A DISCUSSION OF CERTAIN FUNDAMENTAL PRINCIPLES INVOLVED IN HELIOTHERAPY

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Heliotherapy is an attempt to apply the radiant energy of the sun to the treatment of disease. As in all therapeutic procedures, technique and dosage are extremely important. In order to use the sun's rays intelligently, one should know those factors which increase or decrease the amount of solar energy available for therapeutic purposes. It is equally important to know the effect of the energy upon the physiological reaction of the patient. Anything that will give information along these lines will help to place heliotherapy upon a sane and sound basis. In this paper it is my desire to discuss some of these problems.

SOURCES AND FINAL DISTRIBUTION OF SOLAR RADIATIONS

The sun, directly and indirectly, is the source of most of the energy existent in our world. It has been estimated that the centre of the sun sustains a temperature of 9,000°F. The sun is influenced by gravitational forces the same as the earth. Its atmosphere also is subject to many changes. Some of the important phenomena which have been carefully studied in their relationships to the radiant energy of the sun are sun-spots, the solar constant, electrical and magnetic disturbances, and various currents and storms which seem to correspond to winds and cyclones in the terrestrial atmosphere. These phenomena produce variations in the amount of radiation emitted from the sun and cause changes in the earth's atmosphere, which, in turn, influence the passage of radiant energy to the earth's surface.

The energy emitted by the sun follows certain cycles. At times, when increased energy is put forth, volumes of gas are projected into space for great distances,—thousands of miles. Scientists consider that of all the disturbances in the sun's atmosphere, the study of sun-spots is most helpful because longer and more accurate records have been kept of these than of other phenomena. The solar constant, which is a measure of that portion of solar energy which reaches the earth and is converted into heat, is also a subject of importance for study, but available records extend over only a few years, too few for basing conclusions.

There has been much speculation as to the cause of sun-spots and also as to the regularity of their cycles. It may seem strange to those of us who have learned to think of the sun as the centre of, and the greatest force in the universe, the master of everything, to know that there is much evidence to show that its disturbances in energy are due to influences exerted upon it by other heavenly bodies, particularly the planets.

The period from one time of sun-spot maxima and minima to the next represents a cycle of about eleven or twelve years, with other cycles, not so exact, of shorter and longer duration. It is suggestive that Jupiter requires about this same major period of time (11.87 years) for making a revolution around the sun; and, further, that the sun-spot maxima are related to the time that Jupiter is at perhelion. Other planets exhibit a smaller influence as follows: taking the earth as 1, Jupiter is 35.5, Saturn 3.2, and Mercury 2.5. An appreciable maximum effect on the sun's mass is exerted by each planet when in conjunction with Jupiter, and a minimum effect when in opposition. Then there are numerous combinations of influences of all, as may be imagined. The effect of these planets on the sun's mass is similar to that of the moon on the earth in producing ocean tides; but, in the case of the sun, the disturbance manifests itself in the form of huge masses of energy being projected out into space instead of as oceanic tides.

Inasmuch as our changes of climate and weather depend very much upon changes in solar energy, and inasmuch as changes in solar energy depend upon forces exerted upon the sun by the various planets, we can see how the entire solar system is linked together in the production of atmospheric disturbances of the earth. The most important terrestrial atmospheric disturbances are changes in temperature, pressure, electrical and magnetic force, and wind and storms.

The effect of sun-spots upon climate and weather, and the effects of the sun's radiant and electrical energy upon the human being are just now beginning to be appreciated. While there are many terrestrial factors to be taken into account, variability in the sun's energy is the most important cause of our daily and weekly weather changes.

Since sun-spots are due to the ejection out into space of large bodies of gas, heated to high temperatures, one would think that times of maximum sun-spots would be times of high temperature on the surface of the earth, Such would be the case were it not for the fact that, when gas is ejected out into space in great volumes, tremendous terrestrial disturbances follow. Cyclonic storms of great severity occur in various parts of the earth, and the air movements connected with them protect the earth's atmosphere from the effects of the increased heat.

