PHOTOGRAPHING THE UNSEEN.

A SYMPOSIUM ON THE ROENTGEN RAYS.

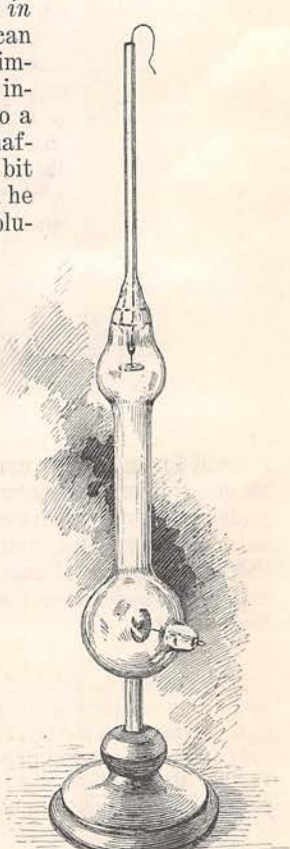
DRAWN BY AUGUST WILL.

A CROOKES TUBE MADE BY THOMAS A. EDISON.

THE most notable event in scientific history last year was the isolation, by two physicists of England, of a new element in the atmosphere. That discovery of argon, the unsuspected existence of which for so long was hardly to the credit of modern science, is now matched by the beautiful work of Professor W. C. Roentgen in photographing the unseen by electric rays from vacuum-tubes. It cannot be said that either of these advances was eagerly awaited as a sequential development. On the contrary, the individuality of argon was very strenuously denied by expert philosophers, and the first announcement of the «X rays,» with their curious Paul-Pry capacity for photographing through a brick wall, was also met with outspoken incredulity. From such incidents as these one may fairly infer that, while patient investigation will always count for much in science, happy chance is an important factor. Innumerable eyes are strained in their gaze upon the gloom, and just at what moment and at which point the veil of fog may casually lift is forever uncertain.

This country is proverbially alert in matters of discovery, yet it was several days before any one repeated the Roentgen experiments, news of which had been cabled in graphic detail by European correspondents. As if to compensate for the delay and inertness, the other extreme has since been rushed to, and no school or college has considered the day well spent in which, with endless iteration, it has not taken «cathodographs» of hands and coins. The sheep-like tendency of human beings is once more exemplified in the fact that, while a large proportion of the inhabitants of the United States have had their hands «taken,» only a single foot, so far as the writer is aware, has been made to reveal the secrets of its flesh-clad anatomy. It is even more remarkable that, outside of the work done by a few investigators (some of it recorded in this issue of THE CENTURY), the vast mass of effort has been mere tiresome repetition of a very limited number of Professor Roentgen's experiments.

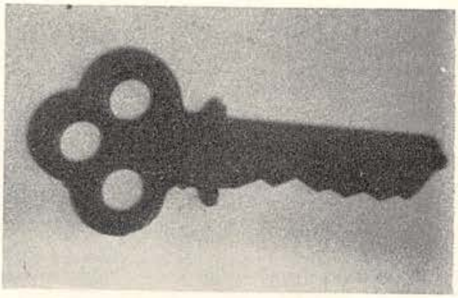
The detection and utilization of the X ray was in a sense evolutionary, although the actual occurrence was quite by accident. Dating, perhaps, from Hauksbee's Royal Society work in obtaining phosphorescent light by rubbing briskly a glass globe exhausted of air, it was a fashionable amusement throughout the whole of the last century to witness electrical discharges *in vacuo*. The reader can test the thing for himself by taking any incandescent lamp into a dark corner, and chafing it briskly with a bit of cloth or silk, when he will see a gleam of bluish light within the bulb. Of late years the favorite means of studying such effects has been a Geissler tube of glass, into which, little wires of platinum being sealed at each end, high-tension currents can be passed, with the help of an induction-coil. The discharge in the tube across the space from wire to wire creates beautiful effects of colored light, dependent on the nature of the rarefied gases within the tube. Professor Crookes followed up this line of work by improving such



DRAWN BY AUGUST WILL.

