THE RÖNTGEN RAYS IN MEDICAL WORK

WALSH

HARVARD MEDICAL LIBRARY

RÖNTGEN

THE LLOYD E. HAWES COLLECTION IN THE HISTORY OF RADIOLOGY

THE RÖNTGEN RAYS IN MEDICAL WORK


PLATE. I.
ONE FIFTH.

THE RÖNTGEN RAYS IN MEDICAL WORK.

BY

DAVID WALSH, M.D. Edin.,

Physician Western Skin Hospital, London;
Hon. Sec. Röntgen Society, London.

SECOND EDITION,

REVISED, REWRITTEN, AND ENLARGED

WITH MANY ADDITIONAL ILLUSTRATIONS

Φάος κάλλιστον τῶν προτέρων

LONDON:
BAILLIÈRE, TINDALL AND COX,
20 & 21, KING WILLIAM STREET, STRAND.
1899.

PREFACE TO SECOND EDITION.

In preparing Part I. of this edition the author has been deprived of the valuable help of Mr. Greenhill, and has, therefore, himself re-written that portion of the book. Since the first edition appeared there have been no great discoveries to record, but rather a general advance along the line. In practical work the times of exposure are shorter, results more certain, and the merits of the statical machine more widely recognised. The author has cordially to thank many friends for advice and help, kindness which has been acknowledged as far as possible in the text.

D. W.

9, Bentinck Street, London, W.
June 1st, 1899.

PREFACE TO FIRST EDITION.

SINCE the famous discovery announced by Professor Röntgen at the end of the year 1895, a new science has sprung into being. This branch of knowledge, although still in its early and undeveloped stages, has found a special application in medical work.

In this little volume the aim has been to deal with the present practical scope of the Röntgen rays so far as physicians and surgeons are concerned. An attempt has been made to treat the matter systematically, and to point out limitations and possibilities as well as to record actual achievements. In this endeavour the author has received invaluable help from Mr. J. E. Greenhill, who has also kindly written an introductory part dealing with electrical methods and apparatus. He is also indebted to Messrs. Barwell, Mackenzie Davidson, Lynn Thomas, Professor Waymouth Reid, and many others, for the use of Röntgen photographs and of notes of cases. Where all is new it is by no means easy to decide what is likely to prove ultimately true; but the task of selection has been guided by a constant reference to the everyday conditions of medical practice.

D. W.

September 1, 1897.

CONTENTS.

	PAGE
INTRODUCTORY	13-15

PART I.

ELECTRICAL APPARATUS AND METHODS.

I. SOURCES OF ELECTRICITY	17
A. BATTERIES	17
(*a*) PRIMARY	17
(*b*) STORAGE OR SECONDARY BATTERIES	22
B. DYNAMOS	25
C. STATICAL MACHINES	28
II. TRANSFORMERS TO HIGH POTENTIAL	31
A. THE INDUCTION COIL	31
B. THE TESLA COIL	37
C. THE TESLA OSCILLATOR	37
III. THE VACUUM TUBE	38
IV. THE EXHAUST PUMP	43
V. THE FLUORESCENT SCREEN	46
VI. PHOTOGRAPHY	47
PRINTING FROM NEGATIVES	51
INTENSIFYING SCREEN	53
DEFINITION	54
LOCALIZATION	57
STEREOSCOPY	58
VII. STANDS AND OTHER ACCESSORIES	61
OPERATING-TABLE	63
VIII. PRACTICAL APPLICATION OF THE RAYS	64
A. EXAMINATION OF PATIENT	67
B. FALLACIES	71
IX. THEORY	72

PART II.

MEDICAL AND SURGICAL APPLICATIONS.

