MARVELS OF THE NEW LIGHT:

NOTES ON THE RÖNTGEN RAYS.

BY H. SNOWDEN WARD.

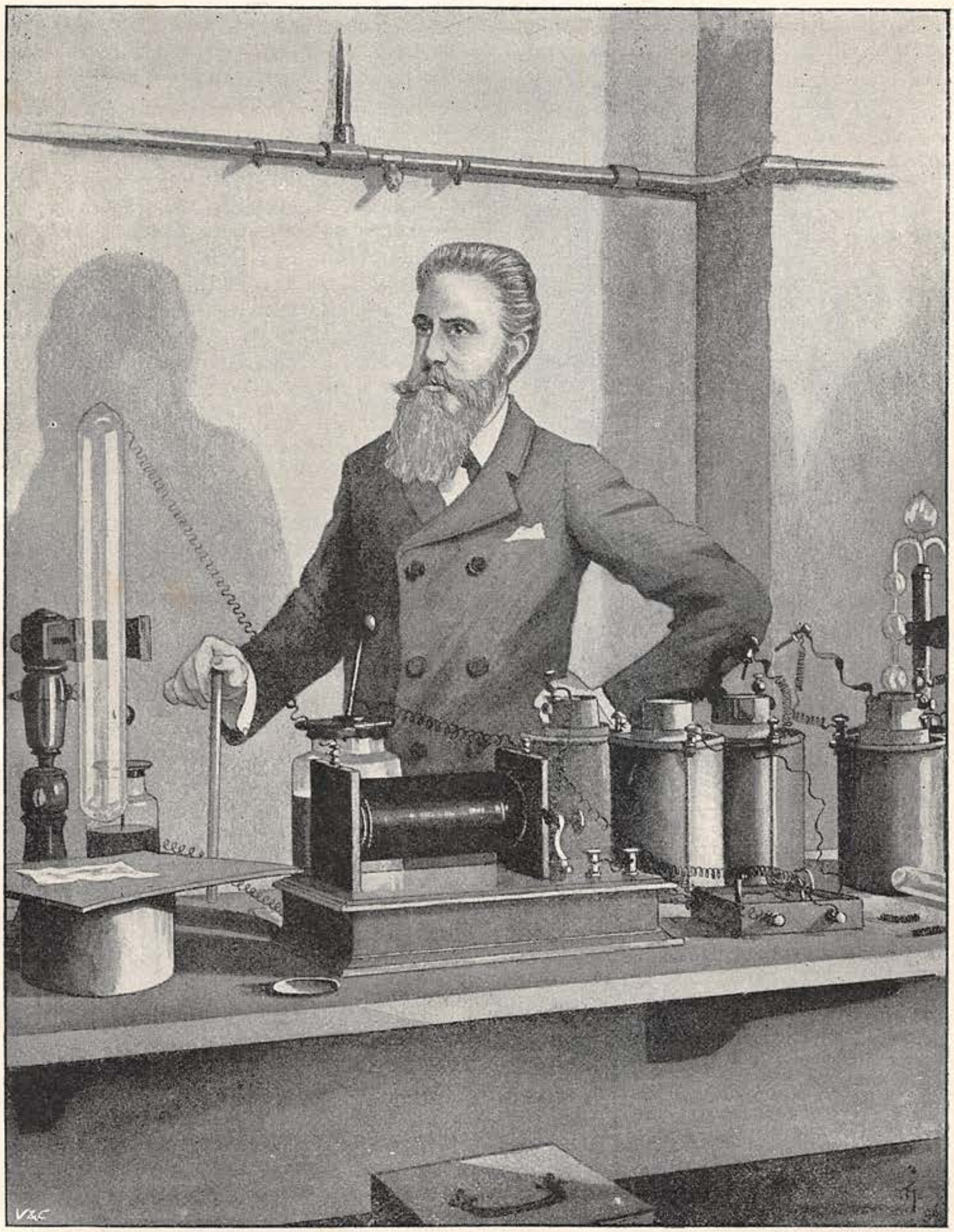
Illustrated by electrographs specially taken for the WINDSOR MAGAZINE *by* MR. *and* MRS. J. W. GIFFORD *and* MR. A. A. CAMPBELL-SWINTON.

ABOUT three months ago a simple modest statement of a discovery relating to an abstruse scientific subject was laid before a learned society in an obscure Bavarian university city by a man who was unknown to the world. The particulars were published—if publication it can be called—in the *Sitzungsberichte der Würzburger Physik-medic. Gesellschaft.* An enterprising newspaper correspondent caught at the matter, and the world was electrified with stories of how a German professor could photograph through a deal board, and take a picture of the skeleton within the living flesh. In three or four days Professor Röntgen's name was immortal, and in as many weeks the few Englishmen who had succeeded in repeating his results were overwhelmed with queries, with requests for lectures, demonstrations, and assistance generally, and with all the other worries that come to the man who is suddenly popular.

Konrad W. Röntgen is a native of the little Prussian town of Lennep, where he was born just fifty-one years ago. In 1870, after completing his military service, he became assistant in the Physical Institute of Würzburg University. Eighteen months later he took an assistantship in Strassburg, and a year later secured an appointment as professor at Hohenheim, which he left in 1876 for a similar position at Giessen. In 1888 he returned to Würzburg to become director of the Physical Institute, in which he had originally been an assistant. The results of his labours have been published in many learned essays, of which the public knows nothing, except as regards the last brief monograph, which has made him famous. When his last important work became known, his Emperor, ever interested in scientific progress, commanded a repetition of the experiments in the imperial presence, and invested the discoverer with a distinguished royal order.