ANOTHER FORM OF CROOKES TUBE MADE BY THOMAS A. EDISON.

tubes, and by his brilliant demonstrations in them of matter in the fourth, or «radiant,» state, of which Faraday spoke eighty years ago. From these experiments by Crookes dated new phenomena of phosphorescence



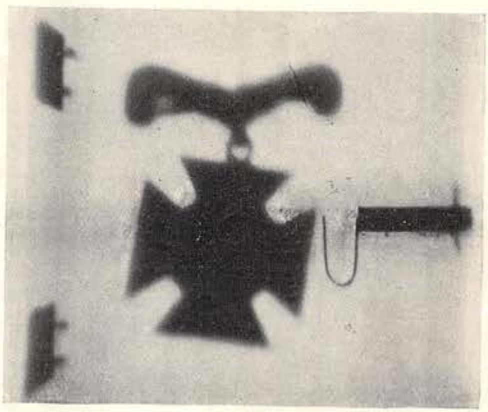
KEY CATHODOGRAPHED THROUGH A BOOK OF 526 PAGES IN THE CHEMICAL DEPARTMENT, U. S. MILITARY ACADEMY, WEST POINT, N. Y.

and fluorescence created by electric action. When the current is passed into a vacuum-tube which has wires or disks sealed into each end or side walls, the glow, starting from the positive, or anode, tip, fades out as it approaches the negative, or cathode, end. Around the cathode exists a dark space, a little No Ray Land, or buffer state, at the outer edge of which the deep violet radiations utterly die out. Just what the conditions are, and just what happens in the dark cathode region, seems uncertain, but the subject has been deeply investigated, and Professor Roentgen's discovery is one fruit of exploration in that mysterious auroral territory.

It was first pointed out by the late Professor Hertz of Germany that these ultra-violet rays from the cathode could penetrate opaque bodies, such as aluminium, in a vacuum. This was interesting, but Dr. Philip Lenard further showed that such rays would also pass out into the air and through any substance lying beyond the vacuum. They would travel a considerable distance, would cause phosphorescence, and would act on photographic plates. From this to the discovery of Roentgen, who has caused the permeable substances interposed in the lines of these rays to register their shadows on a photographic plate, is but a step, though a long and memorable one.

At this moment discussion is rife as to the nature of the Roentgen ray, and many old theories as to light, electricity, and the ether are threatened with change. The obedience of the ordinary cathode rays to a magnet is one of their characteristics; but the X rays are still Bezonians whose king is unknown, for they not only do not respond to magnetic influence, but they refuse to be reflected, and go through various prisms without any sort of apparent refraction. They persist in following absolutely straight lines, starting from the point on the glass bulb that is seen to be faintly fluorescing with a blue-green light, under the action of the invisible rays from the cathode to the glass. While they present analogies with the ultra-violet rays of the spectrum, their close identity with light is still regarded as doubtful. Light is attributed to transverse vibrations of the ether, but Professor Roentgen has suggested that his rays may be longitudinal vibrations, like sound-pulses in the air. They do at least throw shadows, cause chemical action, and set up fluorescence, while the last fact would obviously suggest that they may engender heat. Some trustworthy experimenters find the rays peculiarly irritating to the eye, and others have been making suggestive experiments to prove the similarity of these subtle emanations with non-luminous ultra-violet portions of the spectrum, to which the word «light» is not usually applied.

The electrical conditions involved are of interest by themselves, and hence the energy of investigation is now concentrating upon them. The most striking of the new results is that announced by Professor J. J. Thomson, who discovers that the Roentgen rays dissipate the electrostatic charge of any substance upon which they fall, no matter how the body may be protected against discharge. From this the writer would infer that the Roentgen rays are those which, on emerging from their prison of glass or aluminium, have lost their own electric charge, perhaps entirely. Professor Thomson states, moreover, that the nature of the charge, whether posi-



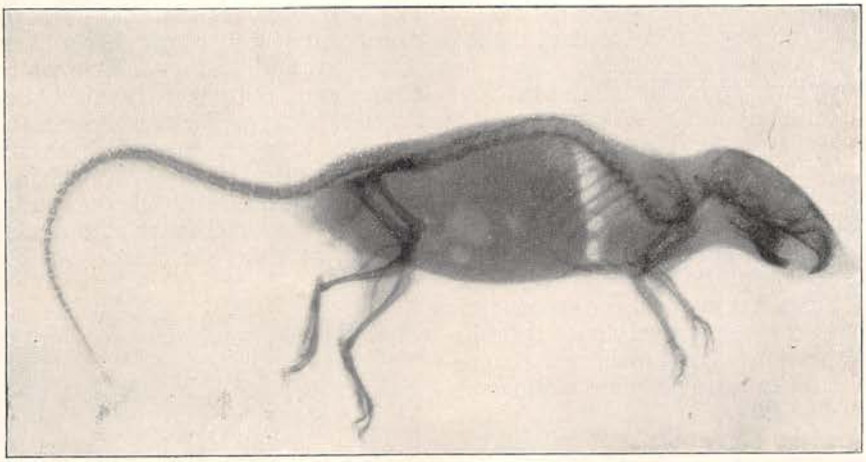
PENDANT AND PIN IN A BOX. CATHODOGRAPH MADE IN 4½ SECONDS AT THE TORONTO UNIVERSITY. (SEE P. 130.)

tive or negative, is immaterial. The corollary drawn by him from this is that all bodies under the influence of these rays become conductors. One such fact indicates many possibilities in the electrical arts and sciences.

