EFFECTS OF LIGHT, SUN, AND OTHER RAYS ON GROWTH*

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(Assisted by Margaret Schott)

Glasser: For thousands of years the sun with its light and heat has commanded the attention and worship of mankind. Primitive man knew that there are great healing powers in the mighty rays of the sun. In the early civilizations the sun-god, Ra, of the ancient Egyptians, and Apollo, of the Greeks and Romans, was acknowledged to be one of the principal deities. The mythological beliefs which ascribed to the sun-god power over vegetation, growth and development, healing of sickness, life and death, have been well substantiated by modern science. Indeed, the ancients were conservative in their viewpoint. They might have been astounded could they have foreseen the almost fantastic discoveries of recent years.

Although it is an everyday experience to observe the importance of the sun's radiation to living things, I imagine that few of us suspect how closely our lives are linked with sunshine. On an overcast summer day, when the world seems unusually quiet, what wonders a sudden burst of sunshine will do to Nature, producing life and activity everywhere. As we shall see, everything in man's life depends upon the sun.

Perhaps the most fascinating mystery of the universe is the origin of physical life upon the earth. Protoplasm, the stuff out of which our bodies and those of every living thing are made, contains water, carbon, nitrogen, and other chemical elements. Although we do not know what vital spark transformed these lifeless chemicals into the first protoplasm, it is highly improbable that this mysterious and important substance could ever have been formed, not to mention being maintained, without the aid of light and heat. For we know that the sun's radiation provides energy for the conversion of inanimate matter into the complex machinery of the living organism.

Our interest is not confined to the sun's radiations, however, for these are actually only a small part of the different types of rays which are known to us, or, as the scientist may say, a small part of the total spectrum of electromagnetic waves. Now, may I ask before I go on, whether you are familiar with the term "spectrum," and with the term "electromagnetic wave," Miss Schott?

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Schott: Well, yes and no, but I should appreciate your explaining what you mean by the phrase spectrum of electromagnetic waves.

Glasser: That is not at all a difficult matter, Miss Schott, if you will recall that x-rays, ultraviolet light, and radio waves are all quite similar to the rays of ordinary sunlight, and travel through space at the same enormously high speed as sunlight—indeed so fast, as you know, that they will pass almost eight times around the earth in one second! Now, some radiations can be seen by the eye, whereas others cannot. Take this diagram, for example, which represents the entire electromagnetic spectrum we are talking about, and you will see that the word spectrum merely refers to the whole set or band of these radiations, some visible, and others, in fact many more, not visible at all.

Schott: Why, yes, here in the center of the diagram are the seven colors of the rainbow! Red, orange, yellow, green, blue, indigo, and violet! They are all here.

Glasser: And those seven colors are the only radiations the human eye can see. You see them in the rainbow, on the surface of an oil puddle in the pavement, or when light strikes highly polished cut glass.

Schott: Oh, certainly! You know, one of my favorite sports as a small child was blowing soap bubbles and admiring their mysterious colorations. Are these iridescent reflections of light related to the visible spectrum?

Glasser: Yes, they are. The white light that comes from the sun is actually composed of the seven colors you see in the center of this diagram. Sunlight is broken up into its component hues by the droplets of water in the clouds, in the films of oil, in the glass prisms, and in your soap bubble.

Schott: Then the rainbow with its series of seven different colors constitutes the visible part of the whole spectrum?

Glasser: Exactly. The rainbow, as this diagram shows, is only a small part of the entire electromagnetic spectrum. The invisible spectrum, containing the rays our eyes cannot see, is really very much greater than the visible part, and extends on the diagram, on either side of the visible rainbow part in the center. That is, some radiations have a longer wavelength, some have a shorter wavelength, than visible light.

Schott: Just what do you mean by wavelength?

Glasser: Have you ever thrown a stone into the water and watched the little waves move away in all directions? The distance from the peak of one wave to the peak of the next wave is what we call the wavelength. All electromagnetic waves, such as light, travel through space in much the same fashion that waves pass over the water; in some types of radiation the distance between waves is short, in others long; hence, we measure different kinds of radiation by their wavelengths.

Schott: Is this what we mean when we speak of ether waves in connection with radio communication, and of Station WGAR, one of the many stations in the Blue Network over which we are now speaking, as operating on a wavelength of 206 meters?

