Radiant Energy

Physiologic effects on the living organism

L. A. Kanegis, fall '43

IT IS generally conceded that the study of radiant energy as such is a matter involving the work of the physicist. It is to their credit that the various forms of radiant energy have been explored, measured, and described. Of the new aids which physics has given workers in biology, probably the most important are the quantum theory of light, and the new implements, techniques of generating, manipulating and measuring radiations. Radiant energy of desired wave lengths and frequencies is now at the command of research workers in the field of biology and physiology who are engaged in the study of the effects of radiant energy on the living organism.

It is the purpose of this article to briefly present some of the work and results along this line of investigation.

The radiant energy range in which we are here interested can be divided into three portions, the infra-red (12,000–8,000 Å*), the visible (8,000–4,000Å), and the ultra-violet (4,000–2,000 Å). The longer waves of the spectrum such as radio waves and the shorter waves, the X rays, gamma rays and cosmic rays, will not be considered, although there is evidence to prove that they all play a part in biologic processes.

Skin Reaction

The skin reacts to radiations in a characteristic manner, the blood supply and the metabolism being increased. The reddening of the skin is a twofold process; the initial erythema is caused by the infra-red and long luminous rays. This hyperemia soon disappears and is followed in about an hour by an erythema due directly to the ultra-violet rays. If the radiation be intense, or if absorbed over an extended period, blistering and even hemorrhage may result. The skin usually peels and pigmentation is evidenced. The longest wave length that is capable of producing this type of erythema is approximately 3150 Angstroms.

Susceptibility Varies

Susceptibility to sunburn varies with groups and with individuals. Light skinned individuals are more sensitive than those of darker skins; the relative amount of cutaneous pigment being the important factor. It is interesting to note that seasonal variation is a factor in individual susceptibility. March-April and October-November are sensitive maxima according to Laurens[1].

The protection from these wave lengths in the dark skinned individual results from an increase in pigment formation and deposition, an increase in thickness in the skin, and an alteration of the cutaneous proteins, increasing their filtering properties.

The wave length of the rays determines the reaction produced. Wave lengths of from 3200 to 4800 Angstroms produce a marked deep red erythema. The longer wave lengths, that is the longer ultra-violet and shorter visible rays, produce a more intense tanning than do the shorter ultra-violet rays.

The characteristic skin reaction is due to the formation of substances in the skin which induces vascular dilatation. If the intensity of the radiations be great enough, actual inflammation results. These sub-

* One Angstrom = 0.1 millimicron.

stances are formed by the direct action of the radiant energy on the proteins present in the skin, converting them to toxic products probably of the histamine type. In many instances the presence of histamine itself has been shown following irradiation. Laurens[1] and associates have shown that carbon-arc irradiation definitely increases the histamine content of the blood.

It has been observed that natural sunlight hastens healing of wounds. This is accomplished by the whole spectrum and promotes disinfection, proliferation of granulation tissue, and an increase in blood supply. It appears that certain substances liberated by the cells which are injured by the radiations effect an acceleration of healing.

Injury to Eye

The sensitive structures of the eye are especially susceptible to injury by strong radiations. Wave lengths of from about 7600 to 3900 Angstroms penetrate to the retina and are perceived as light. Intense white light injures the retina by heat coagulation, the heat energy being derived from the absorption of long visible and infra-red radiations.

It has been observed that the blood picture is improved following irradiation. There is an increase in the number of erythrocytes, leucocytes, and blood platelets. A lower blood sugar level, higher calcium concentration, and an increase in the protein content of lymph have also been noted.

Laurens[1] states that the influence of solar radiation on increased resistance to disease is a matter of conjecture, and is still an unsettled problem. Blood pressure is usually lowered by exposure to sunlight or an artificial source of radiant energy. It has been recorded that in certain cases of hypertension, the systolic pressure has been lowered as much as 40 mm. of mercury. The explanation of this phenomenon rests on the liberation of histamine in the skin which causes a dilatation of the cutaneous blood vessels, thus reducing the general blood pressure. The dilatation is by both direct and reflex action. Increased capillary permeability is also a factor in this mechanism.

The ultra-violet radiations produce hyperemia of the superficial vessels, while the longer visible and the infra-red produce the condition in the deeper vessels. Therefore to the histamine action must be added the direct action or influence of heat energy itself, this being able to cause vascular dilatation in itself. It is to be added, however, that Laurens found a definite positive correlation between lowered blood pressure and histamine content of the blood. The fact that the lowest pressure resulted several days after exposure may indicate that the slow absorption of histamine was the retarding and vital factor. The effect on the heart rate was inconsistent.

It has been found that the metabolism of body proteins is increased by moderate irradiation. An increased uric acid content of the blood indicates an increased purine metabolism. The concentration of lipids may increase to 50 percent above its normal level. A very interesting observation is the lowering of the blood sugar due to an increase of glycogen formation and storage. This action is identical with that of insulin. It has also been suggested that androgenic substances are increased following ultra-violet irradiation. Repeated moderate irradiations are believed to decrease the metabolic rate for as long as three to four weeks following the last irradiation. Over-exposure, however, leads to deleterious effects, manifested by such symptoms as restlessness, anxiety, headache, and nausea.

Vitamin D Increased

An increase in the vitamin D content of the body following ultra-violet irradiation is well known. It is believed that radiations between 2967 and 3131 Angstroms in particular are effective in activating provitamin D in the skin to vitamin D. Vitamin D is necessary for proper calcium and phosphorus absorption from the intestines, and its subsequent metabolism in the body. Upon the proper calcium-phosphorus level and concentration ratio depend normal bone formation and growth, muscular tone and irritability, formation of teeth, and proper lactation.