There is no need now to dwell upon the value of the Roentgen rays in surgery and dentistry, for the newspaper press of Europe and America has been full of their use in revealing the condition of the bony structure of the body. Their employment in the testing of metals, the inspection of objects in closed or concealed packages, and the detection of differences in various substances, is obvious. One immediate and important application already made on both sides of the Atlantic is to the study of moving objects projected on a fluorescent screen, while yet another invention is aimed at seeing and photographing objects hidden by darkness.

It will conduce much to the utility of these rays, however, to determine, first of all, their nature; that is, whether they are simply streams of matter under electrical impulse, or light of short wave-length, or some new phenomenon of vibration in the ether itself.

Thomas Commerford Martin.
EDITOR OF «THE ELECTRICAL ENGINEER.»



A LIVE MOUSE. (UNDER CHLOROFORM.) CATHODOGRAPH MADE BY DR. KAUFMAN, BERLIN UNIVERSITY.

ON entering the room in which are arranged the elaborate paraphernalia necessary for the production of the Roentgen phenomena, the self-acting mercurial air-pump, with its labyrinth of tubes and bulbs, is the first object that attracts notice. Connected with this by a slender tube is the small glass bulb, with its two electrodes of aluminium, which is the source of the new energy; while just below it is the huge Ruhmkorff induction-coil, furnishing the high-tension electricity necessary for its excitation. At the start the bulb is full of air, and as soon as the coil is set in action crooked blue sparks pass freely between the aluminium plates within. The pump is now used, the silvery fluid alternately rising and falling within its tubes, and driving out the air before it. With its first stroke we observe a change in the bulb. The blue sparks cease, and in their place appears a waving purple flame, which, as the air becomes rarer, broadens, and finally breaks up into stratifications. The room is now darkened. Little disks of bluish-white light fill the tube, resembling somewhat a pile of saucers. The spaces between them widen, and finally a dark space appears about one of the electrodes. The discharge is now approaching the form described by Crookes as «radiant,» the light becomes fainter, and the dark space widens out until it touches the glass wall, which instantly glows with its characteristic green phosphorescence. A few more strokes of the pump and the vacuum is practically perfect. The resistance to the passage of the current is now so great, and the potential on the wires rises to such a point, that purple fringes of electric fire spring forth into the air. Sparks occasionally leap about the outside of the bulb, preferring the long air-gap to the shorter but vacuous one within. The entire inner surface shines with a pale emerald light, while directly in front of one of the disks is a very bright spot of a yellowish color, where the full force of the cathode rays falls. This spot is the source of the mysterious «X rays,» which, though unseen, radiate from it in all directions like light.

The bulb is now covered with a thick black

HAND OF A LIVING PERSON. CATHODOGRAPH MADE BY R. W. WOOD.

cloth to shut in the green phosphorescent light, which would interfere with the observation of the phenomena, and the room becomes absolutely dark. A large wooden screen, one side of which has been painted with barium platinocyanide, is set up before the bulb, with its coated side toward us. The invisible rays, passing through the board, excite fluorescence in the barium salt, and the entire surface of the screen shines with a bluish-green light. Placing a few coins in the center of a thick book, we hold it between the screen and the apparatus. The coins instantly appear as circular black shadows on the luminous background. A brass stencil-plate is placed in an aluminium cigarette-case and held against the screen. The light metal is more transparent to the rays than the dense,

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BIRD WITH BROKEN LEG AND TWISTED NECK. CATHODOGRAPHED IN THE LABORATORY OF THE HIGH SCHOOL, CHARLOTTENBURG.

and we see a shadow of the plate with its stenciled word. A wooden box of lead-pencils shows only the shadows of the leads as a number of narrow parallel lines. And now comes the most startling experiment of all. We hold our hand behind the screen, and, closely observing the luminous surface, perceive within the dim outlines of the flesh the sharp and distinct image of its skeleton. Every bone is perfect, even the cartilaginous spaces between being discernible. It is impossible to describe the feeling of awe that one experiences on actually seeing the image of his own skeleton within the enshrouding flesh.