It is difficult to describe in popular language the exact nature of a discovery such as that of Professor Röntgen, and to separate what is new from what was previously known. In the attempt to do so I will briefly recall some of the photographic and physical possibilities of the past. And first, as the fact which seems to have attracted most attention is that the skeleton can be photographed through the living flesh, let us turn to a paper read before the British Association in 1868 by Sir Benjamin Richardson. The subject was "The Transmission of Light through Animal Bodies," and the author stated that what he believed was the first suggestion of such work had been given many years before in Priestley's work on Electricity. The author stated that he had repeated Priestley's methods and then gone on to others of his own suggesting, with the result that "in the human subject, especially in the young, having fragile tissues, the thinner parts of the body could be distinctly rendered transparent, and in a child the bones, under a somewhat subdued light, could be seen in the arm and wrist. A fracture in the bone could in fact be easily made out, or growth from bone in these parts. In a very thin young subject the movement and outline of the heart could also be faintly seen in the chest." This, and a great deal more on the same subject, was recorded in 1868 by Dr. Richardson, who then found magnesium light the most convenient for the purpose. It is likely that, now that attention has been re-directed to the subject, the suggestion of Dr. Richardson will be exhaustively followed out, and with photographic as well as mere visual observation. With the electric light freely available, and photographic plates sensitive to red and yellow (which would be the principal rays transmitted through flesh and blood), it should be fairly easy to make valuable records; and as the scale of transparency to ordinary light is quite different from that to Röntgen rays, one system would supplement the other.

Turning to the other wonder, of photography with "invisible light," there are



Drawn by] [*Walter E. Hodgson.*

Professor Röntgen at work.

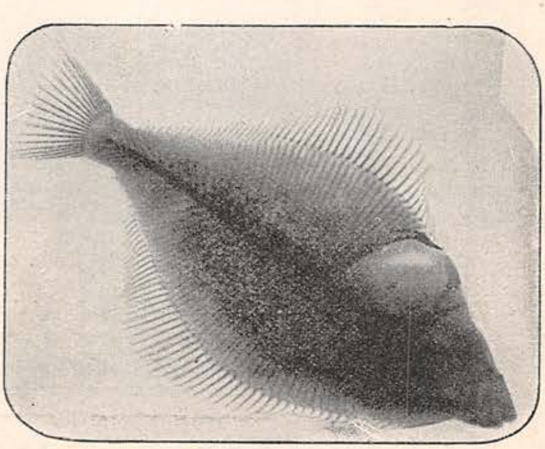
The above illustration depicts Professor Konrad Wilhelm Röntgen in the midst of his experiments on the new light. Ever since his discovery the Professor has been overwhelmed with correspondence and applications from all parts of the world. One of the most reticent of men, he has declined every attempt to pose as a "lion," although his numerous admirers would willingly draw him from his scientific labours into the fleeting popularity of a society favourite. Besides the gratifying mark of his sovereign's favour, the Professor has been just recently the recipient of a doctor's degree. He declares that he is still only on the outskirts of the possibilities of this interesting scientific marvel.

many marvels, almost as old as photography itself, over which the public might have gone off into wonderment had it been so minded.

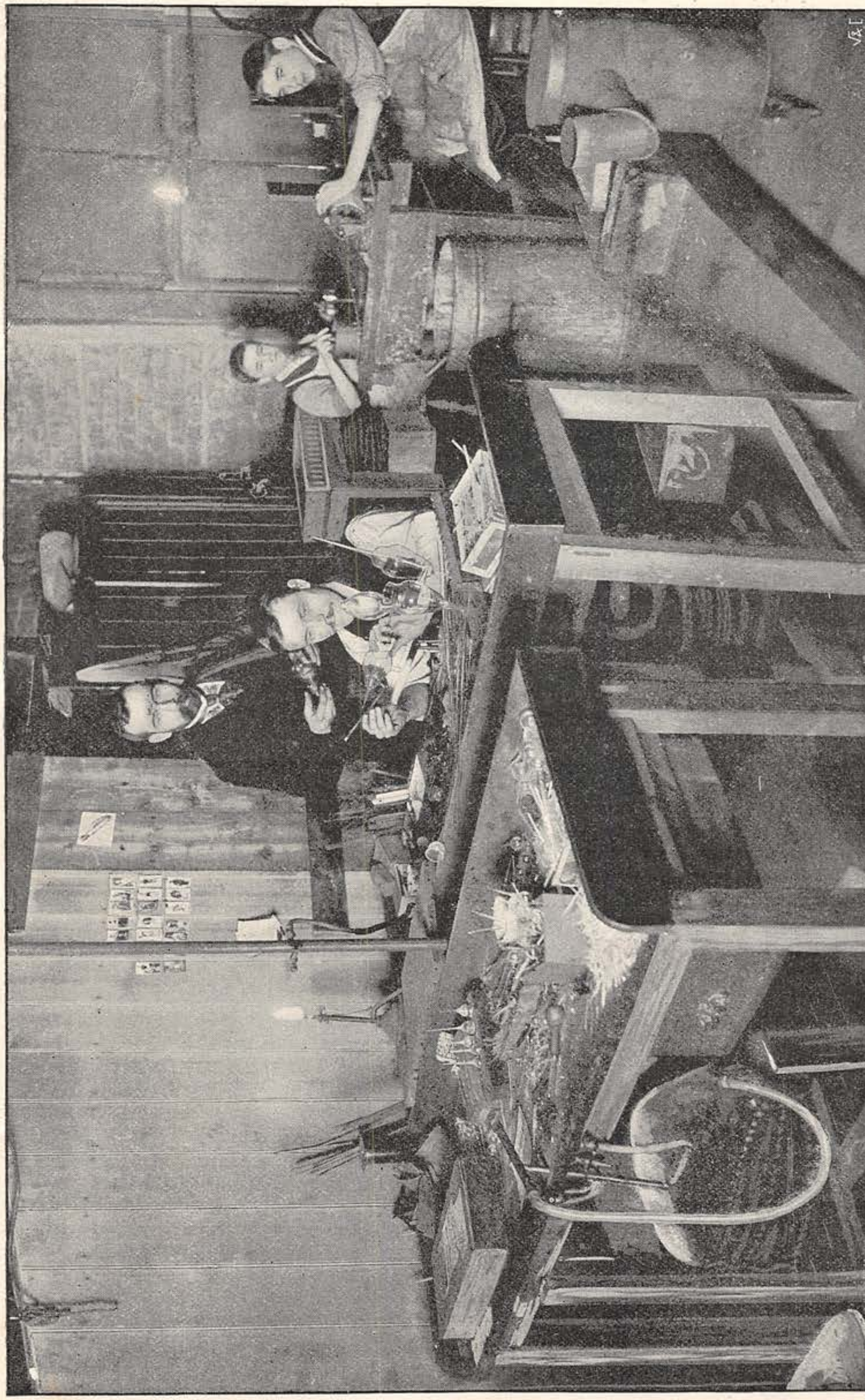
(*Copyright.*)
Back of woman's hand, exhibiting bones down to the wrist. The thumb, not being laid flat, is indistinct. A ring is shown on one of the fingers.—Electrograph by J. W. Gifford.

