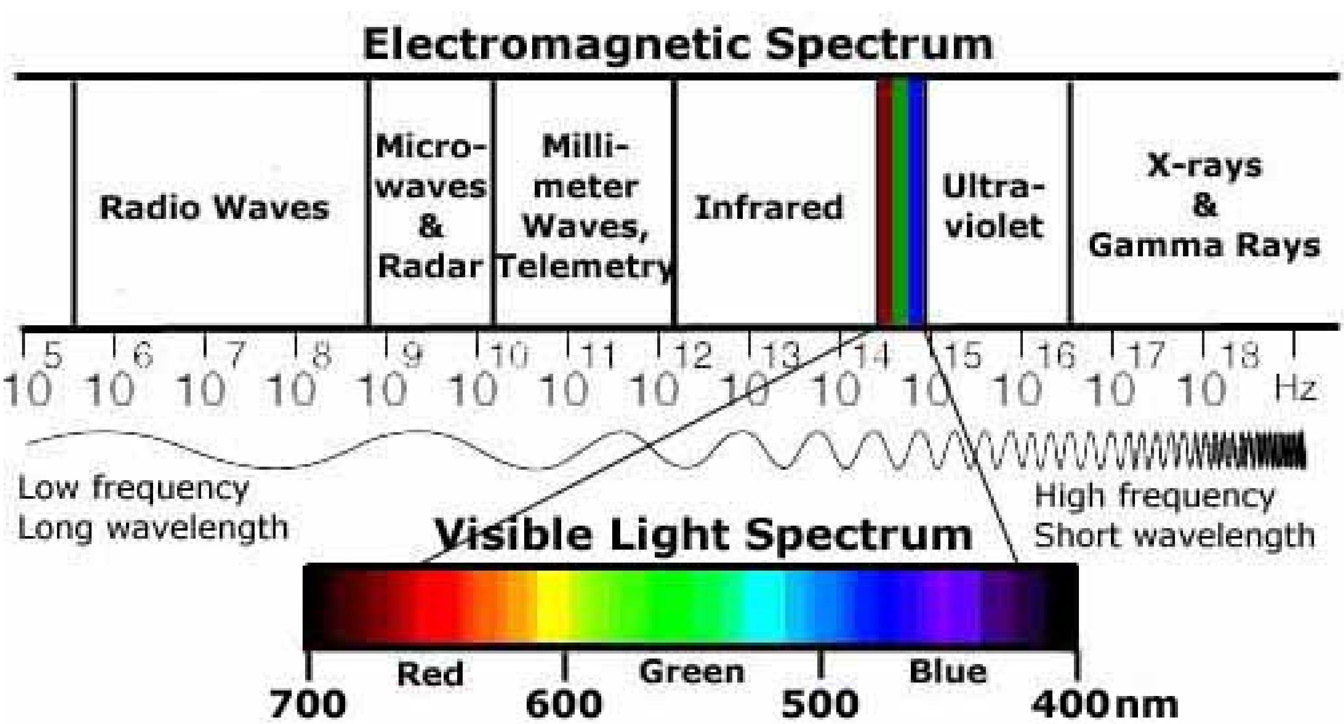
Introduction

What kind of lighting is best for people with retinal diseases like macular degeneration? Researchers tell us that ultraviolet (UV) and blue light rays may be harmful to those of us with retinal disease, while marketers tell us that lamps with enhanced UV and will help us to see better and stay healthier. Advertisers tell us that the intensity and range of colors offered by lamps that replicate sunshine and daylight are necessary for best vision and visual health. At the same time, doctors admonish us to wear blue-blocking, UV-protective sunglasses when we go outdoors.

What's going on? What should we believe? How can light hurt our retinas? What are the differences between fluorescent, halogen, neodymium, and regular incandescent lightbulbs? What do they mean by labels such as "full spectrum" and "daylight?" To sort all of this out, let's begin with a definition of light and its effects on the retina.

What is Light?

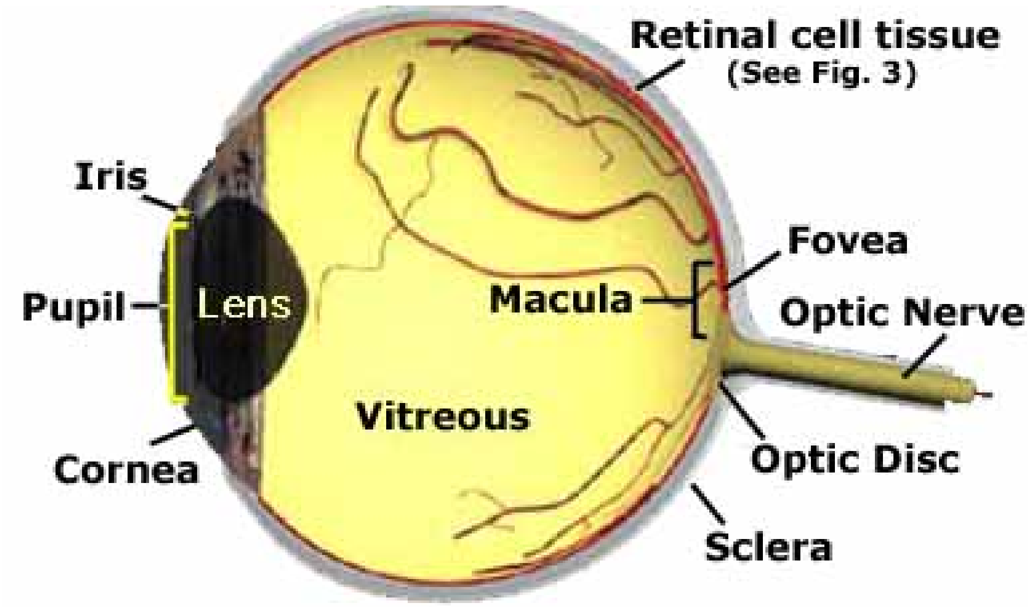
Light is made up of electromagnetic particles that travel in waves. Our retinas are capable of responding to only a small part of the entire electromagnetic spectrum. From the longest waves (lowest frequency) through the shortest waves (highest frequency), lighting specialists identify the electromagnetic wave regions as 1) radio waves, 2) microwaves and radar, 3) millimeter waves and telemetry, 4) infrared, 5) visible light, 6) ultraviolet, and 7) x-rays and gamma rays.