CLASSIFICATION	75
A. SURGERY	77
I. FOREIGN BODIES	77
MILITARY SURGERY	80

PAGE

I. Foreign Bodies (*continued*).
Gunshot Wounds in Civil Practice - - - 85
Localization of Foreign Bodies - - - - 89
Mackenzie Davidson's Localizing Apparatus - - 93
Foreign Bodies in Brain - - - - - 97
Foreign Body lodged in Spine - - - - 102
Foreign Bodies in Neck and Thorax - - - 103
,, ,, Abdomen - - - - - 107
,, ,, the Eye - - - - - 111
Calculi in Various Positions - - - - 117
II. Bones - - - - - - - - 123
(*a*) General Remarks - - - - - - 123
(*b*) Fractures and Dislocations - - - - 126
Special Fractures - - - - - 133
Fractures about the Head - - - - 145
Dislocations - - - - - - 149
(*c*) Injuries to Epiphyses - - - - - 152
(*d*) Congenital and other Bony Deformities - - 156
(*e*) Diseases of Bone - - - - - - 163
Hæmophilic Bone Conditions - - - - 168
Caries of Bone - - - - - - 169
Bones in Leprosy and Syphilis - - - - 171
(*f*) Other Surgical Points — To ascertain Results of Osteoplastic Operation - - - - - 172
(*g*) Action of the Rays upon Micro-organisms - - 173
III. Mapping of Skin Surfaces - - - - - 175
B. Dental Surgery - - - - - - - 176
C. Nasal and Throat Surgery - - - - - - 180
D. Medicine - - - - - - - - 182
IV. Regional - - - - - - - - 182
(*a*) Thorax and Abdomen - - - - - 182
(*b*) Heart and Great Vessels: Aneurisms, Enlargements of Heart, and so on - - - - 186
Atheroma of the Aorta - - - - - 191
(*c*) Lungs and Lung Diseases: Pleurisy, Pneumonia, Phthisis - - - - - - - 191
(*d*) The Abdomen - - - - - - - 197
Practical Conclusions - - - - - 199
V. Other Medical Points - - - - - - 200
The Diagnosis between Gout and Rheumatoid Arthritis - 200
Calcification of Arteries - - - - - 201
VI. Action of the Focus Tube upon the Skin and Deeper Structures - - - - - - - 201
VII. Therapeutics - - - - - - - 213
Deep Therapeutic Action - - - - - 216
Effects of X-Rays in Colour-Blindness - - - 219
Effects in Tuberculosis - - - - - 219
E. Obstetrics and Gynæcology - - - - - - 221
Obstetrics - - - - - - - - 221
Gynæcology - - - - - - - - 224

PAGE

F. Legal Medicine - - - - - - - - 225
I. Evidence of Injury - - - - - - 226
II. Evidence of Identification - - - - - 227
III. Evidence of Pregnancy - - - - - 228
IV. Evidence of Age of Fœtus - - - - - 229
V. Evidence of Death - - - - - - 229
VI. Evidence in Action for Malpraxis - - - - 230
Hints in preparing Evidence - - - - - 232
G. Anatomy - - - - - - - - 234
Anatomy of Bloodvessels - - - - - 234
H. Physiology - - - - - - - - 238
I. The Rays in Veterinary Surgery - - - - - 240

APPENDIX.

A New Form of Radiation, being a Preliminary Communication to the Würzburg Physico-Medical Society, by Professor Wilhelm Konrad Röntgen, December, 1895 - - - - 243

Index - - - - - - - - - - 251

LIST OF ILLUSTRATIONS.

PLATES.