In Hunt's researches, published in 1840, are many interesting experiments on the effects of heat upon the photographic plate, and many electrical effects, as curious in their way as those of the Röntgen rays, are well known. The spectrum, too, has been examined by photography and found to extend far beyond its visible portion. In fact the photographically active spectrum extends, on the ultra-violet side, to nine or ten times the length of the visual spectrum. In the infra-red, too, is a long series of rays, quite invisible, but possessing chemical energy and heat. With these rays it is perfectly possible to make shadowgrams—as is done with Professor Röntgen's *x* rays—through sheets of ebonite and many other opaque substances. They are also, like the *x* rays, stopped by many "transparent" substances. It is well to bear in mind these well-known facts when approaching a subject like this new light, or one is very liable, as was the case in the present instance, to go wild over wonders that are far from new, and to miss the actual novelty and overlook the true significance of the discovery.

In the realm of electricity a long period of patient investigation by an army of separate workers has led up gradually to the wonderful results obtained by Röntgen, and it does not yet seem absolutely certain how far the force which he tentatively called the *x* rays differs from the rays with which Hertz and Lenard have made the scientific world familiar. One of the most popular of lecture-room experiments is to pass a current of electricity through a glass tube from which the air has been exhausted, and through the centre of which runs a fantastic series of coils and bulbs of glass. When the current passes, the attenuated air within the tube becomes beautifully luminous. This toy, the Geissler tube, is the first step towards the results of Röntgen. Toy though it seems in its conventional form, its phenomena have been most patiently investigated by many very able men, notably by Goldstein, Hittorf, Hertz and Lenard, as well as by Professor Crookes, whose name is given to the form in general use. Crookes' tube is usually a plain empty bulb of glass, globular, egg-shaped or pear-shaped, with two wires fused into opposite sides of it, so that their points project into the interior while their other ends are turned into little rings to which wires from an electric battery can be attached. When this tube or bulb is strongly exhausted by means of a powerful vacuum pump, and a



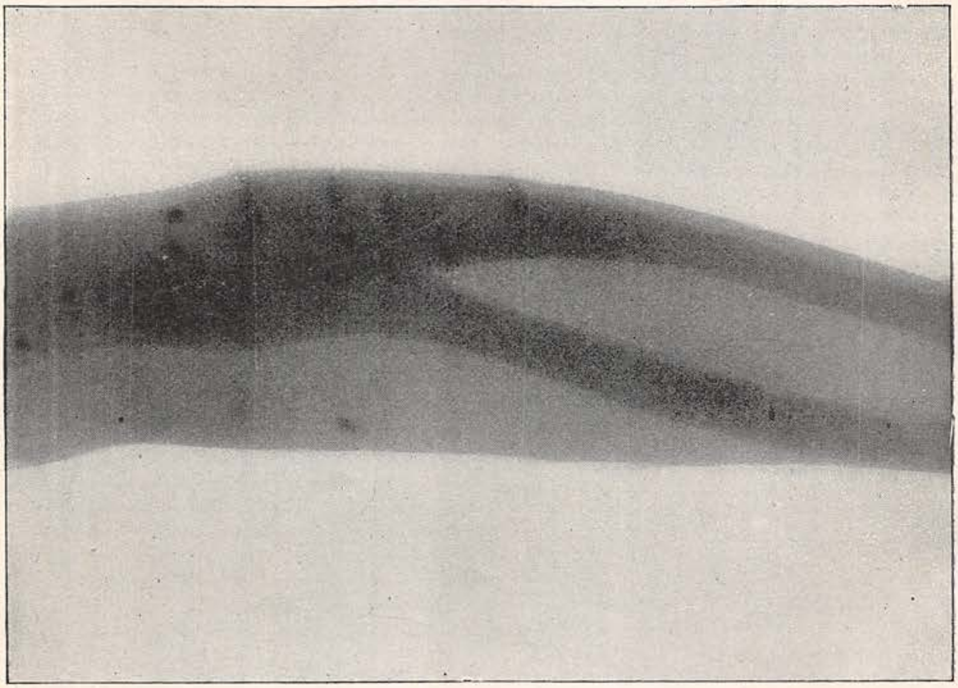
(*Copyright.*)
A plaice—Electrograph by A. A. Campbell-Swinton.



From a photo by] [*Charles W. Gamble.*

Making Crookes' tubes: a corner in Mr. A. C. Cossor's workshop.