(Fig. 1)

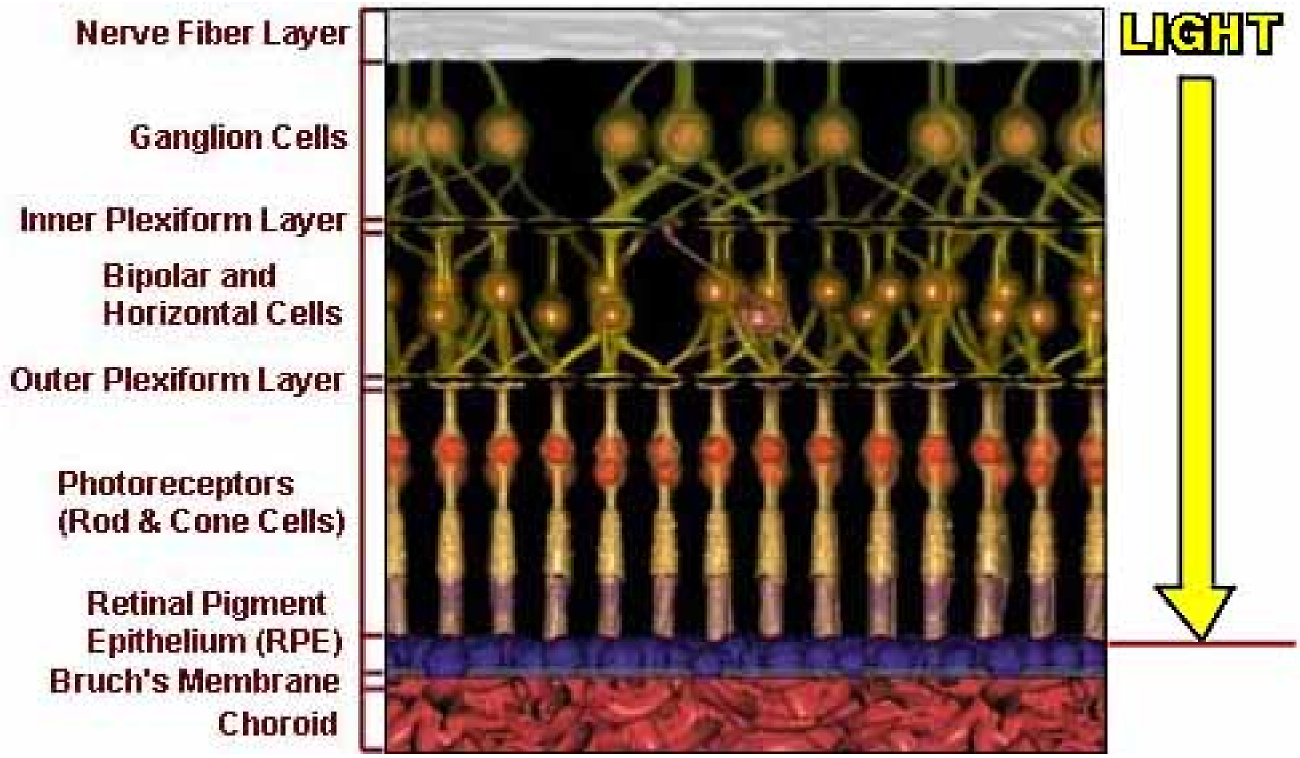
As illustrated in Figure 1, the "visible light spectrum" is that small part of the electromagnetic wave spectrum that we see as colors. The visible light spectrum ranges from about 700nm (nanometers) to about 400nm. In order, the colors are red, orange, yellow, green, blue, indigo, and violet. These are the colors of a rainbow from top to bottom, which can be remembered by the fictitious name ROY G BIV.

The retina is a very thin, multi-layered tissue located at the back of the eyeball. The lens at the front of the eyeball focuses light onto it.



(Fig. 2)

As shown in Figure 3, light first enters the optic (or nerve) fiber layer and the ganglion cell layer, under which most of the nourishing blood vessels of the retina are located. This is where the nerves begin, picking up the impulses from the retina and transmitting them to the brain.



(Fig. 3)

The light is received by photoreceptor cells called rods (responsible for peripheral and dim light vision) and cones (providing central, bright light, fine detail, and color vision). The photoreceptors convert light into nerve impulses, which are then processed by the retina and sent through nerve fibers to the brain.

Until recently, the rod and cone photoreceptor cells in our retinas have been credited with total responsibility for our light sensitivity. Recent research, however, has shown that some of our ganglion cells may be performing as a third type of photoreceptor called “intrinsically photosensitive retinal ganglion cells” (ipRGC).[1] [2] These sparsely situated cells are most sensitive to blue light. They seem to exist principally to help us differentiate between day and night (thus modulating our "sleep/wake" cycles, known as circadian rhythms).[3] [4] [5] The ipRGC have been shown to independently control dilation and contraction of our pupils, with a peak response at the blue light wavelength of 480nm. Some researchers have concluded through testing that the reaction of these ganglion cells is evidence of the importance of blue light to useable vision. An opposing view is that such experiments are actually measuring the subject's psychological reaction to the apparent increase in the field of view caused by the contribution of the ipRGC. This, researchers say, may cause the subject to interpret the environment as "brighter." Both sides agree that more study is needed before any definite conclusions can be drawn.