Glasser: Yes, Miss Schott. The wavelengths used in broadcasting are millions of times as long as those of visible light, and as you know we cannot see them striking the aerial wires of our radio sets.

Schott: Now, I understand, but there are two invisible parts represented in the diagram here, one on either side of the rainbow. Which of these contains the radio waves?

Glasser: Since the radio waves are longer than red light, they appear in the diagram farther and farther out to the right as they become longer. As we get in closer to the red we meet the infra-red waves which produce heat; you can feel them, but you cannot see them when you stand before a heated oven or furnace.

Schott: Don't you also feel them in front of an open fireplace?

Glasser: Yes, of course.

Schott: Ah, but you just told us they are invisible.

Glasser: Those rays you see in the glow of the burning embers are not the infra-red or heat rays, but rather the actual red rays; the heat rays which you cannot see, but which you feel as warmth, are simply produced by the fire at the same time.

Schott: That's quite clear now. What about this other invisible part of the spectrum extending to the left of the violet and blue end of the rainbow? Would these rays then be the cold rays?

Glasser: Those nearest and to the left of the visible violet are the invisible ultraviolet rays. They could be called cold rays only in the sense that the heat they produce is too small to be detected except with sensitive laboratory instruments. But they do have very pronounced chemical and biological effects.

Schott: Are they the rays which tan the skin?

Glasser: Yes, they are. Farther out to the left of them, with continuously decreasing wavelength, you find the x-rays, and beyond them the gamma rays.

Schott: I think I know something about x-rays but I'm not so sure about the gamma rays.

Glasser: Gamma rays come from radium. They are one of the three kinds of rays which are continuously generated by the explosion of the tiny radium atoms; they are so powerful that they can penetrate steel bars several inches thick.

Schott: They must be similar to x-rays, then.

Glasser: Yes, they are. On the other hand they are also similar to the cosmic rays, the last group here at the left, the very shortest waves we know today.

Schott: Are these the cosmic rays of which we read in the papers, especially in connection with stratosphere balloon flights?

Glasser: Yes, Miss Schott. The cosmic rays, as the name implies, arise in the starry spaces of the heavens and, for many reasons, are the subject of a great deal of scientific investigation today, but primarily perhaps because the earth and its people are being continuously bombarded by them.

Schott: Well then, Dr. Glasser, you have now described all the different electromagnetic radiations we know today. These range, as I can see from this diagram, from the shortest invisible cosmic waves here on the left, up through the continuously longer gamma rays, x-rays and ultraviolet rays, to the visible spectrum with its rainbow colors. Then, beyond to the right, the much longer infra-red heat waves, ending with the longest of all, the electrical radio waves. Do all these originate in the sun?

Glasser: No, indeed. The earth receives from the sun and diffuse skylight only heat, light, and ultraviolet waves. But man has succeeded in imitating the sun by producing heat and light artificially with oil lamps, torches, candles, and in recent years with electric lamps. Man has also learned how to produce ultraviolet rays by means of special kinds of lamps. But beyond that, man has even produced rays that are not contained in sunlight, such as x-rays, and radio waves.

Schott: This is interesting, but do all these radiations play an important rôle in our lives, especially with reference to growth?

Glasser: Most, if not all, of these radiations are of fundamental significance in our lives, our development, and our growth. Indeed, as I mentioned previously, it is certain that we owe our very existence to the heat and light of the sun, for these make our climates favorable to the continuation of all plant and animal life.

Schott: But I thought, from what Drs. McCollum and Weech told us a few weeks ago, that our energy was derived primarily from the sugars, starches, fats, and proteins in the food we consume.

Glasser: The immediate source of our energy is, as you say, food. But that energy was originally stored in green plants and vegetables, which themselves received part of their energy from the sun. As you know, spinach, lettuce, and other green leaves are little factories which take raw materials from the soil and from the air and manufacture the complex substances used as food for animals and men. But this happens only when the plants are properly exposed to the sun. The method by which plants can store food energy is something that man has as yet been unable to imitate, and therein lies one of the most important questions confronting modern science. Consider, for example, what the use of wood for fires, in building homes, the use of coal and petroleum deposits as fuel, of cotton for clothing, the cheap manufacture of paper, have meant in the marvelous unfolding of civilization as well as in the development of the race, and that all these can be traced to sunlight.