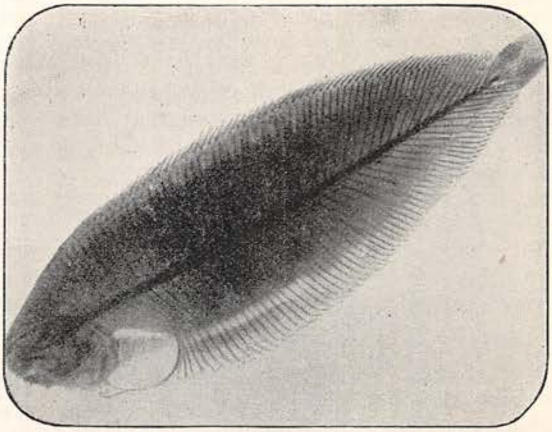
current of high tension electricity is passed through it, the violet glow that is so attractive in the toy Geissler tube is seen. Of course an absolute vacuum is impossible, and when the slight residuum consists of certain gases other than air, the colour and appearance of the discharge are varied. When air is present and the exhaustion of the tube becomes extreme, the light gradually diminishes until finally it becomes invisible altogether. At this point, when a very high-tension current is being passed through a very perfect vacuum, the best conditions for obtaining the Röntgen rays are attained. Under these conditions, and even before such complete exhaustion is achieved, it had been observed by Goldstein and Hittorf in the seventies that a series of emanations, which have been termed cathode rays, proceeded from the cathode or negative terminal in the exhausted tube. The properties of these rays are curious, one of them being the ability to cause glass and many other substances to become fluorescent. This is specially well seen when the exhaustion of the tube becomes so great that the light within it disappears, and the glass then begins to glow with a pale yellow-green light. Lenard in 1894 examined these rays very exhaustively, showed their ability to act upon the sensitive photographic plate and paper, and pointed out that they passed fairly easily through wood, cardboard, aluminium, etc., but with greater difficulty through glass and quartz. His observation of the ease with which the rays passed through aluminium led him to construct a Crookes' tube with a "window" of aluminium in the glass, and so obtain more active results. Professor Röntgen was carrying on similar experiments with the Crookes' tube when he accidentally came upon certain phenomena which led him to the conclusion that rays, other than those which had been hitherto described, were proceeding from the tube. He was working with a tube covered with black paper, impenetrable by ordinary light, and noticed that a fluorescent substance brought near the tube became luminous. This assured him that some influence was proceeding from the tube which had the power to pass through paper impervious to light, and to cause fluorescence. He found, further, that even at a distance of 6 feet from the tube the fluorescence was still excited. Pursuing the subject further Professor Röntgen found



(Copyright.)
Arm of a boy, exhibiting shot embedded.—Electrographed by J. W. Gifford on February 8.

that the rays penetrated a deal board of an inch thick, a book of a thousand pages, or a couple of packs of cards without much diminution of their power. Aluminium half an inch thick, and glass of a like thickness, allowed the rays to pass, but greatly diminished their power. Metals, other than aluminium, obstruct the rays in much greater degree, though no metal seems absolutely opaque when in thin sheets. Platinum and lead are the most opaque, with iron, silver, copper and gold coming between them and aluminium. The effect of lead is so marked that even a transparent sheet of lead-glass is much more opaque than a glass of the same thickness free from lead.

Experiment showed that the new rays had also a chemical effect upon the photographic salts of silver, obtaining a result similar to that produced by light. Photography at once became the principal method of observation, because by its means the results were permanently recorded. The power of the rays to pass through wood and card was especially useful in this connection, for it enabled the photographic experiments to be made in daylight, the plates being protected from the action of light by the usual dark slides.

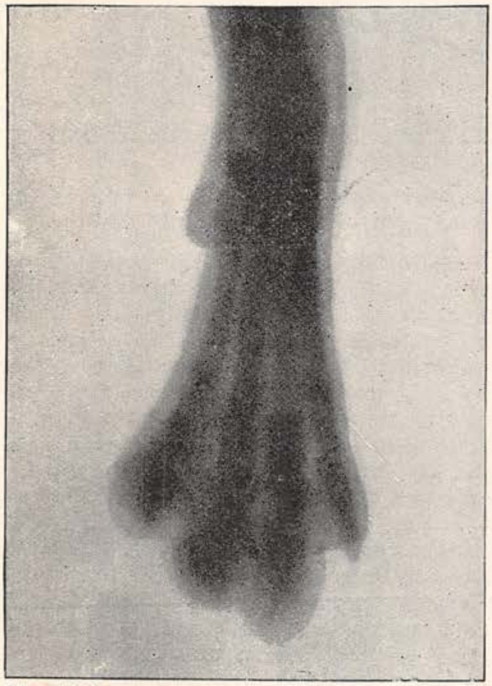


(*Copyright.*)
A sole, showing swimming bladder.—Electrograph by A. A. Campbell-Swinton.

(*Copyright.*)
Foot, showing deformity of toes owing to tight boots.—Electrograph by J. W. Gifford.

One of the most interesting properties of the Röntgen rays, which they possess in common with the cathode rays, is their inability to be reflected or refracted by any substance that the many investigators have been able to test. The cathode rays can, however, be deflected by placing a magnet in their path, while the Röntgen rays cannot, and this is perhaps the most interesting difference between the two forces. It seems probable that the new rays move with equal velocity through all substances which they can penetrate at all, and therefore that they exist in a medium which permeates all these substances. In air the penetrative power of the Röntgen rays appears to be much greater than that of the cathode rays, for their discoverer has obtained results at distances from the source at which the cathode rays are inactive. A series of observations led to the conclusion that in air the power of the new rays varies inversely as the square of the distance from the source. Thus an object through which an image upon the photographic plate can be obtained in ten minutes when placed one foot from the Crookes' tube, would require forty minutes at a distance of two feet. In all other bodies that Professor Röntgen has examined the penetrative power of his new rays is greater than that of the cathode rays, though it would be premature to say whether there is any regular proportion of penetrative power in the different substances.

The researches of Röntgen, dealt with in the communication from which I have quoted, include many other details, interesting to the physicist, but hardly such as need be repeated in a popular paper. In all there seems to be an agreement in the main between the new rays and the cathode rays, differences being in degree rather than in kind. The particular property that has most attracted the public, viz., the ability to penetrate wood, ebonite, etc., is very largely shared by the cathode rays, so much so in fact that there seems reason to believe that many of the results that have been shown since the discovery was announced are largely due to the cathode rays. On the essential difference (if any) between the two classes of rays much patient investigation is yet needed. On many other points in connection with Röntgen's discovery men are busily at work in all parts of the world, and we may almost daily expect new wonders in the way of practical applications. The first objects which many of the investigators have in view are the simplifying and cheapening of the necessary apparatus, and the decreasing of the length of exposure by increasing either the power of the rays or the sensitiveness of the photographic plates. In these directions something has been done, even at the time of writing, and before these lines appear great advances will doubtless have been made. At the time of writing the latest announcement is by Mr. Campbell-Swinton, who has been able to reduce the exposure necessary for showing the bones in a mature human foot to fifty-five seconds, instead of the long time (from twenty minutes to an hour or more) that has hitherto seemed necessary.