The Blue Light Hazard

Sight requires light. As years go by, accumulation of lipofuscin (cellular debris) in the retinal pigment epithelium (RPE) may make our retina more sensitive to damage from chronic light exposure.[6] [7] [8] [9] [10] [11] [12] [13] [14] [15] Retinal light damage has been studied by exposing experimental animals and cell cultures to brilliant light exposures for minutes to hours. According to some of these studies,[16] [17] [18] [19] blue light waves may be especially toxic to those of us who are prone to macular problems due to genetics, nutrition, environment, health habits, and aging. On the other hand, acute retinal phototoxicity experiments such as these can cause retinal injuries, but they cannot simulate a lifetime of normal light exposure. Some researchers have noted strong similarities between photic injury and retinal abnormalities caused by years of overexposure to light.[47] [48] [49] [50] Others have found no similarities. [51] [52] [53] [54] [55] [56] [57] [58] Whereas the shorter wavelengths of UV-A and UV-B are somewhat filtered by the lens and cornea, animal studies have shown that the light spectrum from UV through blue can be harmful. During lengthy exposures of up to 12 hours, toxicity of the retina is known to increase as the light wavelengths grow shorter.[20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [56] More recently, research on human fetal cell tissue has also revealed damage from blue light exposure.[78] Fortunately, healthy retinas have a wide array of built-in chemical defenses against UV-blue light damage. They bear such imposing names as xanthophyll, melanin, superoxide dismutase, catalase, and glutathione peroxidase. And then there are the more familiar agents vitamin E, vitamin C, lutein, and zeaxanthin. [35] [36] [37] [38] [39] Unfortunately, these defenses can weaken with disease, injury, neglect, and age.

Another built-in protective process is that our natural lenses take on a yellowish tint as we age, which helps to filter blue light.[59] [60] After cataract surgery, however, patients lose that benefit. Some doctors now recommend replacing the damaged lens with an intraocular lens (IOL) that is tinted to block blue light.[79] The patient should be made aware, however, that this procedure will diminish scotopic (night) vision.[61] [62]

According to the CVRL Color & Vision database,[63] light waves measuring approximately 470nm to 400nm in length are seen as the color blue. The blue bands of the visible light spectrum are adjacent to the invisible band of ultraviolet (UV) light. UV is located on the short wave, high frequency end of the visible light spectrum, just out of sight past the color violet. It is divided into three wavelengths called UV-A , UV-B, and UV-C. The effects of UV-C (100nm-290nm) are negligible, as the waves are so short they are filtered by the atmosphere before reaching our eyes. UV-A (320nm-400nm) and UV-B (290nm-320nm) are responsible for damaging material, skin, and eyes, with UV-B getting most of the blame.

When light hits a photoreceptor, the cell bleaches and becomes useless until it has recovered through a metabolic process called the "visual cycle." [30] [31] Absorption of blue light, however, has been shown to cause a reversal of the process in rodent models. The cell becomes unbleached and responsive again to light before it is ready. This greatly increases the potential for oxidative damage, which leads to a buildup of lipofuscin in the retinal pigment epithelium (RPE) layer[64] (see Fig. 3). Drusen are then formed from excessive amounts of lipofuscin, hindering the RPE in its ability to provide nutrients to the photoreceptors, which then wither and die. In addition, if the lipofuscin absorbs blue light in high quantities, it becomes phototoxic, which can lead to oxidative damage to the RPE and further cell death (apoptosis).[65]

Blue light is an important element in "natural" lighting, and it may also contribute to our psychological health.[71] [72] Research, however, shows that high illumination levels of blue light can be toxic to cellular structures, test animals, and human fetal retinas.[56] [66] [67] [68] [69] [70] [78] [79] [80] [81] (Also see "Random Quotes" below.) The industry has established standards for protecting us from extremely bright light and from UV radiation; but no standards address the blue light hazard that may be affecting millions of us who have retinal problems. Blue light is a duplicitous character who needs to be carefully watched. Until research proves him to be either a friend or a foe, we need to educate ourselves so that we may make decisions based upon the facts.

The next section defines the terms used in the lighting industry. Knowing the language will help a great deal with our understanding.

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Terms Referring to Measurement of Light

Color Rendering Index (CRI):

The CRI of a lamp is a number from 20 (effectively) to 100 that describes how well the lamp’s light emission affects the appearance and vibrancy of an object’s color. It is determined by comparing the lamp with a reference source of the same Kelvin temperature (see below).

Kelvin (K):

Kelvin is the basic un it of measurement for temperature. 0 Kelvin = -273.15° centigrade. The Kelvin temperature rating is based on the color most highly emitted. It does not express the range of a lamp’s light spectrum or the strength of it’s illumination (radiant power).

Correlated Color Temperature (CCT):

The CCT number is a measurement of the actual color appearance of light. It is expressed in Kelvins. Low CCT numbers define “warm” lighting, like the yellow and red hues of candlelight at 1500K. High CCT numbers define “cool” lighting, like a clear blue sky at 12000K. Actual light that we see measures from a low of 2000K to a high of 7500K.

Footcandle (fc) and LUX (lx):

FC and LX are unit's of illuminance(light on a surface). 1fc=lm/ft2. 1lx=lm/m2. 1fc=0.0929lx. 50 footcandle is generally considered sufficient for most tasks.

Lumen (lm):

A lumen is the standard unit of luminous flux (the time rate of flow of radiant energy). This is a measurement at the light source (the lamp), not necessarily at the surface being lit.

Nanometer (nm):

A nanometer is the extremely small unit used to measure lengths of light waves. A single nm equals one billionth of a meter.

Watt:

A watt is a unit of power equal to work done at the rate of one joule (approximately 0.738 foot pounds) per second. Wattage is actually a measurement of energy, not of light.

Types of Lamps

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First, what is a lamp?

Contrary to popular usage, a lamp is neither a fixture that holds a lightbulb or tube, nor is it “a light.” A lamp is the lightbulb or tube itself, which is contained in the lighting “fixture” (or “instrument”). Light is the energy that emits from the lamp. Only incandescent lamps, by the way, should rightfully be called lightbulbs, due to their bulbous (i.e. fat and round) shape.