Schott: In spite of our pride in human achievement, it seems that we are dependent ultimately on the sun's radiation not only for our nourishment, but for clothing, shelter, fuel—all the things which make progress possible. Now, if sunlight is not available, does plant growth cease altogether or can some other source of energy be utilized?

Glasser: With all our ingenuity we shall never be able entirely to do without the sun. It is possible, however, to supplement the sun with other kinds of energy. In recent years it has been found that when the supply of sunlight is insufficient, as in greenhouses in the winter, artificial light can be used as an excellent substitute for sunlight. Tomato seedlings, for instance, can be speeded up in growth before outdoor planting. Curiously enough, the different portions of the sun-spectrum are not of equal value to the plant. The green coloring matter contained in the leaves does not take up all the light it receives; it takes up only certain kinds of light, for instance, red-orange may be used for building up sugars and starches, while shorter rays in the violet range are needed to form proteins. Some radiations are actually injurious and could, if properly employed, eliminate weeds and plant parasites, thus aiding desired plant growth.

Schott: Do I understand correctly that the biological effect of any kind of light is merely a matter of its color—that is, of its wavelength?

Glasser: It is necessary to keep in mind the distinction between quality—that is, the wavelength—and quantity of radiation. It is a general rule that those wavelengths which are needed have to be absorbed in order that their energy may be utilized. The green leaf retains the red-orange light which stimulates growth and chemical processes while permitting the useless rays to pass through. An insufficient amount of radiation of any wavelength will be ineffective. On the other hand, too much of a beneficial radiation can do a great deal of harm. I do not need to tell you that although a moderate amount of ultraviolet light is healthful, too much exposure results in painful and sometimes serious consequences.

Schott: Is sun-bathing actually as beneficial as many of us believe, especially for children?

Glasser: All the benefits to be derived from sunlight are not yet known. It is, however, well known that ultraviolet light is essential to healthy development because it stimulates the formation of the sunshine vitamin D, which prevents rickets and helps to regulate not only the growth of bones and teeth, but the growth of the entire body as well. Ultraviolet light acts by producing a chemical change in the substance, ergosterol, converting it into vitamin D, which, as you know, in exceedingly small quantity is equivalent in its effectiveness to enormous doses, even quarts, of cod liver oil.

Schott: Does the ultraviolet light penetrate deeply into the body in order to produce its effect on bones and teeth?

Glasser: No, ultraviolet light and visible light are absorbed at the surface by the skin. It is here that the production of vitamin D from ergosterol contained in the glands of the skin occurs. But it has been observed that ultraviolet light absorbed in the skin has also an effect upon deeper seated organs; for example, in healing certain forms of tuberculosis. There are other close connections between ultraviolet light and growth. You are familiar, for instance, with the fact that certain animals can give off visible light?

Schott: You mean the fireflies and the tiny animals which produce the phosphorescence of sea-water when you disturb them?

Glasser: Exactly. Now, whereas all animals give off heat as a byproduct of their activity, some give out light in addition. It is not startling therefore, to learn that scientists today are investigating the possibility that ultraviolet light might be produced by the work of body cells. This radiation may in turn stimulate other cells to reproduce themselves, thus aiding or hastening the process of growth.

Schott: But has such a radiation actually been observed?

Glasser: With sensitive devices, such as those used for capturing cosmic rays, it has been claimed that an ultraviolet radiation can be observed from active muscles, for example. In time, as the methods are improved, it may be possible to detect a difference in radiation between healthy and diseased tissues or bodies. The widespread usefulness of such a method to medical science can be easily imagined, but it has not, as yet, passed beyond the stage of laboratory experimentation.

Schott: From what you have said, I should conclude that sunlight is essential as the source of energy required for vital processes, and that ultraviolet light is extremely important in determining healthy growth. Are there other forms of radiation which are beneficial?

Glasser: Thus far I have told you only of the obviously beneficial effects, but there are other short wave radiations which, although harmful, can be used to promote normal growth. This seemingly paradoxical action is found in x-rays and the gamma rays of radium. The effect which these radiations have in depressing growth and even destroying tissues provides the physician with a powerful method for controlling unwanted or abnormal growths or other factors which may suppress growth, thus permitting the normal growth processes to continue unhindered. Of course, it is necessary to exercise great caution in administering x-rays and radium in order to protect the healthy tissues.

