THE EFFECTS OF LIGHT ON THE HUMAN BODY

By: Richard J. Wurtman

Since life evolved under the influence of sunlight, it is not surprising that many animals, including man, have developed a variety of physiological responses to the spectral characteristics of solar radiation and to its daily and seasonal variations. With the coming of summer in the Northern Hemisphere millions of people living in the North Temperate Zone will take the opportunity to darken the shade of their skin, even at the risk of being painfully burned. Coincidentally, the sunbathers will replenish their body's store of vitamin D, the vitamin that is essential for the proper metabolism of calcium.

Investigators are slowly uncovering subtler physiological and biochemical responses of the human body to solar radiation or its artificial equivalent.

There is growing evidence that fundamental biochemical and hormonal rhythms of the body synchronized, directly, or indirectly, by the daily cycle of light and dark. For example, Dr. Wurtman and his co-workers at the Massachusetts Institute of Technology have recently discovered a pronounced daily rhythm in the rate at which normal human subjects excrete melatonin a hormone synthesized by the pineal organ of the brain. In experimental animals melatonin induces sleep, inhibits ovulation and modifies the secretion of other hormones. In man the amount of the adrenocortical hormone cortisol in the blood varies with a 24 hour rhythm.

The most familiar type of artificial light is the incandescent lamp, in which the radiant source is a hot filament of tungsten. The incandescent filament in a typical 100-watt lamp has a temperature of only 2850 degrees K., so that its radiation is strongly shifted to the red, or long-wavelength, end of the spectrum. Indeed, about 90 percent of the total emission of an incandescent lamp lies in the infrared.

Each of the various effects of light on mammalian tissues can be classified as direct or indirect, depending on whether the immediate cause is a photo-chemical reaction within the tissue or a neural or neuroendocrine signal generated by a photoreceptor cell. When the effect is direct, the molecule that changes may or may not be the one that actually absorbs the photon. For example, certain molecules can act as photosensitizers: When they are raised to transient high-energy states by the absorption of radiation, they are able to catalyze the oxidation of numerous other compounds before they return to the ground state. Photosensitizers sometimes present in human tissues include constituents of foods and drugs and of toxins produced in excess by some diseases.

The indirect responses of a tissue to light result not from the absorption of light within the tissue but from the actions of chemical signals liberated by neurons or the actions of chemical messengers (hormones) delivered by circulation of the blood. These signals in turn are ultimately the result of the same process as the one that initiates vision: the activation by light of specialized photoreceptive cells. The photoreceptor transduces the incident-light energy to a neural signal, which is then transmitted over neural, or combined neural-endocrine, pathways to the tissue in which the indirect effect is observed.

For example: when young rats are kept continuously under light, photoreceptive cells in the retina release neurotransmitters that activate brain neurons: these neurons in turn transmit signals over complex neuroendocrine pathways that reach the anterior pituitary gland, where they stimulate the secretion of the gonadotropic hormones that accelerate the maturation of the ovaries.

The ovaries are not responding directly to light can be shown by removing the eyes or the pituitary gland of the rat before exposing it to continuous light. After either procedure light no longer has any influence on ovarian growth or function. Photoreceptors in the eye release the neurotransmitters that ultimately affect the pituitary gland.

Ultraviolet wavelengths in the narrow band from 290 to 320 nanometers cause the skin to redden within a few fours of exposure. Investigators generally agree that the inflammatory reaction, which may persist for several days, results either from a direct action of ultraviolet photons on small blood vessels or from the release of toxic compounds from damaged epidermal cells.

Sunlight or its equivalent initiates photochemical and photosensitization reactions that affect compounds present in the blood, in the fluid space between the cells or in the cells themselves.

In the past few years physicians have treated several skin diseases by deliberately inducing photosensitization reactions on the surface of the body or within particular tissues. The intent is to cause selective damage to invading organisms (such as the herpes virus), to excessively proliferating cells as in psoriasis) or to certain types of malignant cells. The activated photosensitizers appear to be capable of inactivating the DNA in the viruses or in the unwanted cells.

John G. Haddad, Jr., and Theodore J. Hahn of the Washington University School of Medicine, some 70 to 90 percent of the vitamin D activity in blood samples was found to be accountable to vitamin D, or its derivatives. The investigators concluded that sunlight was vastly more important than food as a source of vitamin D, (Although vitamin D was also found is fish, seafood is not an important source on most diets.

A direct study of the influence of light on the human body's ability to absorb calcium was undertaken a few years ago by Robert Neer. The study conducted among elderly, apparently normal men at the Chelsea Soldiers Home near Boston, suggests that a lack of adequate exposure to ultraviolet radiation during the long winter months significantly impairs the body's utilization of calcium, even when there is an adequate supply in the diet.

Perhaps 25,000 premature American infants were successfully treated with light last year as the sole therapy for neonatal jaundice. The rationale for this remarkable treatment is as follows: when red blood cells die, they release hemoglobin, which soon degrades into the yellow compound bilirubin. An increase in the concentration of bilirubin in the blood, due to excessive production of the compound or to failure of the liver to remove it, gives the skin its characteristic jaundiced color.

A potentially dangerous form of hyperbilirubinemia afflicts from 15 to 20 percent of premature infants because their liver is physiologically immature; in some cases the amounts of bilirubin

released into the bloodstream are also increased as a result of blood-type incompatibility or concurrent infections.

The treatment consists in exposing jaundiced infants to light for three or four days or until their liver is able to metabolize bilirubin. Although it was initially assumed that the light converted the bilirubin into nontoxic products that could be excreted, it now turns out that a major fraction of the excreted material is unchanged bilirubin itself. Hence it is at least conceivable that phototherapy has a direct beneficial effect on the liver and the kidneys.

There is strong presumptive evidence, however, that in most mammals light exerts its effects indirectly through photoreceptors in the eye. It is not known whether the photoreceptors are the same ones (the rods and the cones) that mediate vision, discharging into non-visual pathways, or whether they are a distinct family of photoreceptors with their own neural network.

We found that green light is the most potent in changing the phase of the temperature cycle and that ultraviolet and red wavelengths are the least potent. The action spectrum plotted from these results closely follow the absorption spectrum for rhodopsin, the photosensitive pigment in the rods of the retina.

The best-characterized indirect effect of light on any process other than vision probably the inhibition of melatonin synthesis by the pineal organ of mammals. Although melatonin seems to be the major pineal hormone, its precise role has not yet been established. When melatonin is administered experimentally, it has several effects on the brain: it induces sleep, modifies the electroencephalogram and raises the levels of serotonin, a neurotransmitter. In addition melatonin inhibits ovulation and modifies the secretion of other hormones from such organs as the pituitary, the gonads, and the adrenals, probably by acting on neuroendocrine control centers in the brain.

Experiments performed on rats and other small mammals during the past decade provide compelling evidence that the synthesis of melatonin is suppressed by nerve impulses that reach the pineal over pathways of the sympathetic nervous system. These impulses in turn vary inversely with the amount of visible light impinging on the retina. In rats the pineal function is depressed to half its maximum level when the animals are subjected to an amount of white light only slightly greater then that shed by the full moon on a clear night.

Antisynaptic neuronal system mediates the effects of light on the pineal. The pathway involved, which is apparently unique to mammals, differs from the route taken by the nerve impulses responsible for vision.

Light is potentially too useful an agency of human health not to be more effectively examined and exploited.