FIG.			PAGE
I.	MAPPING OF SKIN SURFACE		*Frontispiece*
II.	PIN IN LARYNX (NUMBERED 28)	*Facing*	103
III.	COIN IN GULLET (NUMBERED 29)	*Facing*	105
IV.	STONE IN BLADDER (NUMBERED 32)	*Facing*	122
V.	NORMAL CHEST (NUMBERED 56)	*Facing*	192
1.	GROVE CELL		18
2.	BICHROMATE CELL		19
3.	BICHROMATE BATTERY		19
4.	CELLS IN SERIES		21
5.	CELLS IN PARALLEL		21
6.	VOLTMETER AND AMMETER		24
7.	SECONDARY CELL		25
8.	SECONDARY BATTERY		25
9.	SCHALL'S RHEOSTAT		26
10.	WIMSHURST MACHINE		28
11.	APPS-NEWTON 10-INCH SPARK COIL, APPS' CONTACT BREAK, TUBE WITH SPECIAL INDIARUBBER PROTECTOR (WEBSTER'S)	*Facing*	32
12.	VRIL CONTACT-BREAKER		33
13.	ELECTRO-MAGNETIC BREAK		34
14.	THE WEHNELT ELECTROLYTIC CONTACT BREAK		35
15.	MOTOR MERCURY BREAK		36
16.	PLAN OF COIL		37
17.	FOCUS TUBE FOR CONTINUOUS CURRENT		39
18.	FOCUS TUBE FOR ALTERNATING CURRENT		39
19.	COX'S RECORD TUBE		40
20.	WATSON AND SONS' PENETRATOR		41
21.	TOEPLER MERCURY PUMP		44
22.	THE CRYPTOSCOPE		47
23.	AFTER A STEREOSCOPIC PHOTOGRAPH SHOWING HORIZONTAL BAR WITH CROOKES' TUBE AND 'CHANGING BOX' ARRANGED FOR TAKING STEREOSCOPIC RADIOGRAPHS	*Facing*	58
24.	AFTER A STEREOSCOPIC PHOTOGRAPH OF A WHEATSTONE'S STEREOSCOPE	*Facing*	60
25.	TUBE-HOLDER		61
26.	STAND (WATSON'S)		62
27.	ROWLAND'S STAND FOR TUBE AND CONDUCTING WIRES		62
28.	OPERATING-TABLE		63

FIG. PAGE

29. Davidson's Couch, with shifting Tube-Holder, for Röntgen Ray Work - - - - - - - - - - 64
30. Complete Apparatus for Röntgen Ray Work - - *Facing* 64
31. Finger showing Absorption of Bone and Fibrous Anchylosis - 79
32. Shot embedded in Muscular Forearm - - - - - 86
33. Bullet in Shoulder, lying on Scapula - - - - - 87
34. Thumb showing Leaden Débris and Absorption of Bone (Distal End of Metacarpal) after Impact of Bullet - - - 88
35. Needle in Finger, showing Eye - - - - - 89
36. Diagram showing Path of Rays - - - - - - 90
37. Diagram showing Path of Rays - - - - - - 91
38. Diagram showing Path of Rays - - - - - - 92
39. Mackenzie Davidson's Cross-Thread Localizer - - - 95
40. Diagram - - - - - - - - - - - 96
41. Three Bullets in Head of a Cadaver; One in Neck; reduced about one-third - - - - - - *Facing* 97
42. Bullet in Brain (or within Skull) of Living Subject - *Facing* 98
43. Diagram explaining Dr. Reid's Case - - - - *Facing* 98
44. Diagram - - - - - - - - - - - 102
45. Stomach of 'Ostrich Man' distended with a Mass of Metallic Articles and Glass, which caused his Death - - - 109
46. Watch and Chain in Œsophagus, swallowed by 'Ostrich Man' - 110
47. Shot in Eyeball of Rabbit - - - - - - - 111
48. Pellet and Fragment of Lead in Human Eye - - - 112
49. Sweet's Localizing Apparatus - - - - - - 113
50. Davidson's Eye Apparatus - - - - - - - 114
51. Three Small Bones from Foot of Sheep: on Left, Normal; in Centre, Decalcified; on Right, Calcined (and Cracked by the Heat) - - - - - - - - - - 123
52. Lynn Thomas's Distortion Experiment - - - - - 128
53. Injured Right Hand of Workman - - - - *Facing* 128
54. Lane's Screw in Tibia - - - - - - *Facing* 130
55. Fracture of Humerus united with a Forward V-shaped Bend *Facing* 132
56. Double Colles' Fracture showing Ordinary Fracture of Radius with Outward Displacement, and Fracture of Styloid Process of Ulna - - - - - - - - - - 133
57. Double Colles' Fracture showing Longitudinal Fracture of Radius with Slight Impaction, and Fracture of Styloid Process of Ulna - - - - - - - - - 134
58. Colles' Fracture, with Rupture of Radio-ulnar Ligament - 135
59. Double Fracture of Forearm, showing Displacement; Grain of Wooden Splint plainly shown - - - - - - 137
60. Double Fracture of Forearm, showing Displacement - - 138
61. Hand showing Old-Standing Fracture of Metacarpal Bone, Result of Cogwheel Accident - - - - *Facing* 140
62. Rare Spiral Fracture of Tibia - - - - *Facing* 142
63. Fracture of Tibia and Fibula; Three Months after Injury; no Outward Deformity - - - - - - - *Facing* 144

