upon as capable of concentrating the X rays; in effect, both an ebonite and a glass lens of large size prove to be without action. The shadow photograph of a round rod is darker in the middle than at the edge; the image of a cylinder filled with a body more transparent than its walls exhibits the middle brighter than the edge.

8. The preceding experiments, and others which I pass over, point to the rays being incapable of regular reflection. It is, however, well to detail an observation which at first sight seemed to lead to an opposite conclusion.

I exposed a plate, protected by a black paper sheath to the X rays, so that the glass side lay next to the vacuum tube. The sensitive film was partly covered with star-shaped pieces of platinum, lead, zinc, and aluminum. On the developed negative the star shaped impression showed dark under platinum, lead, and, more markedly, under zinc; the aluminum gave no image. It seems, therefore, that these three metals can reflect the X rays; as, however, another explanation is possible, I repeated the experiment, with this only difference, that a film of thin aluminum foil was interposed between the sensitive film and the metal stars. Such an aluminum plate is opaque to ultra violet rays, but transparent to X rays. In the result the images appeared as before, this pointing still to the existence of reflection at metal surfaces.

If one considers this observation in connection with others, namely, on the transparency of powders, and on the state of the surface not being effective in altering the passage of the X rays through a body, it leads to the probable conclusion that regular reflection does not exist, but that bodies behave to the X rays as turbid media to light.

Since I have obtained no evidence of refraction at the surface of different media, it seems probable that the X rays move with the same velocity in all bodies, and in a medium which penetrates everything, and in which the molecules of bodies are embedded. The molecules obstruct the X rays the more effectively as the density of the body concerned is greater.

9. It seemed possible that the geometrical arrangement of the molecules might affect the action of a body upon the X rays, so that, for example, Iceland spar might exhibit different phenomena according to the relation of the surface of the plate to the axis of the crystal. Experiments with quartz and Iceland spar on this point lead to a negative result.

10. It is known that Lenard, in his investigations on cathode rays, has shown that they belong to the ether and can pass through all bodies. Concerning the X rays the same may be said.

In his latest work, Lenard has investigated the absorption coefficients of various bodies for the cathode rays, including air at atmospheric pressure, which gives $4 \cdot 10, 3 \cdot 40, 3 \cdot 10$ for 1 cm., according to the degree of exhaustion of the gas in discharge tube. To judge from the nature of the discharge, I have worked at about the same pressure, but occasionally at greater or smaller pressures. I find, using a Weber's photometer, that the intensity of the fluorescent light varies nearly as the inverse square of the distance between screen and discharge tube. This result is obtained from three very consistent sets of observations at distances of 100 and 200 mm. Hence air absorbs the X rays much less than the cathode rays. This result is in complete agreement with the previously described result, that the fluorescence of the screen can be still observed at two meters from the vacuum tube. In general, other bodies behave like air; they are more transparent for the X rays than for the cathode rays.

11. A further distinction and a noteworthy one results from the action of a magnet. I have not succeeded in observing any deviation of the X rays even in very strong magnetic fields.

The deviation of cathode rays by the magnet is one of their peculiar characteristics. It has been observed by Hertz and Lenard that several kinds of cathode rays exist, which differ by their power of exciting phosphorescence, their susceptibility of absorption, and their deviation by the magnet; but a notable deviation has been observed in all cases which have yet been investigated, and I think that such deviation affords a characteristic not to be set aside lightly.

12. As the result of many researches, it appears that the place of most brilliant phosphorescence of the walls of the discharge tube is the chief seat whence the X rays originate and spread in all directions; that is, the X rays proceed from the front where the cathode rays strike the glass. If one deviates the cathode rays within the tube by means of a magnet, it is seen that the X rays proceed from a new point, i. e., again from the end of the cathode rays.

Also for this reason the X rays, which are not deflected by a magnet, cannot be regarded as cathode rays which have passed through the glass, for that passage cannot, according to Lenard, be the cause of the different deflection of the rays. Hence I conclude that the X rays are not identical with the cathode rays, but are produced from the cathode rays at the glass surface of the tube.

13. The rays are generated not only in glass. I have obtained them in an apparatus closed by an aluminum plate 2 mm. thick. I purpose later to investigate the behavior of other substances.

14. The justification of the term "rays," applied to the phenomena lies partly in the regular shadow pictures produced by the interposition of a more or less permeable body between the source and a photographic plate or fluorescent screen.

I have observed and photographed many such shadow pictures. Thus, I have an outline of part of a door covered with lead paint; the image was produced by placing the discharge tube on one side of the door, and the sensitive plate on the other. I have also a shadow of the bones of the hand, of a wire wound upon a bobbin, of a set of weights in a box, of a compass card and needle completely inclosed in a metal case, of a piece of metal where the X rays show the want of homogeneity, and of other things.

For the rectilinear propagation of the rays, I have a pin hole photograph of the discharge apparatus covered with black paper. It is faint, but unmistakable.

15. I have sought for interference effects of the X rays, but possibly, in consequence of their small intensity, without result.

16. Researches to investigate whether electrostatic

forces act on the X rays are begun but not yet concluded.

17. If one asks, what then are these X rays? Since they are not cathode rays, one might suppose, from their power of exciting fluorescence and chemical action, them to be due to ultra violet light. In opposition to this view a weighty set of considerations presents itself. If X rays be indeed ultra violet light, then that light must possess the following properties:

(a) It is not refracted in passing from air into water, carbon bisulphide, aluminum, rock salt, glass or zinc.

(b) It is incapable of regular reflection at the surfaces of the above bodies.