Full-Spectrum (FS):

Technically, there is no such thing as a true full spectrum lamp, but the term is used to define a light source with a CCT of 5000K or higher and a CRI of 90 or higher. FS lamps are fluorescent, and they often have enhanced levels of UV. Only lamps that meet these specifications should be called FS.

Fluorescent:

This type of lamp is a phosphor-coated tube filled with mercury and argon vapor. Phosphors in lamps are rare earth compounds of various types that glow during absorption of light radiation. An electrical current discharged into the vapor causes the phosphor to glow (fluoresce). Fluorescent lamps require an electrical component (a “ballast”) to create the arc that excites the gas. The type and blend of phosphors used in the coating determine the color of the emitted light.

Fluorescent tubes containing the older halophosphate type phosphors emit light that is high in the blue spectrum. The phosphors increase the wavelength of the invisible UV rays enough to convert them into visible light beginning at 400nm. In common fluorescent tubes, UV rays are blocked mostly by the glass enclosure, protecting us to some extent from those harmful wavelengths. The blue light, however, passes through unimpeded.

Most fluorescent tubes now use a triphosphor mixture, based on europium and terbium ions, which more evenly distributes over the visible light spectrum. With a blend of phosphors designed for a CCT of 5000K-6500K, these lamps come close to imitating the colors of daylight. Blue light is an important component of that mixture, so the 470nm-400nm band is not only unfiltered, it is often enhanced in the manufacturing.

Incandescent:

Commonly known as a lightbulb, an incandescent lamp contains a tungsten filament in a vacuum. An electrical current causes the filament to glow (incandesce), while the absence of oxygen keeps it from burning up.

Neodymium:

This is a natural heavy metal element used as a coating on the inside of some light bulbs. It filters out the yellow spectrum, thus creating a CRI closer to that of daylight. Neodymium bulbs, therefore, are often marketed as one of the types of modified-spectrum lamps, but they should not be confused with FS lamps.

Tungsten Halogen:

Also called halogen, this lamp contains a filament made of tungsten, so it is a type of incandescent lamp. It is different than an incandescent lightbulb, however, in that it contains a gas called halogen. Halogen recycles the burned particles of the tungsten, constantly rebuilding the filament and giving it a longer life. Halogen burns very hot and bright, so it can be a safety hazard if not properly used.

The Problem With Full-Spectrum Lamps

With growing evidence that both UV and blue light damage the retinas of us who are affected by, and at risk of, retinal disease, we should do everything possible to avoid aggravating our condition. We should arm ourselves with good information and educate ourselves against the advice of marketers who may not be familiar with (or who ignore) the possible hazards.

Manufacturers promote FS lamps as more conducive to seeing than traditional lighting systems, based upon the belief that we see best outdoors on a bright cloudless day. That assumption is disputed by others who suggest that better vision under such conditions may be a result of increased light intensity and uniformity rather than color. I am unaware of any studies that have tested this hypothesis. Part of the reason for that paucity may be because FS lamps are difficult to define and compare. The essence of daylight is constantly changing as Earth moves in relation to the sun, and varied atmospheric conditions throughout the world measure differently.[73] In view of such variables, "daylight" is a vagarious term with no standard scientific definition, so it really has no meaning in the lighting market. "Daylight" is actually a pejorative term to most low vision people, as it is a condition that we try to avoid.

We inarguably see better in the light of day than in the dark of night. A good deal of research is showing, however, that the light of day (i.e. high in the UV-blue spectrum) may be deleterious to the retinas of people like us. Since light is both practical and desirable, we need to enjoy its benefits but, at the same time, protect ourselves from potentially accelerated vision loss. Just as we shield our skin from prolonged sunlight, it makes sense that we should also shield our eyes when outdoors. Until good science provides more definite answers, we might also be wise to not bring the sun into our houses and place it on our desktops.

As discussed above, a growing body of research suggests that people who are at risk of retinal deterioration should avoid spending extended periods of time with unprotected eyes in daylight environments with a CCT of 5000K or higher (the range of the visible blue light spectrum), especially when that light is at high intensity, as in direct sunlight.

Market Survey

In an attempt to learn more about such products currently on the market, I have gathered data on 19 high-intensity lamps offered by 12 companies during the year 2004. I have listed the CCT, CRI, type of lamp, and advertised descriptions for each, and then drawn conclusions from that information. I have relied upon the accuracy of each company’s CCT and CRI measurements as published, and I take no responsibility for inaccuracies due to manufacturers’ oversight or misrepresentation.

Survey of Full Spectrum and Daylight Lamps on the Market as of December 31, 2004

Balanced Spectrum by firstStreet (formerly TechnoScout)

- CCT: 6500K
- CRI: 82-84
- Type: Neodymium
- Described as contributing to vision health.

BioPure Full Spectrum Light Bulb (marketed by Joseph Mercola, D.O.)

- CCT: 5500K
- CRI: 93
- Type: Fluorescent
- Described as "full spectrum."
- Advertising recommends not filtering any of the visible or UV spectrum: "Unfiltered sunshine is important. If you are wearing glasses or sitting in front of a window, some of the 1500 wavelengths present in sunshine will not reach your retina and nourish your brain."

"Bright As Day!" Desk Lamp (Sharper Image Design)

- CCT: 5000K
- CRI: 91
- Type: Fluorescent
- Described as "wide spectrum" and "daylight spectrum."

Chromalux by Truesun

- CCT: 5000K
- CRI: 50
- Type: Neodymium
- Described as contributing to vision health.
- Advertising implies that it is a “full spectrum” lamp. Quote: "...provides bright light

that closely mimics the spectrum of Natural Sunlight (infrared, visible spectrum and beneficial U.V.A. rays)."

Coil-Lite Compact Fluorescent by True Sun

- CCT: 6500K
- CRI: 82
- Type: Fluorescent
- Described as “full spectrum” lamp.