FIG.		PAGE
64.	Fracture of Lower End of Fibula, with Dislocation of Ankle-joint - - - - - - - - *Facing*	144
65.	Backward Dislocation and Fracture of Body of Astragalus -	145
66.	Fracture-Dislocation of Cervical Spine - - - *Facing*	146
67.	Fracture-Dislocation of Cervical Spine (From side) - -	148
68.	Fracture-Dislocation of Neck - - - - - -	148
69.	Backward Dislocation of Bones of Forearm in a Child - -	150
70.	Pelvis, showing Rickety Distortion of Neck of Thigh-bones *Facing*	150
71.	Backward Dislocation (old) of Metacarpo-phalangeal Joint of Thumb - - - - - - - - -	151
72.	Pure and Complete Separation of Epiphysis - - -	155
73.	Partial Separation, with Fracture of the Diaphysis - -	155
74.	Partial Separation, with Fracture of the Epiphysis - -	155
75.	Complete Separation, with Fracture of the Epiphysis - -	155
76.	Talipes Equinus in a Young Man of Nineteen - - -	157
77.	A Normal Foot bent strongly downwards - - - - -	158
78.	Mr. Reeves' Case—Thumbless Right Hand of Patient in Fig. 80 *Facing*	158
79.	Dr. Beatson's Case of Bifid Terminal Thumb Phalanges - -	160
80.	Mr. Reeves' Case of Deformed Left Upper Limb, showing Bony Outgrowth from Humerus and Deficiency of Elbow-joint and Bones of Forearm - - - - - - - *Facing*	160
81.	Polydactylism: Hands of a Girl of Twelve - *Facing*	160
82.	Feet of same Patient, showing Suppression of Toes and possible Reversion to Two-toed Type - - - - *Facing*	160
83.	Hallux Valgus - - - - - - - - *Facing*	160
84.	Dr. S. D. Clippingdale's Case of Deficiency of Development of Distal Portion of Upper Extremity - - - *Facing*	160
85.	Ossifying Enchondroma of Finger, of old Standing: following Injury - - - - - - - - - -	164
86.	Hand deformed by Chronic 'Rheumatoid' or Osteo-Arthritis *Facing*	166
87.	Finger of Cricketer, showing Absorption of Bone and Fibrous Adhesions of Joint - - - - - - - -	167
88.	Knee in Hæmophilia - - - - - - - -	169
89.	Knee-joint showing Erosion of Cartilage of Femoral Epiphysis. Shaft of Femur Healthy - - - - - *Facing*	170
90.	Skiagram of Teeth, showing Various Pathological Conditions -	177
91.	Half-grown Cat, showing Bronchi, Liver, Heart, etc. - -	183
92.	Aneurism of Aorta in which Physical Signs were absent - -	189
93.	Empyema and Collapsed Lung - - - - - -	196
94.	Fœtus from an Extra-uterine Fœtation - - - *Facing*	222
95.	Fœtal Monster - - - - - - *Facing*	222
96.	Injected Bloodvessels of Human Kidney - - - - -	235
97.	Injected Bloodvessels of Human Heart - - - - -	236
98.	Phalanges of Horse's Hoof - - - - - - -	241