The proper conception then is that the sun is a varying source of radiant energy, one from which now more and now less energy is emitted, the amount changing from day to day and also over longer periods of time. Among conditions which affect radiant energy are latitude; altitude; the condition of both the upper and lower atmosphere; the content of the earth's atmosphere in water-vapor, dust and smoke; wind movement; storminess; and the altitude of the sun in the sky.

Solar radiations consist of waves of many different lengths, each differing from the other in the degree with which it is transmitted to the earth and in its action on things upon the earth. Rays between 4.000 and 8,000 Ångstrom units make up the visible spectrum. The long waves are heat-rays, and the short ones are chemical rays. The shortest visible ray is 4,000 units, and there are many beyond which are shorter, some approaching zero units in length; so are there many longer than 8,000 units. Most of those which are shorter than the shortest visible rays are screened out by the ozone in the upper atmosphere and do not reach the earth. Helland, Hansen and Nansen estimate that 40 per cent of the sun's total emitted energy is lost by reflection, 40 per cent is absorbed in the upper air, and 20 per cent reaches the earth. This 20 per cent is made up mostly of waves longer than the ultraviolet, for the shortest wave reaching the earth from the sun is 2,900 units.

The radiant energy absorbed in the upper atmosphere exerts an important effect upon the temperature, electrical reactions, atmospheric pressure, wind movement and storminess of the earth.

The following measurement of radiation, just below the shortest visible rays taken at the Mt. Wilson Laboratory at an altitude of about 6,000 feet, illustrates the difference in the transmission of rays according to the position of the sun in the heavens. The relative number of radiations of different lengths when the sun is at its zenith and at 75° altitude shows how the short rays are screened out in passing through greater depths of atmosphere, as they do when the sun is low in the heavens.

		LENGTH OF RAYS IN ÅNGSTROM UNITS					
		3,000	3,200	3,400	3,600	3,800	4,000
Relative amount of rays when	Sun at zenith	25	58	135	192	239	302
	and						
	Sun at 75°	2	8	26	49	74	117

While the short rays are screened out by the ozone of the upper atmosphere, they readily pass through water and hence are not influenced so much by the water-vapor of the air. They are absorbed, however, by the smoke and dust of the atmosphere. The long rays, on the other hand, are not influenced so much by the ozone of the upper atmosphere, but are absorbed by the water, smoke and dust found in the lower atmosphere. Therefore, the amount of radiant energy which reaches the earth varies greatly in different places, and increases or decreases the desirability of the place for residence as well as from the standpoint of health and comfort.

SOLAR RADIATIONS AND PLANT LIFE

One of the most interesting experiments showing the value of light to the animate world was performed by the late Benjamin Moore in conjunction with Webster. They exposed carbon dioxide in water, in the presence of uranic and ferric hydroxides, to sunlight, and produced formaldehyde. Formaldehyde being a forerunner of sugar, this work proved experimentally that the organic can be made from the inorganic.

This experiment affords a peep into the laboratory of the plant, as it is played upon by sunlight, and explains the production of carbohydrates. In the presence of the chlorophyl and its pigments which are found in the cells of plants, light acts upon carbon dioxide in the presence of water, and produces starches and sugars. This light-energy is converted into chemical energy, and is stored in the plant to become the great source of food for animal life.

Sugars are built up by the action of sunlight, and fats are elaborated from sugars, but protein must be produced from nitrogen. Moore showed that nitrates in dilute solution will absorb light-energy and be changed to nitrites, and that the cells of green plants can absorb these nitrites and build up nitrogenous substances. Nitrites are deposited upon the leaves of plants as rain and dew, whence they are absorbed under the stimulation of light.

Sunlight is necessary to the plant's metabolism. Neither sugar, fats nor proteins can be synthesized by the cells without it. With light and the chlorophyl acting as catalyst, the bulk of the energy of the animate world is produced and stored in the plant kingdom; but even without chlorophyl a certain degree of synthesis will go on with the production of oxygen. The chlorophyl itself is synthesized by sunlight acting upon iron salts found in the chloroplast of the plant.

Chlorophyl contains magnesium, without which it would be powerless to store or transform energy, the same as hemoglobin would be without iron. Both are powerless without sunlight. Whereas through the action of sunlight upon colloidal iron in the chloroplast, chlorophyl is built up from inorganic compounds, and through the action of sunlight upon chlorophyl, starches, sugars, fats and proteins are synthesized with the setting free of oxygen, hemoglobin acted upon by sunlight causes the breaking down of the food which the plant has synthesized, and thus liberates the energy necessary to animate life and action, with a setting free of carbon dioxide.