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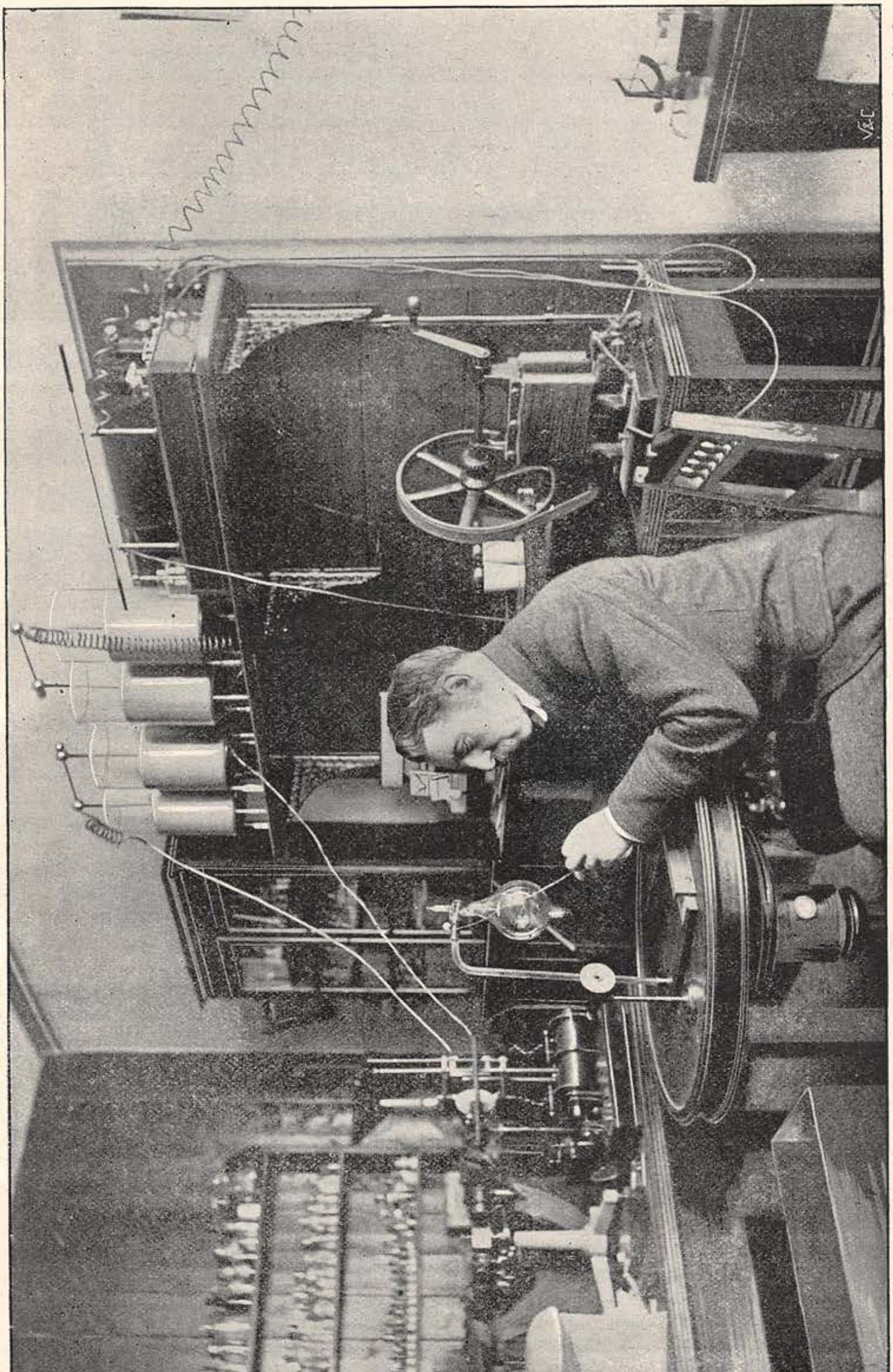
A cat's paw, after four minutes' exposure.—Electrograph by Mrs. J. W. Gifford.

At this point I may briefly describe the necessary apparatus, which consists of (*a*) a source of electricity, (*b*) an induction or intensity coil, and (*c*) a Crookes' tube. The first may be the street mains, a battery of ten or a dozen large cells, a hand dynamo, or a powerful Wimshurst machine. The intensity coil should be capable of giving a six or seven inch spark in ordinarily dry air, and the Crookes' tube should be of the greatest possible exhaustion. All these conditions are subject to modification, and even at the time of writing there are reports of satisfactory results obtained with an electric tension capable of giving no more than a two-inch spark; and other cases where the power is ample, but the highly exhausted tube is replaced by a broken-down incandescence lamp, with a metal plate outside to form the cathode. For those who are not well acquainted with electrical apparatus I may refer to the portrait of Mr. J. W. Gifford in his laboratory, in which he is seen connecting up the Crookes' tube which hangs before him upon an insulating support. Immediately behind him stands a hand dynamo, with a driving wheel at the further, and a handle at the nearer, side. On the shelf above the dynamo is a ten-inch Apps' intensity or induction coil, the term ten-inch referring to the length of spark it is calculated to give, which is a fair measure of the tension of the electricity. The charge from such a coil will kill a couple of men, so that it is not a power to be played with. On the table immediately beyond the round one at which Mr. Gifford is seated is another form of intensity coil, capable of giving a three or four inch spark.

With such a set of apparatus—the dynamo being driven by a sturdy pair of arms—a photographic plate can be placed beneath, or at front or side of the Crookes' tube, and in a few minutes (although enclosed in its light-tight dark slide) will have all the effects of an exposure to light. If a hand be laid upon the dark slide the rays from the tube will

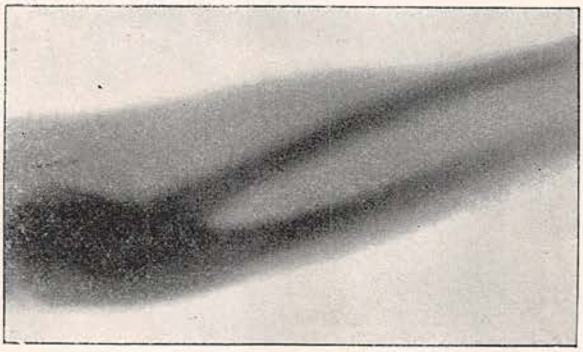


From a photo by] [*Higgins, Chard.*

Mr. J. W. Gifford experimenting in his laboratory at Chard.

penetrate the flesh, but as the bones are relatively impenetrable they will show, when the plate is developed, as distinct shadows. In the same way if pieces of glass, metal objects, etc., are placed on the slide their shadow-images will be found upon development clear in proportion to their power of obstructing the Röntgen rays.