THE RÖNTGEN RAYS IN MEDICAL WORK

INTRODUCTORY

In December, 1895, Professor Röntgen announced his since famous discovery to the Physico-Medical Society of Würzburg. On that memorable occasion he described certain rays which, themselves invisible, were capable of penetrating many substances opaque to ordinary light. Like numerous other scientific advances, the starting-point of his researches was due to the happy chance of an accidental observation. While making experiments with what is known as a Crookes' tube—that is to say, a glass tube exhausted of air and rendered luminous by the passage of an electric current through its vacuum—he noticed that a piece of paper covered with barium-platino-cyanide became fluorescent. This result the Professor obtained even when the luminous tube was wrapped in a black cardboard cover. The 'rays' given off by the electrified tube he found to have the power of exciting photographic action and of penetrating various bodies in differing degrees—roughly speaking, in inverse proportion to their thickness and to their density. Thus, bismuth, which has a high atomic weight, offered an extreme resistance to the passage of the rays, which he named the *x*, or unknown rays. He found that, in addition to the properties already mentioned, the rays were neither reflected, deflected by a magnet, nor refracted by prisms and other media of ordinary refraction. On the peculiar powers of penetration, of exciting fluorescence, and of acting upon sensitive photographic plates, the art of Röntgen ray diagnosis has been founded.

The position of the average medical man towards the Röntgen ray process may be here briefly defined. In the majority of instances he will most likely place his patient in the hands of an expert operator, just as he would apply to a photographer for a photograph, or to a colour artist for a painting. Indeed, it would be out of the question for the busy practitioner to attempt to expose and develop his own Röntgen plates, any more than it would be possible for him to undertake complicated bacteriological or chemical examinations. Here and there it is true that an exceptionally energetic surgeon or physician may find it possible to use the fluorescent screen daily in his consulting-room. For prolonged and tedious examinations, however, and for obtaining permanent pictures, the practitioner will naturally have recourse to the professional Röntgen worker. Where the latter is not a medical man, little can be expected from him beyond the actual printed record, which, it need hardly be remarked, in many cases yields all the requisite information. Where he is a trained medical man, on the other hand, from his knowledge of the facts of anatomy, of surgery, of pathology, and of other branches of medicine, he will be able to furnish a skilled reading both of the screen and of the negative. In other words, the full interpretation of Röntgen ray results requires not only practice, but also the knowledge of many co-ordinate facts.

Should the medical man desire to act for himself, he can soon learn to work the apparatus both with intelligence and with safety. Dealing with that point, Dr. Richardson,* of Boston, has remarked, pithily enough, that he himself knew nothing about photography, nothing about electricity, and but little of physics. Notwithstanding those drawbacks, however, he applied the x-ray method of examination as a matter of daily routine practice. To quote his own words, his knowledge of the subject extended to 'just enough of the principles involved to place the patient, the tube, and the plate in a proper position, and to turn on the current.'

With a good Röntgen apparatus, then, and a skilled workman somewhere within easy reach in case of breakdown, any medical man may teach himself how to use the fluorescent screen and to expose the sensitive plates. The latter can be sent to a photographer to be developed and printed from. It will be advisable,

* *Boston Medical News*, December 19, 1896.

however, for the operator to have some knowledge of the principles involved. In order to present him with a brief outline sketch, the main facts will be dealt with under the headings of—

I. The Sources of Electricity.
  A. Batteries.
    (*a*) Primary.
    (*b*) Storage.
  B. Dynamos.
    (*a*) Continuous.
    (*b*) Alternating.
  C. Statical Machines.
II. Transformers to High Potential.
  A. The Induction Coil.
  B. Tesla Coil.
  C. Tesla Oscillator.
III. Vacuum Tubes.
IV. The Exhaust Pump.
V. The Fluorescent Screen.
VI. Photography and Stereoscopy.
VII. Stands and other Accessories.
VIII. Practical Application.
  A. Examination of Patient.
  B. Fallacies.
IX. Theory.

PART I

ELECTRICAL APPARATUS AND METHODS

I. SOURCES OF ELECTRICITY

So far the one unvarying essential for the production of the *x*-rays is the vacuum tube of high exhaust. The electrical discharge of high potential that excites the tube may be applied directly from a frictional machine, or indirectly through the agency of an induction or a Tesla coil, which transform the current to the necessary degree of tension. The transformers, again, may be supplied with electricity from primary batteries, with current from dynamos, or with current from secondary storage or accumulating batteries charged with energy from the two foregoing sources.

Where the Röntgen ray worker lives in the country, away from any system of public or private electric lighting, the simplest way will be to trust to primary or 'wet' batteries. In that event he must be prepared to face the cost and inconvenience of the extra time, trouble, and outlay required for the cleaning and the renewal of plates and the purchase of chemicals.