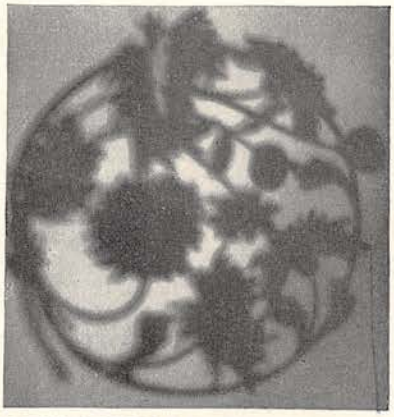
Wonderful as are these phosphorescent pictures, even more so are the photographic images. The X rays, though making no impression on the eye, exert a very powerful action on the photographic plate. It is this property which renders the discovery of such value; for in place of the transient shadows on the luminous screen, sharp and clear photographs can be made, which may be examined at leisure. These photographs can be taken in broad daylight. The plate, protected from light by a holder of the usual kind or by several thicknesses of black paper, is placed at a distance of eighteen or twenty inches from the vacuum-tube, and the object to be photographed is laid upon it. The photograph of the human hand which appears on page 123 was made by the writer with the apparatus of the Berlin Physical Institute. The seal-ring on the little finger shows the opacity of the heavy metals to the rays, its image being much darker than that of the bones. In taking this picture the hand was placed near the exhausted tube, which was directly over the little finger; here the rays fell perpendicularly, while those that cast the shadows of the other fingers struck the plate in an oblique direction, which caused a slight distortion or broadening of the image. The photograph of a bird was made by Herr Klingenberg in the laboratory of the Technical High School in Charlottenburg. One of the legs was broken, and the position of the splintered ends is distinctly shown in the picture. The dislocation of the vertebræ in the neck, caused probably by wringing, is also noticeable.

The other picture illustrating this note was taken by Dr. Kaufman in the physical laboratory of the University of Berlin, and shows the anatomy of a living but chloroformed mouse. This is perhaps the most interesting of all. Beginning with the head, we see within the outline of the creature's profile the sharp contours of the skull and teeth. A trace appears of the thin, delicate ears. Just behind the skull are the almost transparent shoulder-blades, in shape not unlike the wings of a bee. Through the ribs we discern an almost white area, the lungs, which, being filled with air and of trifling density, allow the rays to pass. Just in front of and below this white patch is seen the faint outline of the heart. Even the tendons of the hind legs appear, and the entire skeleton stands out almost as clearly as if the flesh had been removed.

BERLIN, GERMANY. *R. W. Wood.*

THE cathodograph on page 127 was taken by me in an exposure of about an hour. The source of current was a Wimshurst machine with two plates about sixteen inches in diameter. The Crookes tube was connected between the outside foils of a pair of Leyden jars, the knobs of which were connected with the terminals of the machine respectively, discharges at the rate of about thirty per minute taking place between the separated terminals.

The sensitive plate (5×7) was placed in a pasteboard box, face up, and had a sheet of black paper wrapped about it. It was thus shielded by a layer of paper and another of pasteboard. Just above the plate, and on the top of the box, were laid a variety of objects; and above them, at a distance of about four inches, was the under side of the Crookes tube. An ordinary photograph of the objects was taken by the camera, a print of which is shown on the following page. It shows several things which do not appear in the cathodograph, the reason being that they were practically transparent. Near the center is a small brass gear-wheel which is quite opaque; it was one eighth of an inch thick, except the hub, which gave a full thickness of one fourth of an inch. Near the brass wheel is a small sea-urchin, the structure of which is partly calcareous. The rays have gone through and revealed a portion of the interior structure. Likewise, the rays have passed through a small starfish



SILVER ORNAMENT IN A BOX. CATHODOGRAPHED BY WILLIAM JAMES MORTON. (SEE P. 130.)

and rendered considerable detail, which is better distinguished in the negative than in the print. By the starfish was a piece of white paper with a collection of blue-black crystals of silicon. These are too transparent to show in the ray-print. Adjoining the wheel and the sea-urchin is a plate of aluminium about three sixty-fourths of an inch thick, having letters stamped into it. The stamp depressions go about half-way through. The whole plate is seen to be partly transparent as compared with the brass wheel, and the

THE PHOTOGRAPH. MADE BY ELIHU THOMSON.

letters more than the body of the plate. Adjoining the objects mentioned may be seen a pair of insulated wires tightly twisted together. In the ray-print the insulation is almost invisible, and the wires stand wide apart. The three irregular pieces seen near the twisted wire are coal: one piece, in the form of a wedge or prism, is of anthracite three eighths of an inch at its thickest part, and tapering to an edge; the other two are of bituminous coal varying in thickness from one sixteenth of an inch to over one fourth of an inch. The coal is relatively quite transparent, and the bituminous somewhat more so than the anthracite. The negative clearly shows by darker marks the presence of seams probably richer in earthy matter.

