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CROOKES'S "X" AND OTHER LIGHT RAYS.

A PROBLEM YET TO BE SOLVED IN THERAPEUTICS, ETC.

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This communication is the forerunner of a series of experiments now under way to determine the further effects of all light rays on animal and vegetable life, the outcome of which as yet is not settled.

The whole civilized world is at present engaged in the task of solving the problem of the penetrative power of the cathode rays. That these rays do force their way through opaque bodies that ordinarily arrest the transit of sunlight has been demonstrated, and the questions to be solved are as to the practical application of this peculiar property. We know, or rather Röntgen has told us, that unlike sunlight these cathode rays do not undulate in waves from their source of origin, but move backward and forward, and to this property their power to penetrate opaque bodies is most probably due; or, as has been mooted, this power as demonstrated may be an energy in the shape of radiation. The advantages that may accrue from it to the science of surgery, the valuable adjunct that it may prove to be as

a means of diagnosis, have already been spoken of, and it only remains to complete the experiments that will demonstrate easy means of their practical application. Aside from this it is fair to presume that the rays have a subtler power than this one of penetration. Ordinary light is one of the main factors in the development and growth of animal life. We have studied the effects in this direction, and know that sunlight is essential for the growth and development of both animal and vegetable tissue. What effect may these different light rays have on pathological conditions?

The subtlest chemical force is sunlight; it brings about the most powerful reactions that are apparent yet undemonstrable. We see the reaction of a ray of sunlight upon a plate prepared with sensitive salts and observe the chemical decomposition. So, too, do we watch its action upon the plant, and we know that color, strength, and fructification depend to a large measure upon sunlight.

The same applies to animal life. We have in light a therapeutic agent that has been underestimated, if not altogether lost sight of and neglected. The few thoughtful men who have striven to advance the title of light in this direction have been scoffed at. Their labors have not even been accorded respectful consideration, and simply because the average therapist will adopt nothing that can not be demonstrated in the glass receiver of his laboratory, the reaction of which he can not see going on before his eyes, and the formula of which he can not determine.

Modern chemistry, as I have said, is far subtler than this, and the great evidence is the spectrum as an analyst. Who to-day refers to the work of the great Moleschott? Yet in the light of recent observations we are slowly arriving at the realization that our principles of therapy must soon change, that their Waterloo is impending, that

we must hold physiology higher than we have been accustomed to.

These are the reasons why I have undertaken a few investigations in order to ascertain the effect of these rays upon animal life and upon the tissues. The only leg we have to stand on at present is the singular phenomenon of the penetrative force of these rays Is not the hypothesis fair to set up that these rays, in forcing their way through tissues, exercise some action upon the tissues in their transit through them? The work is notably slow and tedious, besides involving much cost and time. I can hold forth little beyond saying that up to the present moment close observation of the action of these rays upon animal and vegetable life is being carried on.

In view of the great interest being displayed at this time over these "X" rays, or unknown rays, and the many series of experiments which are being carried on by learned scientific men in their various institutions along the lines laid out by Röntgen and others, I have thought it of some value to give my little mite herein, by foreshadowing, perhaps rightly and perhaps wrongly, the possible rôle that these unknown rays may yet play in our therapeutics and physiology.

These "X" rays have not only given a stimulus to further scientific investigations in different lines, but have also excited great popular interest. Up to the present time many interesting problems have been solved and still the beginning has not been made! This might one say at the finish of this paper at the word "*conclusion*," which is an absurd one to write in this instance, when the whole subject of "X" rays is astir with life, and when every day seems to bring out some fresh aspect, to develop more clearly some truth of which we have now only a glimpse. The only proper conclusion to such an important discovery

as that of Professor Röntgen's now is to herald the advent of the very latest discoveries and to prepare for more to come.

Crookes's most classical researches on electric discharges in high vacua have taught us that in the extremely attenuated gaseous residues in the tubes which he employed the discharges from the negative pole, or cathode, can cast shadows on the walls of the inclosing tube. Since then these "X" rays have received attention and much patient investigation at the hands of many experimenters, including Röntgen, Goldstein, Weidmann, Lenard, etc.

These mysterious and curious rays are very active in exciting phosphorescence, and move quite differently from all ordinary rays. Hertz added much toward elucidating these discoveries by the acute observation that the "X" rays, though passing through glass with difficulty, would pass through thin sheets of metallic substances which would be quite opaque to ordinary light. To these Professor Röntgen adds his miraculous discovery in producing the noted "shadowgraph" through opaque substances. We are all familiar with the methods of producing these pictures, so no further details need be here discoursed upon; besides, the dailies and scientific papers have devoted so many of their pages to discussing the various and numerous opinions of savants from all over the world that those who have kept abreast with the time are fully informed.