This should explain why the results are called shadowgrams, for photograms are made by reflected light proceeding from the surface of an object, while these new results are distinguished from the surrounding surface by the amount of light which they obstruct. It is true that modelling and relief may be obtained with the new rays, but it is a modelling entirely due to the variation of density and thickness, which may or may not coincide with the surface contour. A curious example of this would be given if a penny were shadowgraphed with a sufficient exposure to give a slight action through the thickest parts of the coin. In the thinnest parts the action would be most complete, while in other portions the strength of the image would vary according to the thickness and the "image and superscription" would be a strange medley of the portrait of our sovereign lady and the mythical figure of Britannia.



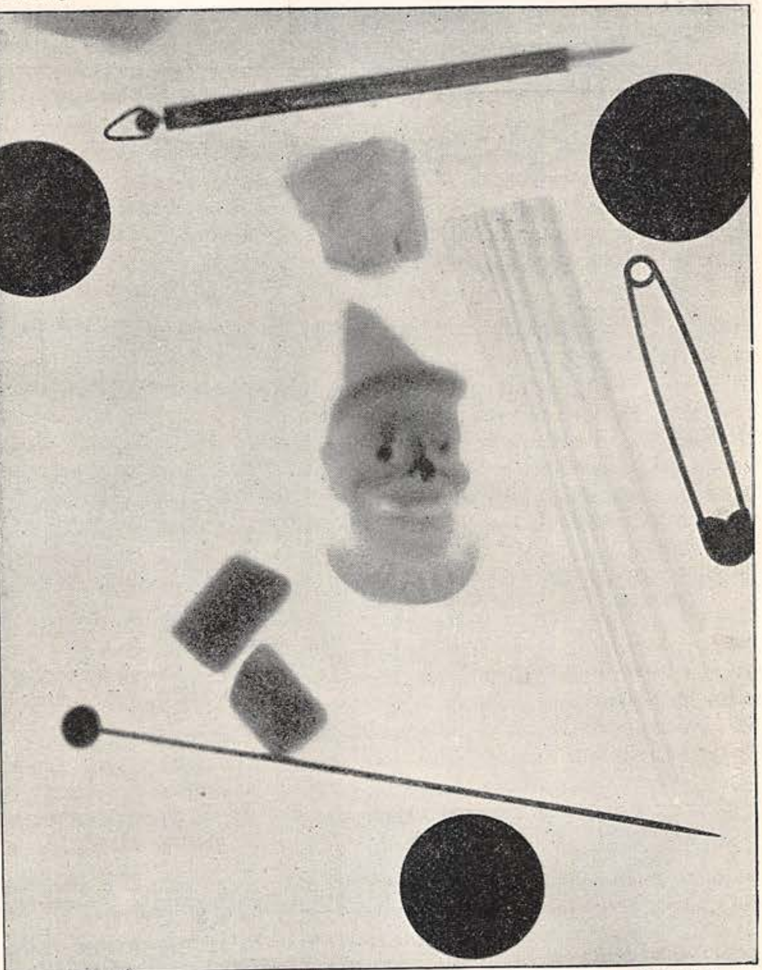
(*Copyright.*)
Elbow-joint of a girl.—Electrograph by J. W. Gifford.

The practical applications of "the new photography" have been so fully recorded in the newspapers that it is unnecessary to do more than recapitulate a few of them. The surgical advantages were at once appreciated, and though many wild and impossible things were announced at first, there were almost immediate practical cases which proved its real value. The positions of pellets and bullets in wounded hands were shown in such a way as to secure their removal without unnecessary probing. A needle, which had defied the surgeon's efforts to find it without mercilessly carving the hand, was exactly located and easily removed. A glass-worker's hand, into which several splinters of glass had been driven, was shadowgraphed and successfully operated upon, and many cases of abnormal and diseased bones became fully patent to the surgeon by the revelations given in the new light. In fact the few workers were overwhelmed with applications for their professional services from doctors and sufferers of all degrees. Mrs. Gifford, who assisted her husband in his experimental work, wrote me at the beginning of February: "Our house has become a veritable hospital; the halt and the maimed are begging us to help them to diagnose their exact infirmities." No doubt before long we shall have public laboratories fitted for this work, and probably one will be attached to every great hospital. Dr. Oliver Lodge pointed out another direction in which the new rays could be used with great advantage, namely, in the testing of metals for flaws and faulty mixing in alloys. Dr. Lodge has shown that inequalities of substance are clearly indicated by the varying action of the rays when the metals acted upon are in sufficiently thin sheets to be penetrated, and there is a possibility that as the subject is further investigated and the apparatus improved we may be able to test such objects as compressed gas cylinders, boiler-plates, and even, eventually, armour plates and heavy ordnance.

When the first accounts of Professor Röntgen's work reached England many British investigators took up the subject, in spite of the vague and somewhat contradictory nature of the reports. The first public announcement was made on January 13 by Mr. J. W. Gifford, of Chard, in a communication to the President of the Royal Photographic Society. On the 16th of the same month the first English results were shown at the Camera Club by Mr. A. A. Campbell-Swinton, and a few days later, on the 21st, Mr. Gifford made a further communication to the Royal Photographic Society and at the same time sent a series of his results. These were not only Röntgen ray work, but also some very interesting electro-photographic results obtained in an attempt to get Röntgen rays without a Crookes' tube.