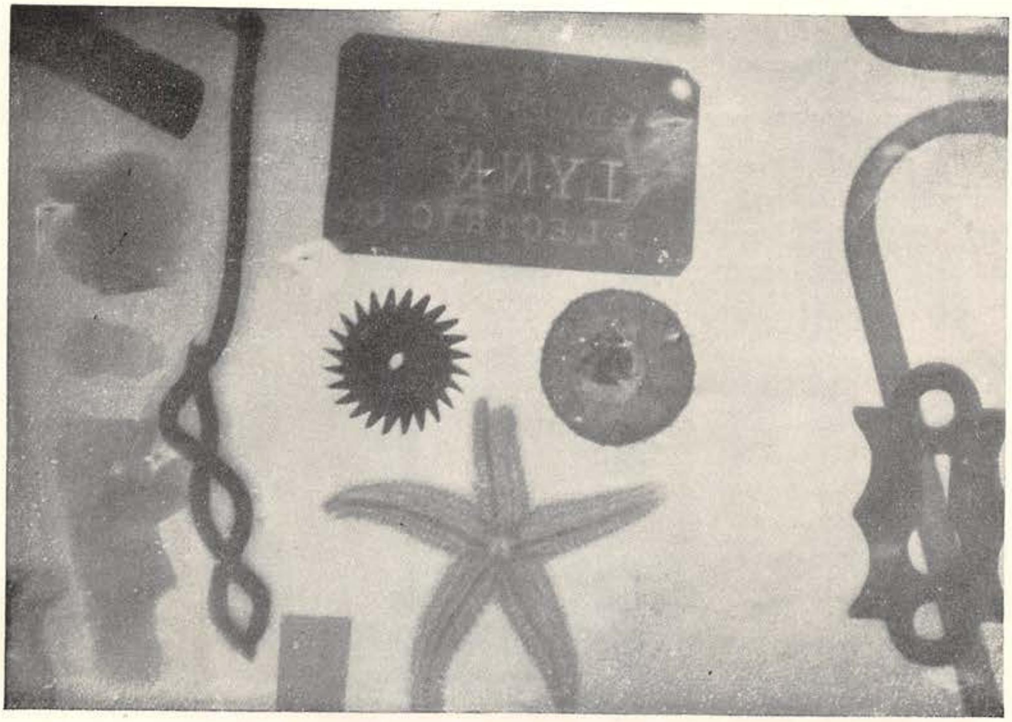
In this connection I make a suggestion. Instead of analyzing the coal for ash percentage, take a cathodograph of a definite thickness of it along with coals bearing known percentages of ash, and compare the shadows.

At the upper left-hand corner of the photograph on this page is a small hardwood awl-handle, the awl being broken. The cathodograph shows the brass ferrule to be opaque, and shows that the wood is fairly transparent—sufficiently so to reveal the end of the broken awl above the ferrule in the wood.

Adjoining the lettered aluminium plate was placed a piece of cellulose about one thirty-second of an inch thick. It was too transparent to show in the cathodograph. By the cellulose was a piece of bromide print in black, with white letters, «Assembly.» This was too transparent to be visible in the shadow-picture. The keyhole escutcheon seen near it is of iron, about one sixteenth of an inch thick, with chamfered edges. It is opaque, but by inspection of the negative the edges are clearly seen to transmit rays. In the upper right-hand corner of the photograph is a cork about one inch in diameter, having two glass tubes passing through it. The cork has disappeared in the shadow-picture, being too transparent. (Cathodography of corked bottles would *uncork* them.) The glass tubes are seen to be partly transparent.

It is indeed surprising to find the dense black coal masses transmitting the rays so freely that an inch or more in thickness would be no particular obstacle to the taking of a picture.

In developing a cathodograph picture it is noticeable that the development goes on all through the film, back as well as front. This is not the case with ordinary camera exposures, which develop from the front toward the back of the plate. The behavior noted is with the cathodograph an indication of the fact that the sensitive film itself is largely transparent to the cathode rays, and therefore lets them through without fully utilizing them. If they could all be absorbed and made to do chemical work, our time for making an impression would be much abbreviated.



THE CATHODOGRAPH. MADE BY ELIHU THOMSON.

To test this, I placed in front of a sensitive plate, and between it and its slide in the plate-holder, four thicknesses of sensitive bromide paper. It was then placed under the Crookes tube, with a few objects—one of which was a small permanent magnet—on the cover of the plate-holder containing the plate and paper. There were thus five superposed sensitive layers traversed by the rays. A picture was obtained on each of them. These pictures were of equal intensity, and the glass had a strong impression. The indication that a dozen or twenty paper pictures might have been obtained at one time, I have since verified.