Since it has been demonstrated to us that certain metals are permeable to "X" rays, it is now timely to test the permeability of other materials. It should thus appear to every thinking man that we need not stop the test at metals alone, but push on to other substances as well.

Who knows to what extent such investigations may prove yet more fruitful?

Let us understand a little more in detail something about the Crookes's tube. One must always know the manner of the working of an engine before he can put it to use. Then, practically speaking, this vacuum tube, as known by the inventor's name, is a vacuum bulb much like an ordinary electric-light bulb without the carbon filament in the centre. It has two platinum electrodes, one at the top and one at the bottom, just penetrating the glass. When it is ready for use the current is first passed through the induction coil and thus raised from a low to a high potential. A mechanical device, if attached for convenience, rapidly opens and shuts the circuit and gives a great number of alternations. The Crookes's tube must be placed in the circuit and the cathode or "X" rays are generated. While the current is making its high potential discharges in this vacuous tube a violet fluorescence is observed in the glass. This fluorescent effect is very much like that obtained by rubbing a sulphur match on a dampened hand.

A little more theory on this subject will lead us still better to understand our subject in hand, especially if we are going to apply these "X" rays in another domain which is not yet explored.

We are entirely ignorant of electricity in all its forms, and we can not even directly recognize it as we do light and heat; we know it only by its luminous, calorific, chemical, or mechanical effects. Yet, though electricity does not appeal to any one of our five senses, we have a sort of vague sensation of it; as, for example, when the air is charged with electricity on the approach of a thunder storm. It then produces in us a particular nervous condition, before the storm has manifested itself by any calorific, mechanical, or luminous effects, and this particular nervous condition evidently corresponds to the electric state of the atmosphere. But all this is limited to a vague

sensation which does not concentrate itself in any special organ, such as the organs of the five senses, and thus can not become a distinctly marked perception.

On the other hand, there is no doubt that electricity is not the only one of the properties of matter which partly evade our perceptions. We may reasonably suspect that many others are entirely unknown to us even by their effects, because these effects are not among those which are perceived by the five senses.

Long ago philosophers remarked that our knowledge of Nature was limited by the number of our senses, and would probably extend itself if these were increased or even perfected. Nothing, indeed, authorizes us to believe that the properties of Nature are limited to those which affect the senses of man.

Electricity in its many forms furnishes a good example of a property which we never knew directly and whose existence is still perfectly certain, since we have for a long time studied it in its manifestations and have succeeded in thoroughly mastering it. Physicists who live on intimate terms with this electric agent or prankster have not succeeded any better than ordinary observers in penetrating into the very bosom of this mysterious force, which, nevertheless, they control and direct at pleasure. But, to facilitate their explanation of it, they represent it as an invisible fluid, many million times lighter than air, whose different forms of movement produce heat, light, etc.

Clerk Maxwell was beyond a doubt one of the greatest physicists that the present century has produced, and next, if not his equal, was Dr. Hertz. Both these grand minds placed upon a safe and sound experimental footing certain electrical phenomena which have revolutionized modern thought.

To be brief, perhaps the most important of Maxwell's

contributions to our knowledge was his electro-magnetic theory of light.

In the development of his theory, in which the identity of the light ether and the electro-magnetic ether was assumed, he reached certain conclusions which ought to be valid if the fundamental propositions of his theory are correct. These conclusions have since been largely verified by experiment, and the tendency of physical research has been toward the confirmation of Maxwell's theory.

Within the last two years, however, evidence in its favor has accumulated with wonderful rapidity, and has been of such a character as to leave hardly any doubt as to the reality of Maxwell's hypothesis.

It is almost entirely embodied in a series of brilliant and elaborate investigations made by Dr. Hertz, who, in their planning and execution, exhibited great experimental skill, together with a keen appreciation of the meaning of electrical phenomena.

To get some idea of their character it will be well to refer to the oscillatory nature of an electric discharge, a mechanical illustration of which may be found in the behavior of a bent spring or any other elastic body subjected to a strain.

If a spring is bent, the work expended in the bending is stored in the spring as potential energy, assuming its elasticity to be perfect. If it is freed from restraint, there will generally follow a series of oscillatory discharges of this energy, or conversions of potential into kinetic energy, and *vice versa*.

These rapid vibrations from side to side, passing from rest at the extremes of its motion to maximum velocity in the middle, would continue indefinitely were it not for the dissipation of energy through molecular and other frictions. The electric ether in a Leyden jar or other con-

denser is in a condition somewhat similar to that in a bent spring, and especially in the fact that energy is stored as *potential* in the charge.