(c) It cannot be polarized by any ordinary polarizing media.

(d) The absorption by various bodies must depend chiefly on their density.

That is to say, these ultra-violet rays must behave quite differently from the visible, infra-red and hitherto known ultra-violet rays.

These things appear so unlikely that I have sought for another hypothesis.

A kind of relationship between the new rays and light rays appears to exist; at least the formation of shadows, fluorescence, and the production of chemical action point in this direction. Now it has been known for a long time that, besides the transverse vibrations which account for the phenomena of light, it is possible that longitudinal vibrations should exist in the ether, and, according to the view of some physicists, must exist. It is granted that their existence has not yet been made clear, and their properties are not experimentally demonstrated. Should not the new rays be ascribed to longitudinal waves in the ether?

I must confess that I have in the course of this research made myself more and more familiar with this thought, and venture to put the opinion forward,

an ordinary gelatinous bromide dry photographic plate was placed in an ordinary camera back. The wooden shutter of the back was kept closed, and upon it were placed miscellaneous articles such as coins, pieces of wood, carbon, ebonite, vulcanized fiber, aluminum, etc., all being quite opaque to ordinary light. Above was supported a Crookes tube, which was excited for some minutes. On development, shadows of all the articles placed on the side were clearly visible, some being more opaque than others. Further experiments were tried with thin plates of aluminum or of black vulcanized fiber interposed between the objects to be photographed and the sensitive surface, this thin plate being used in place of the wood of the camera back. In this manner sharper shadow pictures were obtained. While most thick metal sheets appear to be entirely opaque to the radiations, aluminum appears to be relatively transparent. Ebonite, vulcanized fiber, carbon, wood, cardboard, leather and slate are all very transparent, while, on the other hand, glass is exceedingly opaque. Thin metal foils are moderately opaque, but not altogether so.

As tending to the view that the radiations are more akin to ultra-violet than to infra-red light, it may be mentioned that a solution of alum in water is distinctly more transparent to them than a solution of iodine in bisulphide of carbon.

So far as our own experiments go, it appears that, at any rate without very long exposures, a sufficiently active excitation of the Crookes tube is not obtained by direct connection to an ordinary Rhumkorff induction coil, even of a large size. So called high-frequency currents, however, appear to give good results, and our own experiments have been made with the tube excited by current obtained from the secondary circuit of a Tesla oil coil, through the primary of which

ROENTGEN PHOTOGRAPH OF A HUMAN HAND, SHOWING RING ON THIRD FINGER.

while I am quite conscious that the hypothesis advanced still requires a more solid foundation.

PROF. ROENTGEN'S DISCOVERY.

By A. A. C. SWINTON, in Nature.

THE newspaper reports of Prof. Roentgen's experiments have, during the past few days, excited considerable interest. The discovery does not appear, however, to be entirely novel, as it was noted by Hertz that metallic films are transparent to the cathode rays from a Crookes or Hittorf tube, and in Lenard's researches, published about two years ago, it is distinctly pointed out that such rays will produce photographic impressions. Indeed, Lenard, employing a tube with an aluminum window, through which the cathode rays passed out with comparative ease, obtained photographic shadow images almost identical with those of Roentgen, through pieces of cardboard and aluminum interposed between the window and the photographic plate.

Prof. Roentgen has, however, shown that this aluminum window is unnecessary, as some portion of the cathode radiations that are photographically active will pass through the glass walls of the tube. Further, he has extended the results obtained by Lenard in a manner that has impressed the popular imagination, while, perhaps most important of all, he has discovered the exceedingly curious fact that bone is so much less transparent to these radiations than flesh and muscle, that if a living human hand be interposed between a Crookes tube and a photographic plate, a shadow photograph can be obtained which shows all the outlines and joints of the bones most distinctly.

Working upon the lines indicated in the telegrams from Vienna, recently published in the daily papers, I have, with the assistance of Mr. J. C. M. Stanton, repeated many of Prof. Roentgen's experiments with entire success. According to one of our first experiments,

were continuously discharged twelve half-gallon Leyden jars, charged by an alternating current of about 20,000 volts pressure, produced by a transformer with a spark gap across its high pressure terminals.

For obtaining shadow photographs of inanimate objects, and for testing the relative transparency of different substances, the particular form of Crookes tube employed does not appear to greatly signify, though some forms are, we find, better than others. When, however, the human hand is to be photographed, and it is important to obtain sharp shadows of the bones, the particular form of tube used and its position relative to the hand and sensitive plate appear to be of great importance. So far, owing to the frequent destruction of the tubes, due to overheating of the terminals, we have not been able to ascertain exactly the best form and arrangement for this purpose, except that it appears desirable that the electrodes in the tube should consist of flat and not curved plates, and that these plates should be of small dimensions.

A photograph of a living human hand was exposed for twenty minutes through an aluminum sheet 0.0075 in thickness, the Crookes tube, which was one of the kind containing some white phosphorescent material (probably sulphide of barium), being held vertically upside down, with its lowest point about two inches above the center of the hand.

By substituting a thin sheet of black vulcanized fiber for the aluminum plate, we have since been able to reduce the exposure required to four minutes. Indeed, with the aluminum plate, the twenty minutes' exposure appears to have been longer than was necessary. Further, having regard to the great opacity of glass, it seems probable that where ordinary Crookes tubes are employed, a large proportion of the active radiations must be absorbed by the glass of the tube itself. If this is so, by the employment of a tube partly constructed of aluminum, as used by Lenard, the necessary length of exposure could be much reduced.