This looks as if only a small portion of the silver bromide is susceptible to these rays, and that to get the best results special preparation of the sensitive materials will be needed; or the impression may depend on fluorescence, in which case strongly fluorescent chemically inert powders should be incorporated with the sensitive substances.

There is every reason to believe that much greater speed will be attained by the use of highly sensitive materials and of greater energy in the Crookes tube apparatus.

The detection of cathode rays by fluorescence will undoubtedly be of great service in saving time in making explorations in surgery, etc. With a highly fluorescent screen placed within the range of vision, in a dark box provided with sight-holes, the observer will be able at once to detect the presence or absence of the rays, the forms of the shadows, etc., instead of photographing them. He will be able also easily to change the direction of the rays and make observations in the different directions without loss of time.

It is possible also that an exploring apparatus, consisting of a negatively electrified body with an electroscope, may be so arranged as to give a record, or map, as it were, of the shadows cast by the cathode rays. In this case the sensitiveness can be made exceedingly great.

It is too early to settle upon any theory as to the nature of the rays. They agree in several particulars with what is called ultra-violet light, or with ultra-violet rays. Yet they are not refracted or reflected, or at least no observations have as yet been made showing that they possess the capability of refraction or reflection. Certain delicate markings which I have observed on a few cathodographs would almost indicate a trace of refraction or reflection existing; still, there may be another explanation of these markings.

May it not be that high-pitch waves in the ether, even when transverse like light-waves,

HAND OF A GIRL, AGED 11, SHOWING DISEASED BONES. CATHODOGRAPH MADE BY PROFESSOR S. P. THOMPSON.

can pass between the molecules and travel in free ether between them, or otherwise undergo absorption in the molecule itself when the latter is across the path?

Be they what they may, the study of cathode rays will open up the way to further discoveries in that borderland between matter and ether. We know that magnetism concerns the ether far more than it does ordinary matter. We know that light and radiant heat are electromagnetic vibrations of high pitch in the ether. It is more than probable that gravitation is dependent on some form of ether vibration. We shall await the proof of the true nature of cathode rays, fully assured that it will come in due time.

LYNN, MASSACHUSETTS. *Elihu Thomson.*

FOR success in producing electric shadows the first requisite is a Crookes tube having a very perfect vacuum. The highest exhaustion is essential, many tubes failing from having only a sufficient vacuum to produce phosphorescence. The glass should be thin and preferably containing no lead. An ordinary Ruhmkorff coil, capable of throwing a spark four or five inches in length, suffices to stimulate the tube, provided its break works with sufficient rapidity. With the ordinary slow break very long exposures are necessary. If the bulb or tube is large, sharply defined shadows will not be obtained. The rays that produce the shadow effects do not emanate exclusively from the phosphorescent patches on the glass bulb, as Roentgen himself supposed. One of my tubes cast distinct double shadows, the stronger shadow falling in a direction as if the rays had come straight from the cathode, the fainter shadow in a direction straight from the phosphorescent patch on the glass. Interposing a piece of pine-wood, I have found shadows of the grain of the wood upon the sensitive plate, which proved that the dark resinous streaks are more transparent to these rays than the lighter-colored tissue. I have obtained shadows of coins shut up in a leather purse, of pens inclosed in a wooden box, of a pair of spectacles lying in its case, and of gems of various sorts inclosed in a wooden box. Olivine appears to be more opaque than topaz, sapphire, or diamond. Diamond is more opaque than black carbon of equal thickness. A piece of amber inclosing flies shows no shadows of the flies. I have found no difficulty in getting shadows of the bones of the hand, even down to the wrist; but in my sciographs, as in those of Mr. Swinton, the flesh always casts a shadow also. Magnetized iron and non-magnetized iron appear to be equally opaque. Bones are not very opaque: one notices in the shadows of the carpal bones of the hand that the enlarged ends, where there is marrow, are more transparent than the parts where the bone is denser. At present there is not the slightest evidence that these rays can be polarized; that is the strongest argument in favor of the view that they consist of longitudinal vibrations. Neither, as yet, has any means been found of reflecting them. They apparently agree with ultra-violet light in one respect only, that of frequency. But of their wave-length, whether it is shorter or longer than that of ultra-violet light, nothing is certain. It depends on the velocity of propagation of the rays as to whether it is less or greater. The name of «ultra-violet sound» appears to me to be appropriate to the phenomenon. The thing most wanted now is a more powerful means of exciting the rays so as to shorten the time of exposure.