Full Spectrum (VisionMax) by Tensor

- CCT: 6500K
- CRI: 84
- Type: Fluorescent
- Described as "full spectrum" lamp.
- Advertising quotes: "True-to-life colors." "Vivid contrast." "The ultimate natural daylight lamp." "Replicates sunshine indoors." "Especially for aging eyes."

Life-Lite by True Sun (replaces Vita-Lite by Duro-Test Light Corp.)

- CCT: 5500K
- CRI: 91
- Type: Fluorescent
- Described as "full spectrum" lamp.

Lumichrome 1XX by True Sun

- CCT: 6500K
- CRI: 98
- Type: Fluorescent
- Described as "full spectrum" lamp.
- Advertising quote: "...replicates the characteristics of diffused natural sunlight."

Neolite light bulbs by Full Spectrum Solutions

- CCT: 4800K
- CRI: 95

- Type: Neodymium
- Described as "full spectrum" lamp (contrary to standard definition).
- Advertising quote: "...similar to true daylight."

Ott-Lite (Developed by Vita-Lite)

- CCT: 5000K
- CRI: 79-82
- Type: Fluorescent
- Described as "full spectrum" lamp.
- Described as contributing to vision health.
- Advertising quote: “the next best thing to natural daylight.”

Paralite-Maxum 5000 by Full Spectrum Solutions & True Sun

- CCT: 5000K
- CRI: 88-91
- Type: Fluorescent
- Described as "full spectrum" lamp.

Paralite-Spectra 5900 by Full Spectrum Solutions & True Sun

- CCT: 5900K
- CRI: 93
- Type: Fluorescent
- Described as "full spectrum" lamp.

PureLite by Natural Lighting

- CCT: 5000K
- CRI: 90
- Type: Neodymium

Phillips TL 90 Series-T8 Fluorescent Lamps by Full Spectrum Solutions & True Sun

- CCT: 5000K
- CRI: 98

- Type: Fluorescent
- Described as "full spectrum" lamp.

Sunlight Lamp by Bell & Howell

- CCT: 6500K
- CRI: 80-82
- Type: Fluorescent
- Description as "full spectrum" or “daylight” lamp is implied by its name.

UltraLux by Full Spectrum Solutions

- CCT: 5500K
- CRI: 91+
- Type: Fluorescent
- Described as "full spectrum" lamp. Doubles as therapy lamp by tilting to shine directly on the user.

Verilux Happy Eyes

- CCT: 5500K
- CRI: 80-82
- Type: Fluorescent
- Description as “full spectrum” and “daylight” lamp implied in advertising: "natural spectrum," "simulating daylight," and "sunshine in a box."
- Described as beneficial to patients with computer vision syndrome.

Vita-Lite by Natural Lighting

- CCT: 5000K
- CRI: 79
- Type: Fluorescent
- Described as simulating full color and UV spectrum.

Vita-Lite Plus by Natural Lighting

- CCT: 5500K
- CRI: 91

- Type: Fluorescent
- Described as "full spectrum" lamp
- Advertising quote: "Enhanced with UV and blue-green phosphors"

Summary

Number of lamps surveyed	19
Lamps defined as fluorescent	15 (79%)
Lamps defined as neodymium	4 (21%)
Lamps correctly described as “full spectrum”	9 (43%)
Lamps incorrectly described/implied as “full spectrum”	8 (42%)
No claims made regarding "full spectrum" or "daylight"	2 (11%)
Lamps advertised as having enhanced or non-filtered UV	2 (11%)
Lamps advertised as healthy for the eyes	7 (37%)

Discussion

A commercial market will inevitably grow around any human condition with profit potential. For the best protection of our health and our pocketbooks, we must be vigilant about the facts and skeptical about anything that doesn’t pass the test of reason. At first hearing, for example, “Bright daylight is good for the eyes,” seems to make sense. But if that is so, then . . .

1. Why do my pupils constrict in bright light?

2. Why am I temporarily blinded by flash cameras?

3. Why do skiers go "snow" blind?

4. Why shouldn’t I look at the sun?

5. Why does my doctor recommend wearing wraparound, UV-protective, blue-blocker sunglasses?

Seven of the surveyed companies actually advertise their FS lamps as good for eye health. As educated folks, common sense should tell us otherwise; but as human beings, our common sense can sometimes be overridden even by people with the best of intentions.

My grandmother warned, “Turn on the light. You’re going to ruin your eyes.”

I asked why, and she said, “Reading in the dark makes them work too hard. They’ll wear out.”

Fifty years later, after becoming visually-impaired in spite of my grandmother’s well-meaning reprimands, I discovered that her reply to my “why” should have been, “Because you will be able to see better.”

Now that makes more sense. My eyes don’t work any harder at seeing in the dark than do my ears at hearing soft music. Actually, the demand on my photoreceptor cells increases as the light grows brighter. This may prove harmful to the vision of people with retinal problems, so I might be smart to reach a compromise between “enough light to see by” and “too much light.”

The condition of our individual retinas determines the level of light we need. A person with early-stage macular degeneration can usually read well enough under standard lighting. A person with advanced-stage macular degeneration, however, requires higher illumination and contrast. Ironically, many of us are also photosensitive. We need bright lighting, but lamps that replicate sunshine might not only hasten our sight loss, they cause us significant discomfort. “Enough light to see by” cannot be standardized for people like us.

As we have seen, a growing body of research shows that the shorter electromagnetic waves of the light spectrum from blue (also called near-UV) through ultraviolet may harm us. One study even suggests that lower color temperature (i.e. reduced blue light) optimizes the reading rate of people whose visual abilities have been lessened due to ARMD.[74] Another recent study of the Chesapeake Bay watermen reported a significant association between blue light and age-related macular degeneration.[75] [76] In view of this kind of scientifically-based evidence (no matter how small or large the studies might be), people who are at risk for retinal degeneration should consider avoiding light sources measuring higher than 5000K at high intensity.