A. **Batteries—(*a*) Primary**

There are several well-known primary batteries which give a steady current sufficient for the longest Röntgen ray exposure. From four to eight cells are required, according to the kind of battery selected. Of the older forms, the Grove is one of the best, though perhaps hardly the most convenient. It consists of a vessel partly filled with dilute sulphuric acid—one of acid to seven of water ; a cylinder of zinc open at both ends ; a porous vessel of a litre capacity, filled with nitric acid, fitting freely inside the zinc cylinder; and a sheet of platinum placed inside the porous vessel. A binding screw must be attached to the zinc, and one to the platinum. If platinum be too costly, carbon may be substituted, when the cell is known as a Bunsen.

The bichromate cell, of which there are various kinds, is more portable, and does not give off fumes like the Bunsen, although

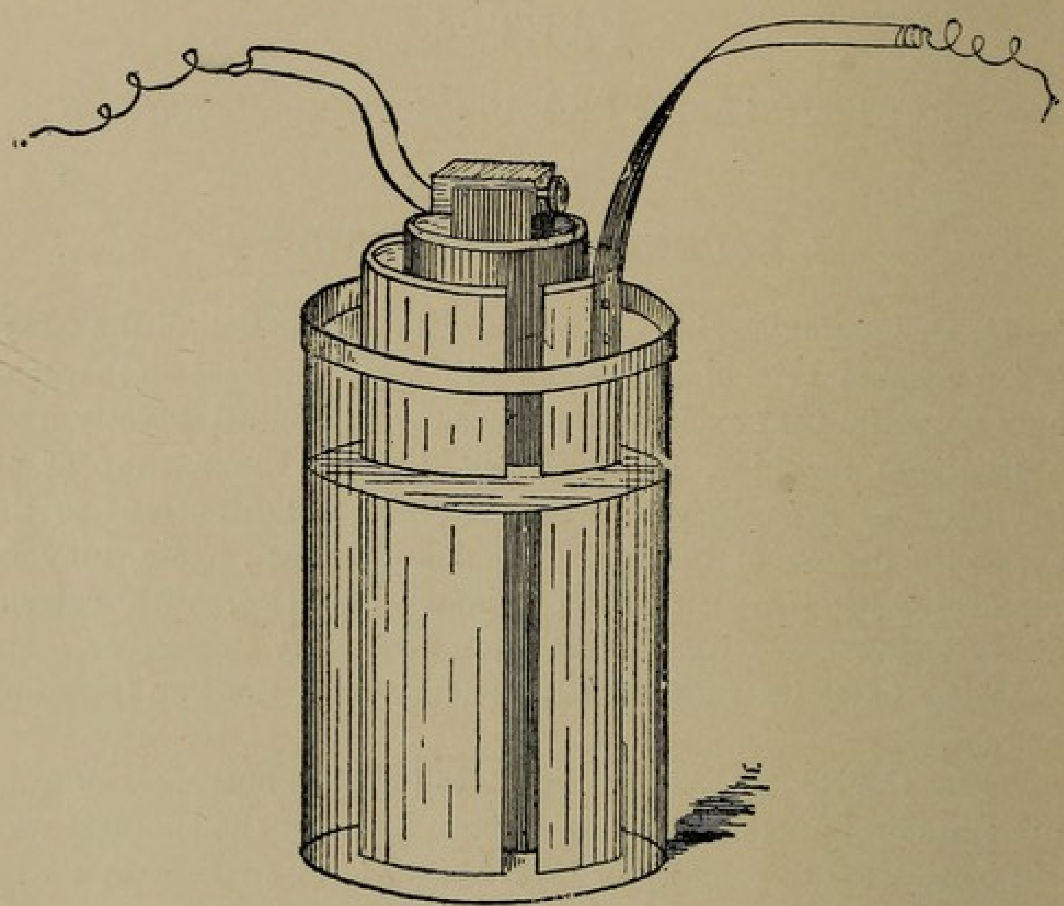


FIG. 1.—GROVE CELL.