I find that metallic sodium is more transparent than metallic potassium, and slightly more transparent than aluminium. Metallic lithium is far more transparent than either. It is certainly ten times more transparent than aluminium, and can hardly be caused to cast any shadow at all. In fact, it appears as though the opacity of bodies to the Roentgen rays was proportional, not to density, but to atomic weight. Imitation rubies made of red glass are more opaque than natural rubies; imitation pearls are more opaque than real pearls. To obtain good sciographs of hands and feet, showing the bones only, a longer exposure is needed than will suffice to show the bones through the flesh. With prolonged exposure the flesh disappears, the rays penetrating it more and more.

The negatives frequently show as though much more fully exposed on the side next the glass than on the front of the film. This gives color to the notion that the photographic effect is of a secondary order, the Roentgen rays penetrating the film to the surface of the glass, where by some transmutation akin to phosphorescence they generate the photographic effect. Abney says that if the sensitive films are spread on ferrotype iron instead of on glass no shadows are produced.

The statement attributed to me in various quarters, that I have found Roentgen rays in the arc-lamp, has never been made by me. What I have found is that, using an arc-lamp, I could get photographic shadows of metal objects through a wooden screen; but they are stopped by an aluminium sheet, and hence are not due to Roentgen rays.

I have succeeded in reading the contents of a sealed letter by the Roentgen method. The ink was of a metallic nature; writing in vegetable inks produces no appreciable shadow.

In the sciograph of the hand of a child aged eleven, in St. Bartholomew's Hospital, London, suffering from growth of bony tumors upon the bones of hands, feet, etc., the distortions of the joints so produced are very plainly shown.

Silvanus P. Thompson.

City of London and Guilds Technical College, London, England.

At the University of Toronto, as elsewhere, the announcement by Professor Roentgen of his discovery of a new form of radiation excited the most intense interest. Together with Mr. C. H. C. Wright and Mr. Keele of the School of Practical Science, I arranged a series of experiments to verify, if possible, the results said to have been obtained. Although we were successful in establishing the extraordinary penetrating power of the rays and their action on a sensitized photographic plate, we found that long exposures were necessary in order to obtain sharp and clearly defined images. As this limited to a very great extent the applications of the «new photography,» we directed our efforts to reducing, if possible, the time of exposure, and this we succeeded in doing to a very marked degree.

On making a careful test of all the tubes in the physical laboratory, we found one which gave a much stronger radiation than any of the others. This tube was pear-shaped, and as it had one electrode inserted in the smaller end and the other in the side, we were able, by making the former the negative terminal, to obtain a large glass surface exposed to the action of the cathode rays. This tube was employed in all our later experiments. Thinking that probably the action would vary with different sensitized films, we conducted tests to determine the relative sensitiveness to the rays of various types of plates; but we observed marked difference, and concluded that any reduction in the time of exposure must be otherwise obtained. Experiments were also made with prisms and lenses of wood, pitch, and other materials, but no indication of refraction at their surfaces could be discovered.

The only remaining method for the concentration of the rays seemed to be an application of the principle of reflection. In order to determine whether the rays could be reflected, a surface of clean mercury was prepared, and it was found that when the rays were directed towards this sensitized films protected from direct radiation were fogged by some action coming from the mercury. To test this apparent reflection still further, a sensitized film, protected by a plate-holder, was placed at a distance of about twenty centimeters below the Crookes tube. A thick plate of glass was then inserted midway between the tube and the film, parallel with the latter, with the intention of screening the plate in part from the action of the rays. The tube was then excited for some time, and on developing the film it was found that the rays evidently traveled in straight lines, since the part of the film protected by the glass plate was well defined and entirely unaffected by them. This experiment was repeated, the arrangement of apparatus being identical, with the sole exception that a glass bell-jar was placed over the whole. Development of the film in this case showed (1) no action on the film outside the jar; (2) no indication that the interposed glass plate acted as a screen; (3) the action much more intense than in the previous experiment, proving conclusively the reflection of the rays from the surface of the jar.

By the employment of this method we reduced on February 11 the time of exposure almost to instantaneousness. The picture of the pendant given on page 121 was taken with the bell-jar over the apparatus, and was obtained by an exposure of four and a half seconds, the object being a medal placed within a leather-covered wooden jewel-case. Very good results were similarly obtained by an exposure of one second through five folds of black paper.