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Nelson, '40, W. L. Munson, '42, and Ed Hanna, '42, are all stationed in Iowa with headquarters at Ft. Des Moines.

Lt. Leslie J. Moore, '42, is stationed at the New York Port of Embarkation where he is doing food inspection work.

Change of Address

Changes of address which have been reported are: Dr. Robert L. Alkire, '36, East Tenn. Packing Co., Knoxville, Tenn.

Dr. Albert A. Peters, '34, 10 S. Main St., Webb City, Mo.

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I.V.M.A.

Dr. P. V. Neuzil, '20, Blairstown, Iowa, retiring president of the Iowa Veterinary Medical Association, installed the officers for the current year, 1943, at the Des Moines meeting. The new officers are Dr. J. A. Barger, Des Moines, president; Dr. V. B. Vanderloo, '21, Dubuque, vice-president; and Dr. C. C. Franks, '11, re-elected secretary and treasurer. Dr. George A. Hawthorne, Clarinda, Iowa, was elected president-elect for 1944.

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It is held that the provitamin D of the skin is 7-dehydrocholesterol. There have been some cases reported in which a hypervitaminosis D existed, characterized by decomposition of calcium salts in the various tissues.

Undesirable Effects

The effects discussed thus far have concerned mainly the beneficial manifestations of radiant energy. There are, however, certain very undesirable effects which are produced when certain substances combine with the radiations in such a manner as to produce unfavorable conditions within the tissues. This phenomenon is referred to as photo-sensitization or photo-dynamic action. There are many dyes and pigments capable of sensitizing cells to the deleterious effects of radiant energy. Certain plants are known to contain such substances, and when these plants are consumed by animals, extensive skin inflammation, loss of hair or wool, and cutaneous necrosis often result after exposure to sunlight. The action appears to be that of an unwarranted direct molecular oxidation in the cells which results in injury and death to the cells. The sensitizing substances have the ability when irradiated to absorb molecular oxygen and transfer it directly to the cell. This molecular oxidation under photo-chemical influence is the actual cause of the trouble, rather than the direct effect of the radiation on the cells. Under normal cell conditions this oxidation would not take place at body temperature. Physiologic oxidations are entirely independent of this phenomenon and occur as dehydrogenations rather than direct molecular oxidations in most cases.

The absorbing of a quantum of radiation by the sensitizer is the initial process which sets the photodynamic action in motion. It must be emphasized that the photo-dynamic action proceeds only in the presence of molecular oxygen. It is important that this injurious effect of photo-dynamic action be distinguished

from the injurious effects of too intense ultra-violet radiations. The former is dependent on molecular oxygen, the latter is not.

It has been found that a malignant skin condition could be induced in laboratory animals by exposure to light. Skin cancer in humans has been suggested following irradiation. It is possible that a positive correlation exists between photo-sensitization and the production of malignancy. Some of the carcinogenic substances are active photo-sensitizers.

Bacteria Killed

Practically all bacteria may be killed or rendered less virulent by ultra-violet irradiation. The strict pathogens which have adapted themselves to living within the body of their hosts are most susceptible. Those living free in nature, being more exposed to radiations, have developed degrees of resistance to them. Direct solar radiation is a potent germicide for almost all bacteria except some of the sulfur bacteria which utilize the sun's rays in their metabolic processes. The maximum germicidal effect seems to be between 2600 and 2700 Angstroms. It is believed that the resistance of irradiated bacteria to heat is much lowered. Bacterial toxins are likewise photo-labile, while antitoxins are relatively photostable. In order to attenuate the virus of tobacco mosaic, wave lengths shorter than 3100 Angstroms are necessary. The resistance ratio of virus to bacteria is 200 to 1. It has been shown that virus vaccines prepared by attenuation with ultra-violet irradiation possess greater immunological properties than those attenuated by heat.

Sterilizing Air

The possibility of sterilizing the air of hospital wards and operating rooms by means of radiations has been investigated. In hospitals over 90 percent of wound infections are caused by staphylococci. In cases where ultra-violet light has been used, the incidence of post-operative wound infection has decreased as much as 85 percent. Denaturation of the protein molecule by ultra-violet rays is considered by some to be the fundamental mechanism responsible for the various physiologic effects of such radiations. The liberation of histamine or histamine-like substances is a similar mechanism whereby ultra-violet causes many complex changes.

Other Ions

In addition to radiation, ions similar to the alpha and beta particles from radium are always darting through the air. These ions are fragments of atoms smashed by the impact of colliding high frequency quanta of radiant energy or with other ions.

According to Gray[5], "It is known that when electrons of high velocity are absorbed in matter, the effect is to release a large number of secondary ions within a very small space. The impact of the speeding particle sets off a veritable explosion, smashing out parts of atoms, each of which recoils at a high velocity to wreak havoc wherever it strikes and in a frenzy of chaotic movements causes destruction of the peculiar organization of protoplasm." In irradiated tissues molecules are ionized or activated. This leads to colloidal changes, increased viscosity, changes in solubility and coagulation.

More Problems

Some of the questions in the field of radiant energy have been answered but there are still many problems to be solved, especially regarding the mechanism of operation. Much work is being done by physicists and physiologists along this line and slowly but resolutely the physical forces affecting life are being explored and unveiled.

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