SOLAR RADIATION AND ANIMAL LIFE

In a discussion of the action of light upon the body there are certain basic facts which claim first consideration. Man must be considered as a mass of cells, orderly arranged and depending upon impulses received from various sources for their activity. These cells represent different and changing colloidal systems, which respond to stimulation by taking up or giving off important ions during the course of their activity. There are two sources of radiant energy in the world: first, the sun, and, second, the radiant energy that is given off from radioactive substances. Stimuli, however, are of many kinds, such as sound, light, heat, odor, taste and touch, each of which is received and transmitted to the body through sensory receptors. Food has been created by the sun's energy and stored in plants, after which it has been eaten by animals and again stored in their bodies. In this manner all food which is consumed by man goes back to sunlight. The ability of the body-cells to utilize the food also depends upon the sun's energy.

Before one can understand the action of radiant energy upon the body, he must grasp the fundamental principle that body-cells are receptors and transformers of energy. There can be no action without absorption of energy; furthermore, there can be no action unless the absorbed energy is transformed into energy that is suited to the activity of the particular tissue. Radiant energy probably acts in two ways: first, upon the sensory nervous system which thickly studs the surface of the body; and, second, upon the blood and tissues themselves, which absorb radiant energy and transform it into substances suited to the requirements of the cells themselves.

Not only does man have receptors throughout the body which pick up stimuli, and cells which act as transformers, but he also is obliged to unify and correlate or integrate all action. The integrative systems, which mould the bodily organism into a whole, are the nervous and the chemical. These two systems distribute energy in such a manner as to keep the whole physiological organism working harmoniously.

There seems to be a close relationship between the sun's energy and calcium metabolism. Just what this is, we are unable to state definitely. We know that in summer months, when the sun's energy is greatest, the blood-calcium is increased. The meaning of this, however, is not clear. It may not be due alone to the greater activity of the sun's rays, but may only accompany it. It may be due to the necessity of the retarding influence of calcium upon cellular activity during the warmer season, when the demands upon the metabolic activity are not so great. This, however, will require further observation to determine.

We know clinically that the sun's rays will aid in the prevention and cure of rickets. It is thought that the influencing of calcium metabolism is an important factor in the result obtained. We also know that sunlight will aid pregnant women in maintaining a normal level of calcium metabolism. The effect of sunlight on the tuberculosis patient is also associated with a rise in blood calcium.

Experience shows that either solar radiation or radiation by ultraviolet rays from artificial lamps will have the desired therapeutic effect. This is particularly interesting because we are prone to consider the ultraviolet as the essential rays in the therapy of these maladies. Experiment shows that very few ultraviolet rays reach the earth, yet solar radiation is effective. It must be that we are too narrow in our view, and that our bodies are able to obtain from light, whether it be the radiant energy of the sun or the radiant energy of ultraviolet lamps, those substances which are essential to maintaining a normal calcium metabolism, or to the restoration of it when disturbed.

PHYSIOLOGICAL AND THERAPEUTIC ACTION OF RADIANT ENERGY

Body-cells react differently to radiations of different wave-lengths. The reaction also differs according to the amount or dosage of radiation, no matter what the quality of the ray. It is essential in discussing sun-treatment not to assume that it is either good or bad, beneficial or harmful, but to assume that each individual may have sun-treatment according to his own powers of utilizing light and still maintaining or improving his physiological balance.