UNIVERSITY OF TORONTO. *J. C. McLennan.*

ALL about and within us exist rates of vibration known as forms of energy, some of them forced by man's ingenuity to record themselves by aid of mechanisms, others yet awaiting this sort of detection. Recording devices to reveal laws of light, heat, or chemical affinity are familiar, but no one has in a similar manner recorded thought or gravitation. Electricity yields its secrets slowly. While Faraday divined and Maxwell proved mathematically its existence outside of the conductor, Hertz actually detected its vibration and its wave-lengths by means of his oscillator. Lenard detected and recorded cathodic rays outside of a vacuum-tube, and now Roentgen comes forward to show by a device that the leather of a purse and the flesh of the hand may be penetrated by a radiation, leaving coins within, and bones otherwise invisible, pictured. At once man's curiosity in uncovering the otherwise unseen became highly excited.

Reference to one's own personal participation in the development of the Roentgen process even now seems like a reminiscence, so rapidly have events moved onward. The announcement of its possibility found me fully equipped with all needful electrical apparatus, except a Crookes tube, which could not be purchased anywhere. I therefore turned my attention at once to the static machine and ordinary vacuum-bulbs, and with these simple appliances have progressed to a point of picturing all sorts of metallic objects upon six-inch by eight-inch, or even larger plates, in from three to five minutes, and have obtained a perfect shadowgraph of a small piece of a needle behind a bone in the foot. The bones of the hand have already become an old story. I find my X rays are very intense, so much so that over-exposure easily penetrates some bones and thin plates of metal.

My first experiments demonstrated that shadowgraphs could be obtained simply by causing a powerful spark from the static machine to pass around, but not through the plate-holder. One of my first working vacuum-bulbs was a radiometer such as is commonly sold by opticians, to which I attached external electrodes. Another form of vacuum-bulb had one external and one internal electrode. The illustration on page 125 represents an early effort with the radiometer bulb. I now use some bulbs a foot in diameter and having no entering electrodes. I make use of no coil or converter, but excite the vacuum-tube directly from the external armatures of Leyden jars in a manner published by me as novel in 1881, or I dispense entirely with the Leyden jars.

My chief pleasure in this work has been in its simplification, and in its possible adaptation to medical uses.

NEW YORK CITY. *William James Morton.*

MY experiments with the Roentgen rays have been almost entirely devoted to investigating the phenomena with a view to obtaining the most practicable and powerful form of apparatus—especially the fluorescent lamp, the photographic plates, and the best form of electric oscillation to energize the lamp. Having all the appliances for working with incandescent-lamp vacua, I have been enabled to try a large number of experiments with this end in view. I have not as yet attempted to take pictures other than a standard figure of a number of bars of metal, bone, etc., on cardboard.

I am now fitting up a complete apparatus, and expect soon to conduct a number of accurate experiments in the photography of animate and inanimate objects. From the rough experiments recorded in my note-book I «brief» the following:

1. The ray proceeds from all parts of the glass illuminated by fluorescence.

2. With the same degree of fluorescence, the effect is independent of the size or position of electrodes.

3. Under the same conditions as to the distance of the lamp from the plate, the distortion increases with the increase in the size of the lamp-bulb.

4. Records taken every three inches up to thirty-six inches show that the photographic effect of the ray diminishes as the square of the distance, as stated by Roentgen.

5. Commercial dry plates vary much in their sensitiveness to the ray. The most rapid plates for light are the slowest for the ray.

6. As nearly as can be ascertained at present, the power of the ray to photograph varies as the square of the illuminating power of the fluorescence.

7. The phosphorescence of the lamp after the current is stopped does not photograph. Powerful after-phosphorescence of a lamp is no indication of its value for photographic work.

8. High vacuum diminishes fluorescence and the sensitiveness to photographic work. The point of maximum fluorescence is where the residual gases just perceptibly glow.

9. Fluorescent lamps with aluminium electrodes gradually change to higher vacuum, with diminishing fluorescence and consequent lower sensibility. Gentle heating of the lamp restores the absorbed gases temporarily.

10. The smaller the lamp the less will be the distortion of the shadow, and the closer can the plate and the lamp be placed, thereby increasing the sensibility greatly.

11. Substances so far tried which powerfully phosphoresce in the bulb of the lamp do not photograph when phosphorescent after the current is stopped.

12. Heating the dry plate does not appreciably increase its sensitiveness.

13. A good lamp should give a clear photograph of thin metallic strips through eight inches of Georgia pine in fifteen minutes.

ORANGE, N. J. *Thomas A. Edison.*

THE GOOSE FEATHER.

(AN AMERICAN INDIAN SONG.)

BLACK lake, black lake—
The wild goose hid within the brake;
The string upon my bow fell loose,
The arrow slipped and missed the goose.

He heard my step and flew away;
I found a feather where he lay.
Arrow thin, arrow thin—
I stuck the black goose-feather in.

Black lake, black lake—
A goose lies dead within the brake.
This morn his own black feather whirred,
And sped the shaft that killed the bird.

Charles A. Collmann.