In studying this subject closely we find that as far back as 1842 Joseph Henry observed that the discharge of a condenser was oscillatory in its character, consisting of "several reflex actions backward and forward until equilibrium is attained."

Also Helmholtz showed a few years later that the discharge of a jar was not a simple motion of the electricity in one direction, but a backward and forward motion between the coatings in oscillation, which became continually smaller until the entire oscillation was destroyed by the sum of the resistance.

Sir William Thomson and Lodge took it up from the mathematical point, from which the conclusions have been verified by many experiments.

Dr. Oliver Lodge estimates that a gallon Leyden-jar discharge through a stout wire fifty or sixty feet long gives rise to oscillations as frequent as a million a second, while a pint jar, discharged in the ordinary manner by a short, good conductor, gives as many as fifteen millions a second.

These electrical oscillations must give rise to waves in the ether precisely as the oscillations of a tuning fork produce waves in the air, and the length of these waves will, of course, be equal to the velocity with which the wave is transmitted multiplied by its period. Assuming with Maxwell that the electric ether is identical with the light ether, and that therefore the velocity of transmission of the waves is approximately one hundred and eighty-six thousand miles a second, it is easy to calculate that the waves in the first instance will be about a thousand feet long, and in the second about sixty-five feet in length.

By diminishing the electrostatic capacity of the appa-

ratus the period can be made still shorter and the wave length correspondingly less. For some years the existence of these waves has been accepted by physicists, but to Hertz belongs the great credit of having first actually found them in space, and of having established their existence by a series of his own experiments, remarkable alike for their beauty and their simplicity. It is impossible here to describe either method or results except in the briefest possible manner. As to the method, it may be said that it was in principle somewhat analogous to the use of a resonator in acoustic experiments, which responds to and makes sensible any sound with which it is synchronous.

Hertz's "resonator" is very simple in form, consisting of a short metallic circuit broken by a small interval across which sparks may pass. As to results, it is enough to say that he has been able to show that these waves obey all the laws, such as those of reflection, refraction, polarization, interference, etc., to which light waves are subject when proper consideration is given to the nature of the material employed to produce these various effects.

They have been concentrated by metallic mirrors and refracted by huge prisms of pitch. Metals, which are conductors of heat and electricity, are opaque to them, while non-conductors, or poor conductors, are trans parent.

It is easy to see that if the vibration frequency is made sufficiently great, these waves will possess all the essential characteristics of light waves, and, remembering that *the smaller the capacity* of the charged body the more rapid the oscillations of the charge when it is disturbed, it will appear that electric charges on atoms or molecules might readily oscillate thousands of millions of times a second, and thus light might be regarded as a *purely electrical phenomenon*, as affirmed by Maxwell.

Altogether, the discoveries of Hertz must take high rank as making a distinct advance in electrical science, and especially as opening a wide field for investigation which promises rich rewards.

It must be remembered from close study of physics that if cords, chains, water, etc., can assume a wavelike motion, the wonderful tension and elasticity of the hypothetical ether would permit the latter to adapt itself to the most complicated movements almost with the rapidity of thought. The very spiral, spindlelike, or corkscrew motion observable in the chain and cord affords a good idea of the mechanism of the propagation of light, as the movement of each molecule of ether is always perpendicular to the path of the ray or wave of light. It can easily be conceived that vibrations of ether or light waves (no matter from what source generated) must affect even material substances, whether endowed with life or not. Thus it is maintained by General Pleasonton, U. S. army,* that remarkable cures have been effected in cases of nervous disease (when the voltaic shock has failed) by merely exposing the part affected to the rays of the sun passed through blue glass. Also he has experimentally made many most practical demonstrations in the development of animal and vegetable life, etc. Mr. Willoughby Smith has shown that the electrical conductivity of the element selenium is affected by exposure to light, and it was while in charge of the electrical department of the work of laying the cable from Valentia to Heart's Content (1860) and using the high resistance of selenium that Mr. Smith noticed that the deflection of the needle varied according to the intensity of light falling on the selenium, thus explaining the cause of that element not being constant as a

* *The Influence of the Blue Ray of the Sunlight and of the Blue Color of the Sky.* Philadelphia, 1876.

resistance medium. Mr. Smith says, during the laying of the Atlantic cables (1873 and 1874): "I have with success adopted selenium bars protected from the action of light." Why, then, may we not expect that rays of light propagated from many sources will give us valuable effects in disease and growth? I bring these arguments and the problematic question before the notice of the profession in order to stimulate others besides myself to enlarge this field of investigation, as there is no telling what hidden forces await our unraveling of their laws and their probable therapeutic application, etc.

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