its current is not quite so trustworthy. It consists of a vessel filled with seven-eighths of saturated solution of bichromate of potash and one-eighth sulphuric acid. In this fluid are immersed a plate of zinc and one or two plates of carbon. There should be some means of lifting the zinc, or zinc and carbon, from the solution, when not in use, and also some handy means of renewing worn-out or broken plates. The bottle form has a closely-fitting cap, to which are attached the carbon and zinc, with an arrangement for drawing the latter out of the liquid. It is portable and convenient, and may be used with confidence when the current is not required for more than fifteen minutes at a time. A greater capacity may be obtained from a combination

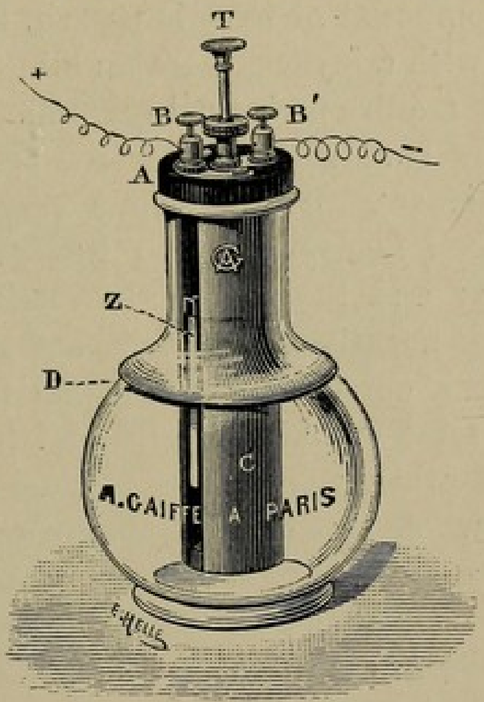


Fig. 2.—Bichromate Cell.

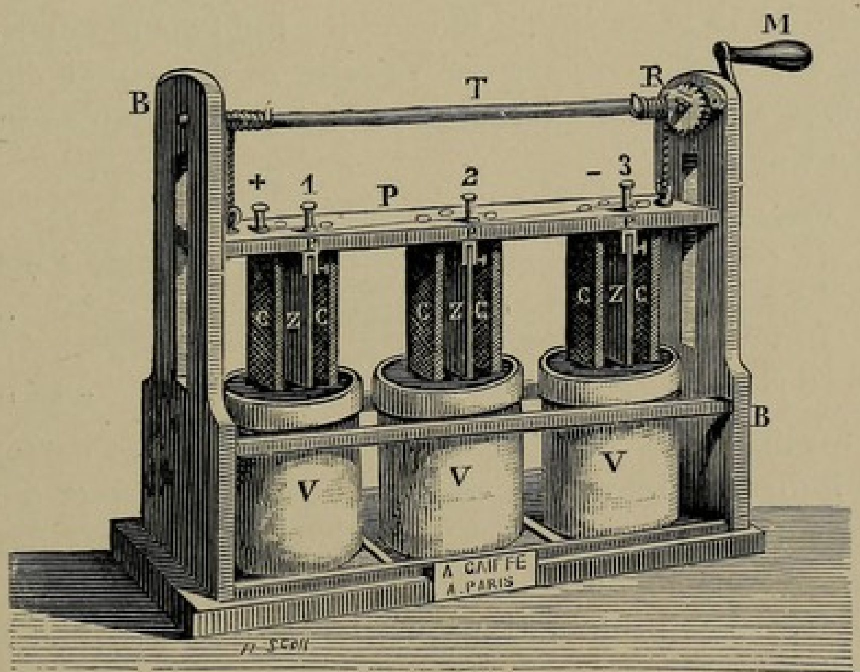


Fig. 3.—Bichromate Battery.

of such cells, the bichromate battery (Fig. 3). The zinc plates must be kept well amalgamated, or the acid soon eats them away.

One of the best modern cells is the Edison-Lalande. It consists of a porcelain jar, with a cover of similar material, from which is suspended a copper frame, holding two plates of oxide of copper, their surface having been reduced to metallic copper. The solution used is composed of caustic potash, two parts, to water six parts, covered with a layer of paraffin oil. Both solution and copper oxide plates require periodical renewal.