Schott: Are any of these radiations injurious enough to kill—in other words, death rays?

Glasser: Yes, indeed. X-rays and gamma rays will prevent the fertilized eggs of insects, such as the common fruit fly, from hatching. In high doses these rays may cause the death of an animal. Oscillations just shorter in wavelength than those used in broadcasting produce sufficient heat to kill small animals. Short ultraviolet has been shown to destroy bacteria and other harmful microbes. At the present time there is little likelihood that death rays can be projected far enough to be used as a weapon against anything as large as man. On the contrary, when judiciously applied, they can be used to our advantage. The heating effect of short wave oscillations is useful in combating certain diseases by inducing artificial fever in the patient. The killing action of short ultraviolet rays can be used in many ways; for example, to sterilize water for drinking purposes or in indoor swimming pools; in hospital operating rooms, or by the dentist to prevent infection and to promote healing of wounds; and commercially, to protect foods against mold formation.

Schott: Then even the death rays can be employed as aids to healthy growth. Are there any other ways besides those of which we have already spoken in which radiations, the powerful x-rays or gamma rays, for example, affect growth processes?

Glasser: Your question leads us to a highly interesting effect which x-rays and gamma rays have upon the development of the embryo. Several weeks ago Dr. Hersh spoke of the mechanism of inheritance, of the action of genes, those minute bead-like objects contained in the cells of the body, which we inherit from our parents.

Schott: By genes you refer to the immeasurably small units which determine, for example, whether or not a baby is to have brown eyes?

Glasser: That is correct. Any given gene, as he pointed out, always possesses the same properties, so that the only uncertainty in heredity is caused by not knowing how the genes will be shuffled, and what combination will appear in the fertilized egg. Once the genes have been finally sorted, the end-result, if development be left to itself, has been unalterably determined. It is possible, however, to cause a change in the structure or composition of a gene with the x-ray, so that subsequently its effect upon development will not be the same. For example, in the common fruit fly, the offspring may have white instead of red eyes, or forked bristles in place of ordinary ones. Even ultraviolet light has been found to have similar action in altering leaf or flower arrangement in the snapdragon.

Schott: In other words, it is possible artificially to imitate Nature's process of evolution?

Glasser: Only in a limited sense. The long, slow process of evolution is undoubtedly not as simple as that. The chief radiations of short wavelength to which organisms are subjected in Nature are the cosmic rays. Now, although the number of cosmic rays which strike the body are few, the shower of cosmic radiation from the heavens is continuous, so that it is not impossible that in the course of years they might exert some effect. Indeed, it has recently been shown in experiments in which fungi were grown under lead shields of different thicknesses that the secondary radiations produced in the lead by the cosmic shower brought about changes in developmental growth pattern.

Schott: Since the various types of radiation have such important effects upon the welfare of an organism, is there any provision made by Nature to enable the organism to respond to radiations according to their desirability or harmfulness?

Glasser: Yes, there is such a mechanism. If you have ever gone fishing, you may have spent the evening before in capturing live earthworms with the aid of a flashlight. Worms and many other kinds of animals respond positively or negatively to light, that is, they move into it, or away from it. It is unnecessary to tell you that insects are attracted by light. It is possible to set up traps for insect pests in the garden and entice them into the traps at night with a lighted lamp.

Schott: I never before imagined that light and other radiations could have such a profound influence on our lives, or be put to so many uses. Would you be good enough, Dr. Glasser, to summarize briefly the important features of all you have told us?

Glasser: There are really four main effects which radiations have on growth and development. First, the stimulative effect of sunlight and heat upon plant life, because this provides the energy for the complex biochemical manufacture of food. Second, the beneficial effect of ultraviolet light in preventing rickets and regulating bone, tooth, and body growth. Third, the indirect benefits to normal, healthy growth derived from the action of x-rays, gamma rays, and death rays in destroying unhealthy growths and invading bacteria and microorganisms. Last, the alteration of inherited characteristics among certain organisms by the action of x-rays and gamma rays on their genes.