Sunlight, direct and indirect, differs greatly in its content of radiant energy under different conditions, some of which have been enumerated herein. Even reflection from the clouds and from the sky carries with it large quantities of solar energy, which produce very important effects upon the physiological mechanisms of the body, and which can also be utilized in the treatment of the sick. Light which passes through ordinary glass loses by absorption much of its shorter rays. So light in houses, passing through closed windows, is deficient in its power to promote well-balanced physiological activity. No doubt, that light which is unobstructed by glass windows is responsible for some of the good effects produced by an open-air life. There has been too much of a tendency to think of solar energy as a force which, in some mysterious way, produces a direct antibacterial effect, and which destroys germs and cures infections; but such is not the case. In the world at large, sunlight is our great destroyer of bacteria, and even in the animal body, if we count the effects of its indirect action, we must give it first place. But, according to our knowledge, we cannot claim much for radiant solar energy as a direct disinfectant of body-tissues, for the penetrating power of the short rays which reach the earth and which are known to possess strongest antibacterial effects, is very slight. Finsen showed that ultraviolet light penetrates the skin only a fraction of a millimetre, and in order to treat lupus successfully he found it necessary to press the blood out of the tissues by some material which was transparent to the rays. This does not mean, however, that ordinary sunlight cannot aid man in making his body a vigorous physical machine or in restoring it, if weakened, to a state of vigor so that his natural defensive forces will be able to overcome infections. It has been shown that the infrared rays have bactericidal qualities, and it seems quite probable that the body-cells may utilize light of all wave-lengths in its indirect antibacterial action.

Aside from the effect of radiant energy acting through the sensory nerve fibres found upon the body-surface, it alters the oxygen tension of hemoglobin which absorbs it, and in this manner influences the activity of body-cells. It has been shown that oxyhemoglobin parts with its oxygen more readily in the light than in the dark; the heat rays most likely take a very important part in this action. The temperature of the part exposed to direct sunlight may be raised several degrees; and it is well known that both chemical and biological reactions are hastened by moderate increases in temperature. Hemoglobin, aside from the rays of the visible spectrum, readily absorbs infrared and ultraviolet radiations, the latter from between 4,000 and 2,900 from the sun and down to 1,850 from the quartz light.

The radiant energy from the sun is the most natural and probably the most important of all stimulants to the physiological activity of the body. It is the duty of physicists in conjunction with physiologists to determine the action upon the organism of various forms of radiant energy found in light. We assume that all wave-lengths, from the longest down to the shortest chemical rays, are of value, but that their action differs according to the particular properties of the waves. It is certain, however, that man has adapted himself to the light to which he is accustomed, so that he is able to maintain perfect physiological equilibrium no matter where he lives. This holds for the tropics, the temperate zones, and the polar regions; for the lowlands, the plains and the mountains; for areas of desert dryness, as well as for areas of rain and abundant moisture. Man is also able to change from one condition to another, and adapt himself to the radiant energy content of the atmosphere of the new habitation.

All solar radiations to which the physiological mechanism has adapted itself are useful in maintaining normal health, and valuable in restoring it when injured by disease. This fact is not sufficiently taken into consideration in the discussion of heliotherapy. I believe we are focusing our attention too much upon ultraviolet radiation to the detriment of the patient. Physicists tell us that few ultraviolet rays reach the earth in the regions most thickly populated, yet no one can doubt the beneficial influence upon the health of people which results from exposure of the bare body to sunlight.

If we accept the symptom complex shown by a patient in the presence of a given disease as *the manner in which his physiological mechanism is able to function in spite of the disease*, we then will be able to apply therapeutic measures such as heliotherapy more understandingly. We will see that they are valuable to the extent that they will aid the body to carry on its functions in a manner as near to normal as possible.

Heliotherapy must not be confused with the therapeutic employment of ultraviolet light. Sunlight, direct or indirect, can be utilized advantageously in the treatment of many diseases. Patients, who for any reason should not be exposed to the direct rays of the sun, frequently can be advantageously exposed to the indirect rays as found in diffuse light. Diffuse light does not contain as many rays as direct sunlight, but it does contain rays which are of value to the body in carrying out its many functions.

Indirect sunlight can be applied advantageously to those patients suffering from active tuberculosis who are not suited to treatment by direct solar radiation. Bare arms, bare chest, or very thin clothing are valuable in that they expose the patient to larger doses of radiant energy.

Ultraviolet rays have a special action. While they are not found in large quantities in the earth's atmosphere, yet they have been shown to be very desirable for certain effects which are often sought. Fortunately, they can be generated artificially by certain lamps and used therapeutically. They are taking a permanent place in the therapy of tuberculosis and also in the treatment of other conditions.

In the investigation of this subject the following works will be found helpful:

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