Many other investigators took up the work, but in too many cases the impossibility of obtaining reliable apparatus prevented their obtaining results. Still, results were obtained in some cases. Dr. Oliver Lodge, as before mentioned, did good work in Liverpool. Dr. Dawson Turner, of Surgeon's Hall, Edinburgh, quickly followed by Lord Blythswood, Dr. J. T. Bottomley, F.R.S., and Dr. McIntyre announced satisfactory pictures. In Bristol, Professors Chattock and Wertheimer; in Birmingham, Dr. Hall Edwards and Mr. Fredk. Iles; and in London Mr. A. W. Porter, Mr. Leslie Miller and others satisfactorily repeated the experiments before the end of January. A man who greatly helped toward this successful end, and who suddenly found himself overwhelmed with fame, was Mr. A. C. Cossor, of Farringdon Road, London, who for a while seemed to be the only man able to make satisfactory Crookes' tubes. While ordinary Crookes' tubes could be bought retail at eightеenpence each, in any quantity, the tubes made by Mr. Cossor were in such demand that the agents who had purchased all his output were quite unable to cope with the demand, though the price was twenty-five shillings each. Even at that price there were doctors, professors and others who begged for the favour of a place on the list, to be supplied in a fortnight's time. Never had the scientific glass-blower been in such demand, and never was the value of the difference between good work and *the best* more fully demonstrated. It is easy to make a tube that will answer for some of Professor Crookes' radiant-matter experiments, but the further exhaustion to fit that same tube for Röntgen's work requires great skill and very perfect apparatus to obtain. Hence I have taken the somewhat unusual course of introducing a portrait of Mr. Cossor at his work.

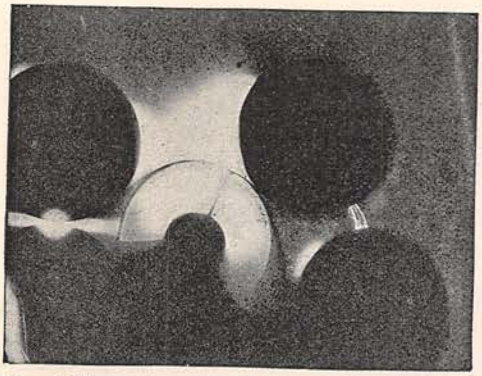
A shilling. A halfpenny.



(*Copyright.*) India-rubber face from a bon-bon. A sovereign. Splinter of firewood.

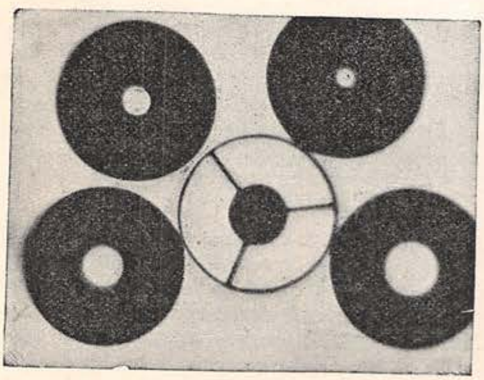
"Forfeits."—Electograph by Mrs. J. W. Gifford.

Mr. J. W. Gifford, whose name has been so much before the public, and to whom I am indebted, not only for many of the examples here reproduced, but also for the permission to use his laboratory and to assist



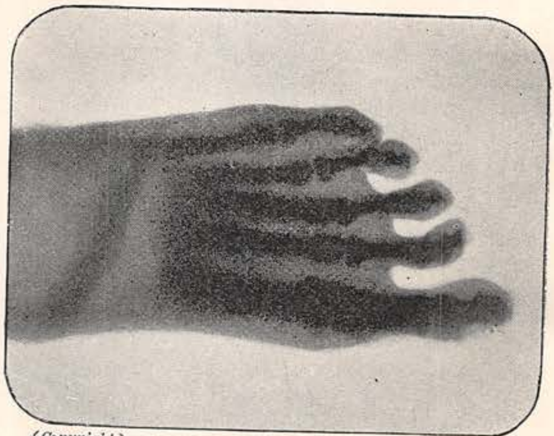
(*Copyright.*)
Taken without Crookes' tube. Metal discs through cardboard box. Exposure ten minutes. Showing electrical discharge.—Electrograph by J. W. Gifford.

him in repeating some of the most interesting experiments, is fortunate in being a gentleman of means and of reasonable leisure. The owner of a large and prosperous lace-weaving business in Chard, his well-appointed private laboratory gives him every opportunity to indulge his love for scientific investigation. As a volunteer assistant of Professor Crookes he has done valuable investigation work in physics, as well as most useful original research on his own account in photographic, electrical and photo-micrographic subjects. With the assistance of Mrs. Gifford, who takes a keen interest in the work, he has devoted much time to the new light, with results that have been shown at lectures in Bath and Bristol, and before the Royal Photographic Society in London.