Lamps that imitate daylight and sunlight are said to help us see better, and some are credited with helping to improve our mood. They will, however, neither improve the health nor extend the life of our retinal cells, a scientifically unsupported implication made by some manufacturers. Lamps such as these may be helpful for people with healthy eyes, but those of us who aren't so lucky should think twice. Even if we ignore the blue light issue, which is still under debate, we can easily find major research showing simply that sunlight in general is a possible causative element in several retinal diseases, from retinopathy of prematurity to age-related macular degeneration.[77] [19]. This kind of evidence alone should be enough to make those who are already visually-impaired wary of FS lamps.

During my survey, I came across a distributor who has established an important precedent by publicly recognizing potential optical risks associated with high levels of blue light. The company is Sunnex Biotechnologies, makers of the Lo-Light Therapy Lamp (a safe low-intensity lamp that screens out blue light). Here is a cautionary statement that I have devised based upon information from their web site. It might serve as a model for makers of FS lamps to follow:

> CAUTION: This lamp emits strong blue light wavelengths (470nm - 400nm), which have been shown in some studies to harm the retina. You may want to avoid prolonged use of this product if . . .
>
> - you are taking photosensitizing medication such as nonsteroidal anti-inflammatory drugs (NSAIDs), most antidepressants, some antibiotics, diuretics, and beta-blockers and other heart medications;
> - you have a pre-existing ocular condition such as macular degeneration;
> - you are diabetic or otherwise at risk for retinal damage; or
> - you are 55+ years of age.

Safe Options

Several lamp manufacturers provide products that offer intensity, contrast, and good color replication without the high color temperatures of full spectrum lamps. Listed below are examples of bright desk lamps and task lamps on the market with CCTs below 5000K. Until we have more conclusive research, these and similar products represent the safest I have found so far for low vision people.

LazLight Task Lamp (www.lazlight.com)

- CCT: 3000K
- CRI: 99
- Type: Halogen with dimmer
- Described as "high performance white light."
- Described as "brightest-available high-contrast true-color task lamp."
- Described as "350% more light . . . with no damaging blue light radiation."

RobinSpring32 Desk Lamp, distributed by the National Association for Visually Handicapped (www.navh.org)

- CCT: 3200K
- CRI: unknown
- Type: Compact Fluorescent
- Described as "glare and shadow free."
- Advertising quote: "Designed to minimize the visual work involved in reading but still be affordable."

SoLux Task Lamp (www.solux.net)

- CCT: 3500K - 4700K
- CRI: 98-99
- Type: Halogen
- Described as "daylight" lamp.
- Described as "closest to true spectrum" with no UV or IR radiation.

Live Comparison of Representative Lamps

To demonstrate the differences in lam p types, I acquired and compared six of the lamps mentioned in this paper. The demonstration was designed for an exhibit at the 2005 meeting of the Academy for Research in Vision and Ophthalmology (ARVO) and at other gatherings of researchers, eye care professionals, and patients. In this section of the paper I will describe the display and discuss the most typical observations that have been made by viewers.

Lamps compared:

1. General Electric Basic 75w, 2700K incandescent
2. LazLight 3000K incandescent halogen
3. Solux 4100K incandescent halogen
4. RobinSpring32 3200K compact fluorescent
5. Ott-Lite 5000K compact fluorescent
6. Full Spectrum (VisionMax) 6500K compact fluorescent

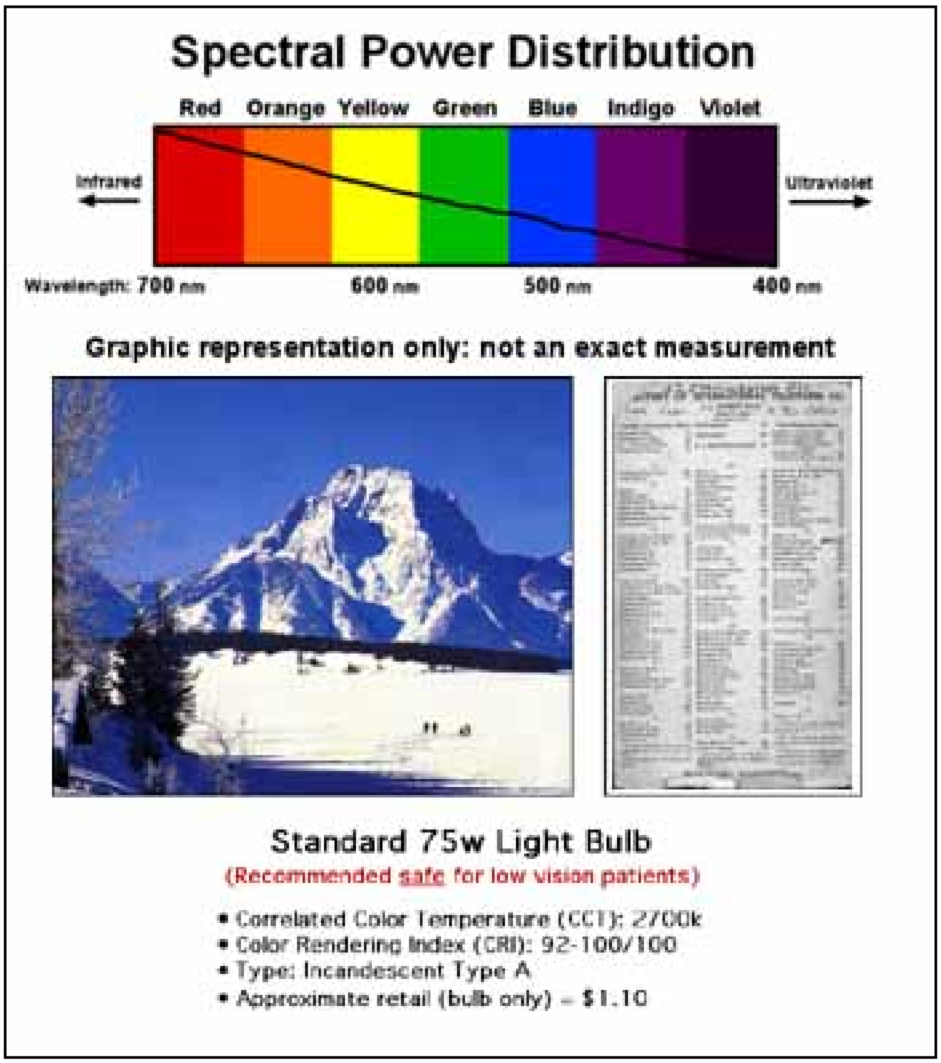
Set-up:

MD Support display at the 2005 convention of the
Association for Research in Vision and Ophthalmology (ARVO)

The lamps are each placed to shine into individual sections of a 6-foot long display unit. All lamp heads are equidistant from the surface and shining at maximum power. They each illuminate posters that display the following content:

- Identical photos of a predominantly blue mountain scene.
- Actual pages from a typical telephone directory.
- A graphic of each lamp's spectral distribution curve of radiant power overlaid on an image of the visible color spectrum.
- Name and description of each lamp, including the CCT, CRI, type, and retail cost.

Sample poster:



Procedure

The viewer is instructed to:

- Observe each lighted section with the naked eye and then through an amber-colored gelatin sheet or 100% blue-blocker lenses.
- Note the differences in terms of light intensity, contrast, color, and general effect.
- Compare each illuminated area to its own spectral distribution curve.

Typical Observations and Discussion

- **"Some lamps are bluer."**

  Blue light emission becomes more apparent as correlated color temperature (CCT) increases for each type of lamp. The blue light intensities of the lamps can be compared by viewing the posters through the amber gel provided or through 100% blue-blocker lenses. Where the CCT is low (lamps 1-2), blue appears gray and black. As the CCT increases from lamps 3 through 6, the blue portions appear increasingly brighter as the color green.

- **"Some lamps are brighter."**

  When all are at full power, the fluorescent lamps 4-6, are less intense than the incandescent lamps 1-3. The high amount of blue in the light of lamps 4-6 deceives the brain into interpreting them as "bright" until they are observed side by side with the incandescents.

Incandescent lamps like 1-3 are capable of several times the intensity of fluorescent lamps like 4-6, and there is little danger of reaching hazardous blue light levels. If the intensities of lamps 4-6 were increased to match the obviously stronger output of lamps 1-3, the amount of blue light would also increase, compounding the potential hazard to the retina. The only way to safely increase the intensities of lamps 4-6 to match that of lamps 1-3 would be to significantly decrease the blue and UV wavelengths. Such lamps, however, could then no longer be called full-spectrum or daylight.

- **"Some of the lamps are too bright for me."**

  Some incandescent lamps, like 2, have dimmers, which allow users to adjust the intensity to various comfort levels. Fluorescent lamps do not normally have dimmers, but they can be found.

- **"Some lamps provide more contrast."**

  Contrast diminishes with increasing CCT. Because of their "blueness," lamps 5-6 provide noticeably less contrast than lamps 1-4. The best contrast is achieved by the opposites of black and white, and that cannot be done with blue light.

- **"Some lamps are too intense for my eyes."**

  Lamps 5-6 are not as easy on the eyes as lamps 1-4. Because of its "blueness," a cloudless day at noon (i.e. "daylight" at 5000K) is not as comfortable for our eyes as the warmer colors of late afternoon. Lamps 1-3 emit light closer to the warm yellow and orange end of the visible color spectrum, with lamp 3 being the "whitest," due to its relative evenness across the visible spectrum.

- **"The best and safest type of lamp seems to be a standard incandescent light bulb, followed by halogen incandescent. So why spend more for a halogen lamp?"**

  Standard incandescent light bulbs (eg. Phillips Type A) cost more to operate, and they have significantly shorter life spans. Also, they emit yellowish light, whereas the light from a halogen incandescent lamp is whiter. White light is preferred for better color replication by professional crafters, photographers, and artists. People with low vision from retinal disease need white light for the same reason.

- **"Why is there such a difference in the prices?"**

  The cost of the lamps themselves (the lightbulbs and tubes) is similar for like-models. The quality of the fixtures holding them actually determine the bulk of the cost. Some fixtures are plastic, some are steel. Some have dimmers, some don't. Some are designed to complement a decor, some are merely functional. Some are made to last, some are not.

- **"The halogen, standard incandescent, and warm-colored fluorescent lamps provide the best lighting."**

  This reflects the opinion of virtually every viewer who has compared the lamps side-by-side. 100% of more than 150 doctors surveyed at the ARVO convention concur that the three display lamps measuring below 5000K provide the best illumination, contrast, and color replication. Their conclusion was reached notwithstanding the blue light issue. Even those who do not align with the research agree that low vision patients should be guided away from full spectrum lamps if only because of the comparatively poor quality of light emitted.

A Message To The Industry

The message from the low-vision community is simple:

1. Include a warning if the product presents a potential blue light hazard for people with retinal disease.

2. Provide accurate and complete specifications and descriptions so the consumer can make educated comparisons.

In view of the expanding volume of research, plus the increasing number of people diagnosed with retinal disease each year, I hope all manufacturers will voluntarily join us and our eye care specialists in this education effort. Modern lighting technology can help us to see better, but only through clear and honest marketing will the liability for our decisions be ours alone.

Random Quotes

Cautionary Statements From The Literature

" ...people with the highest levels of exposure [to UV-A, UV-B, and blue light] in the middle of the day had two fold increased risks of AMD. Our results showing th e increased risk from high exposures to solar radiation underline the importance of ocular protection in European populations." Augood, C. *et al*. Age-related maculopathy and macular degeneration in elderly European populations: the EUREYE study, 2004.

"The photoreceptors in the retina . . . are susceptible to damage by light, particularly blue light. The damage can lead to cell death and diseases." Shaban H, Richter C. A2E and blue light in the retina: the paradigm of age-related macular degeneration. Biol Chem 2002 Mar-Apr;383(3-4):537-45.