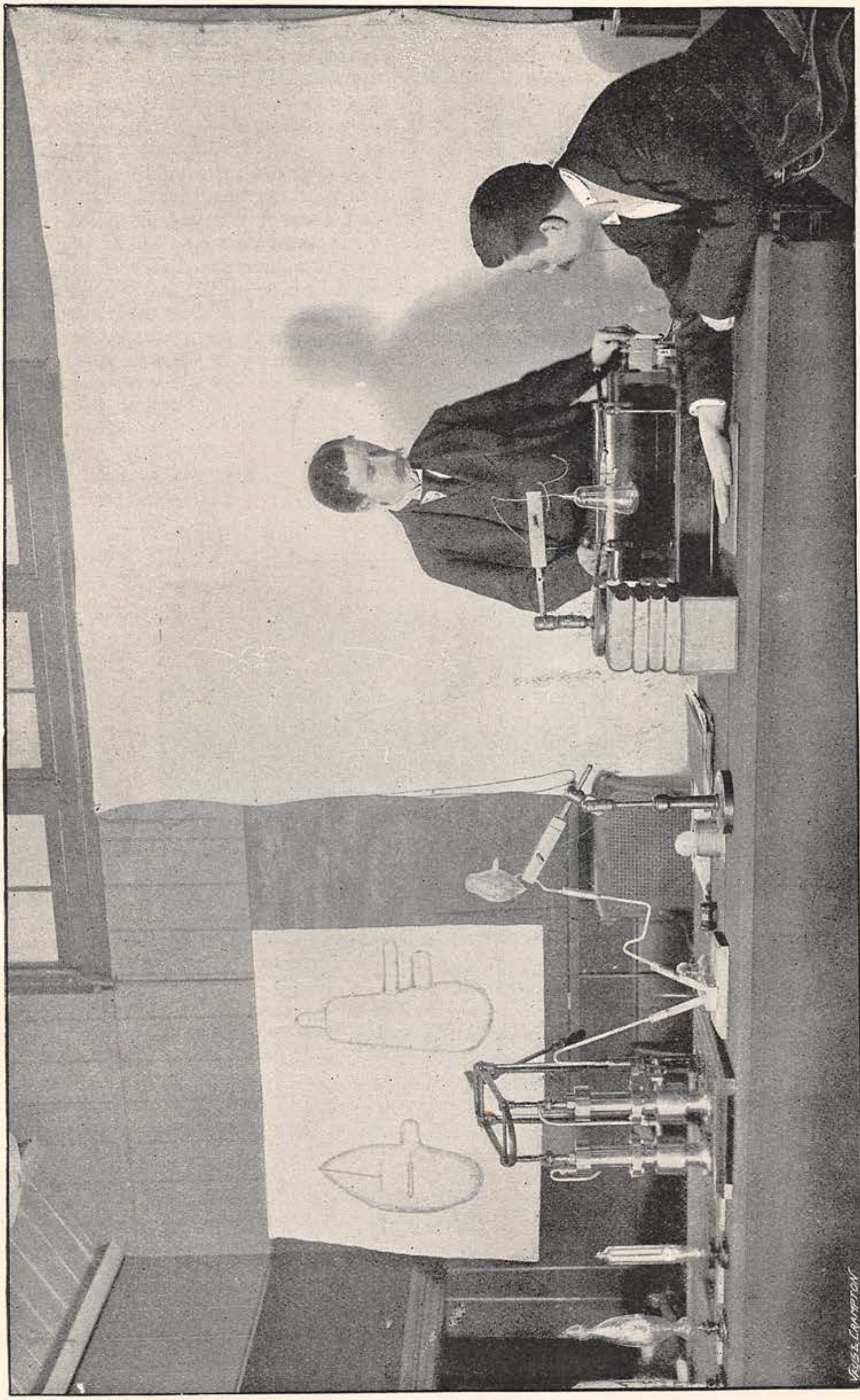
(*Copyright.*)
Metal discs through two sheets of cardboard and a sheet of aluminium. Aluminium between discs and plate. Exposure ten minutes.—Electrograph by J. W. Gifford.

Mr. A. A. Campbell-Swinton, whose name has also been much before the public, and whose work has been reproduced in a hundred newspapers and magazines, is an electrical engineer with offices and laboratory in Queen Victoria Street. A young man, he is one of the many bright and talented investigators who have come from Elswick, trained by Sir W. G. Armstrong, Mitchell & Co. His invention of an important improvement in telephones led to his securing an appointment with a telephone company and removal to London. He has been greatly interested in photography, and a few years ago gave considerable time to the subject, but the increase of electrical work forced him to drop photography and to cease his membership of the Camera Club, of which he had been a member for some years. A portion of his enthusiasm is due to the hearty encouragement of Mr. J. W. Swan, the veteran electrician, and he modestly attributes much of the success of the recent investigations to the energy and ability of Mr. J. C. M. Stanton, his assistant.



(*Copyright.*)
Human foot. One of the shortest successful exposures made (55 seconds).—By A. A. Campbell Swinton.

Day by day we expect, and almost every day we are receiving, reports of fresh developments of this wonderful "new photography." Many of the announcements are based upon hasty and half-understood experiments, made by workers without the necessary training for careful observation. The work of Hunt, published in the *Philosophical Magazine*, October 1840, is being unconsciously repeated by many who know nothing of Hunt or his work, and who are confounding the well-known action of heat with some supposedly novel action of light, or the Röntgen rays.



Mr. A. A. Campbell-Swinton surrounded by his apparatus used in lecturing before the Royal Photographic Society.

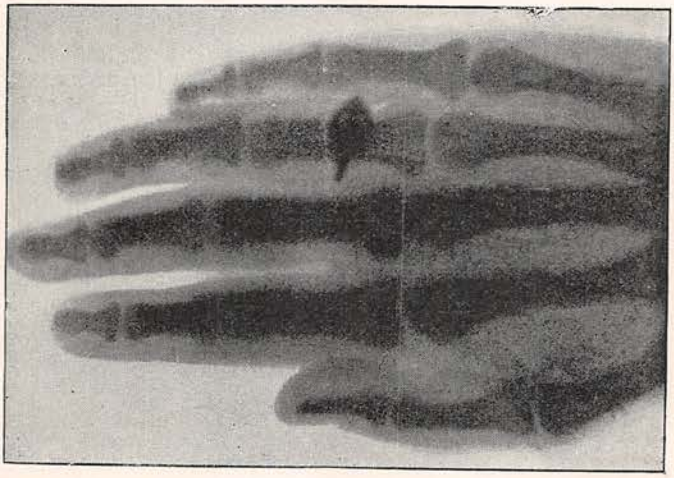
(Specially photographed for the WINDSOR MAGAZINE *by Charles W. Gamble.)*

It is well to take with an ample grain of salt the announcements, based upon one or two experiments only, by men untrained in observation. The most wonderful advance recorded at the time of writing is the invention of Professor Salvioni, of Perugia, of an instrument by which the Röntgen rays may be *seen*. In the absence of all detail it is impossible to comment upon such an announcement, beyond saying that if Professor Salvioni's invention is not exactly what we expect, the direction is one in which we may hope for practical results.

With regard to the electrographs we give from photographs taken by Mr. and Mrs. Gifford, it is worth while noting that the whole of the photos were taken between February 1 and February 10.

It may also be of interest to mention that Mr. J. Lynn Thomas, F.R.C.S., writes concerning the arm, of which we give an illustration on page 376 : "I could feel distinctly one shot near the posterior border of the ulna, and it was so situated that the x rays had to penetrate the whole thickness of the ulna before reaching the shot. If this shot shows in the electrograph, it will demonstrate very clearly that bone after all is only comparatively opaque to the new rays."

London, February 12, 1896



A hand, exhibiting the transparency of cornelian in the ring on third finger.
Electrograph by J. W. Gifford.