"The effectiveness of light in inducing photodamage to the retina increases with decreasing wavelength from 500 to 400 nm." Andley UP,? L.T. Chylack Jr LT. Recent Studies on Photod amage to the Eye with Special Reference to Clinical and Therapeutic Procedures. Photodermatology Photoimmunology and Photomedicine 1990; 7:98-105.

". . . when albino rats were exposed to either monochromatic blue light of 403 nm . . . or monochromatic green light of 550 nm . . . massive apoptotic cell death occurred after illumination with blue light." Remé et al. Apoptosis in the Retina: The Silent Death of Vision C E. News Physiol Sci 15: 120-124, 2000.

". . . continuous exposure to blue light is potentially dangerous to vision." Koide R, Ueda TN, Dawson WW, Hope GM, Ellis A, Somuelson D, Ueda T, Iwabuchi S, Fukuda S, Matsuishi M, Yasuhara H, Ozawa T, Armstrong D. Nippon. Retinal hazard from blue light emitting diode. Ganka Gakkai Zasshi. 2001 Oct;105(10):687-95.

". . . high levels of exposure to blue or visible light may cause ocular damage, especially later in life, and may be related to the development of age-related macular degeneration." Taylor HR, West S, Munoz B, Rosenthal FS, Bressler SB, and Bressler NM. The Long Term Effects of Visible Light on the Eye. Archives of Ophthalmology 1992; 110:99-104.

"I think chronic blue light is probably damaging." Joshua Dunaief, MD, in Bethke W.

Should We Block The Blue. Review of Ophthalmology Oct 15 2003; 10(10).

"Increased risk of AMD may result from low levels of lutein and zeaxanthin (macular pigment) in the diet, serum or retina, and excessive exposure to blue light." Bone RA, Landrum JT, Guerra LH, Ruiz CA. Lutein and Zeaxanthin Dietary Supplements Raise Macular Pigment Density and Serum Concentrations of these Carotenoids in Humans. Journal of Nutrition 2003 Apr;133(4):992-8.

"The high-energy segment of the visible region (400-500 nm) is enormously more hazardous than the low energy portion (from 500-700 nm)." Young RW. Solar Radiation and Age Related Macular Degeneration. Survey of Ophthalmology 1988; 32(4): 252-269.

"Visible light of short wavelength (blue light) may cause a photochemical injury to the retina, called photoretinitis or blue-light hazard." Okuno T, Saito H, Ojima Evaluation of blue-light hazards from various light sources. J. Dev Ophthalmol. 2002;35:104-12.

"[The] Action spectrum for blue-light induced [retinal] damage shows a maximum at 400 nm and 450 nm." Bartlett H, Eperjesi F. A randomised controlled trial investigating the effect of nutritional supplementation on visual function in normal, and age-related macular disease affected eyes: design and methodology. Nutrition Journal 2003, 2:12.

"Because sunlight and many high-intensity artificial light sources contain relatively high proportions of blue, and the retina as well as pigment epithelium contain several types of blue-absorbing molecules, the short-wavelength band of the visible spectrum may contribute to the pathogenesis of age-related macular degeneration and amplify some forms of inherited retinal degeneration." Remé CE, Wenzel A, Grimm G, Iseli HP. Mechanisms of Blue Light-Induced Retinal Degeneration and the Potential Relevance for Age-Related Macular Degeneration and Inherited Retinal Diseases SLTBR Annual Meetings Abstracts 2003.

". . . the photon catch capacity of the retina is significantly augmented during blue-light illumination, which may explain the greater susceptibility of the retina to blue light than to green light. However, blue light can also affect function of several blue-light-absorbing enzymes that may lead to the induction of retinal damage." Grimm C, et al. Rhodopsin-Mediated Blue-Light Damage to the rat Retina: Effect of Photoreversal of Bleaching. Invest Ophthalmol Vis Sci 2001 Feb;42(2):497-505.

"It is not too harsh to state that virtually all persons with vision problems should be removed from a light environment where the predominant light waves are a temperature above 3500K or a wavelength less than approximately 500 nm." Elaine Kitchel, M.ED.VI. The effects of fluorescent light on the ocular health of persons with pre-existing eye pathologies. American Printing House for the Blind, 2000.

"Exposure to the eye to intense light, particularly blue light, can cause irreversible, oxygen-dependent damage to the retina. We have found that illumination of human retinal pigment epithelium cells induces significant uptake of oxygen that is both wavelength and age dependent...and contribute to the development of age-related maculopathy." Rozanowska M, et al. Blue light induced reactivity of retinal age pigment. Journal of Biological Chemistry 1995; 270(32):18825-18830.

". . . blue light induces apoptosis in human fetal RPE cells." E.M. Gasyna, K.A. Rezaei, W.F. Mieler, and K.A. Rezai. Blue light induces apoptosis in human fetal retinal pigment epithelium. Invest. Ophthalmol. Vis. Sci. 2005 46: E-Abstract 248.

For further scientific rationale and references regarding the potential blue light hazard, see Recommendation of protective eye wear for patients suffering from degenerative retinal diseases. (Ch. E. Remé, Laboratory of Retinal Cell Biology, University Eye Clinic, Zurich, Switzerland).

For a critical look at full-spectrum lighting, read "Full-Spectrum Light Sources," a publication of the National Lighting Product Information Program.

For further explanation of the anatomical terms used in this article, see Eye Anatomy and Glossary on the MD Support web site.

Credits:

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Reviews:

< center>

". . . a very well written article and well understandable for lay people." ***(Charlotte E. Remé, Ph.D., Prof., Dept. of Ophth., Univ. of Zurich)***

". . . compelling and provocative." ***(Michael Terman, Ph.D., Prof., Dept. of Psychiatry, Columbia Univ., President, Center for Environmental Therapeutics)***

"You make an excellent point regarding the toxicity of blue light and the failure of most manufacturers to recognize this and address it."***(Richard Rosen, M.D., Director of Resident Training NY Eye & Ear Infirmary)***

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