Batteries may be coupled up either for pressure (voltage) or for quantity (ampèrage). In the former case the negative (−) pole of the first cell is connected to the positive (+) of the second, and so on; and the current is obtained from the first positive and the last negative. The cells are then said to be in *series*, and will give a current in volts equal to that of one cell multiplied by the total number of cells, and in ampères that of one cell only. In other words, this method of coupling yields the voltage of the whole series, and the ampèrage of a single cell.

In the latter case—that is to say, when coupled for quantity—all the positives are connected to one wire, and all the negatives to another; the cells are said to be in *parallel*, and will give a current in volts equal to that of one cell only, and in ampères that of one cell multiplied by the total number of cells.

Sometimes it is desirable to combine the two methods. Suppose, for example, there are twelve cells, each giving a current of 10 ampères at 2 volts' pressure. They can be coupled up in the following ways:

	Series.	*Parallel.*	*Current.*		
(*a*)	In twos	In sixes	60	ampères at	4 volts.
(*b*)	In threes	In fours	40	,,	6 ,,
(*c*)	In fours	In threes	30	,,	8 ,,
(*d*)	In sixes	In twos	20	,,	12 ,,

This arrangement is called *multiple series*. The current may also be indicated in watts. A watt equals a flow of 1 ampère at a pressure of 1 volt. In the arrangement just described, each gives a working current of 240 watts.

In the Grove cell the platinum is the positive (+), and the zinc the negative (−). In the Bunsen the carbon is the positive. In the secondary cell the positive is indicated by +, and the negative by −. Whatever the form of the cells or their method of coupling, the first + and the last − should be left free for connecting with the coil.

The practical bearing of the foregoing points lies in the use to which the primary batteries are to be put. A large current is needed for the induction coil, and one that adds constancy and capacity to a high E.M.F. (electro-motive force). Therefore, in working a coil direct from a primary battery, we take the com-

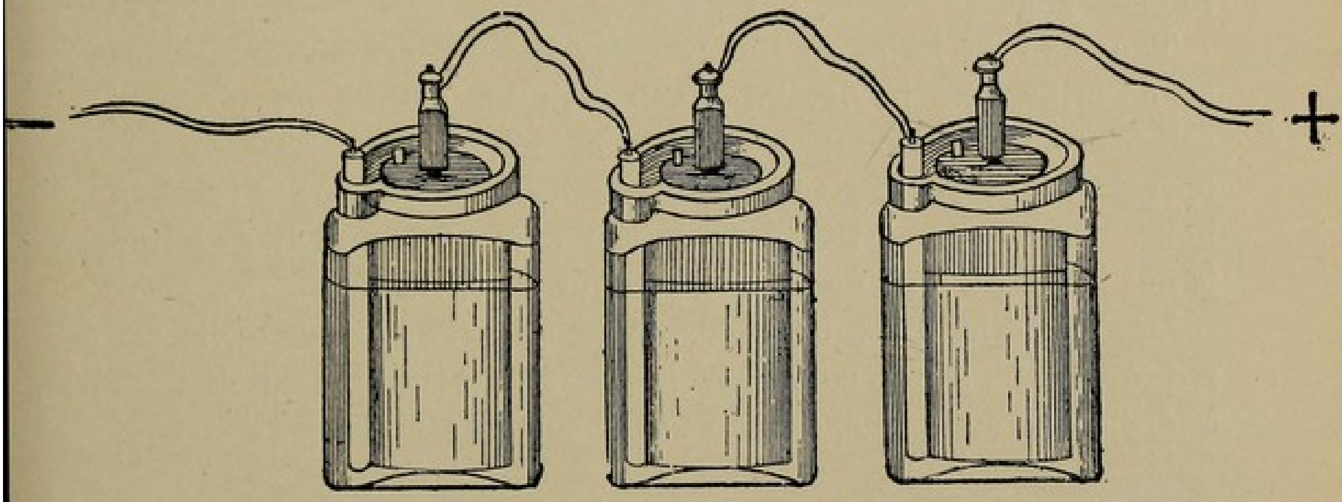


FIG. 4.—CELLS IN SERIES.*

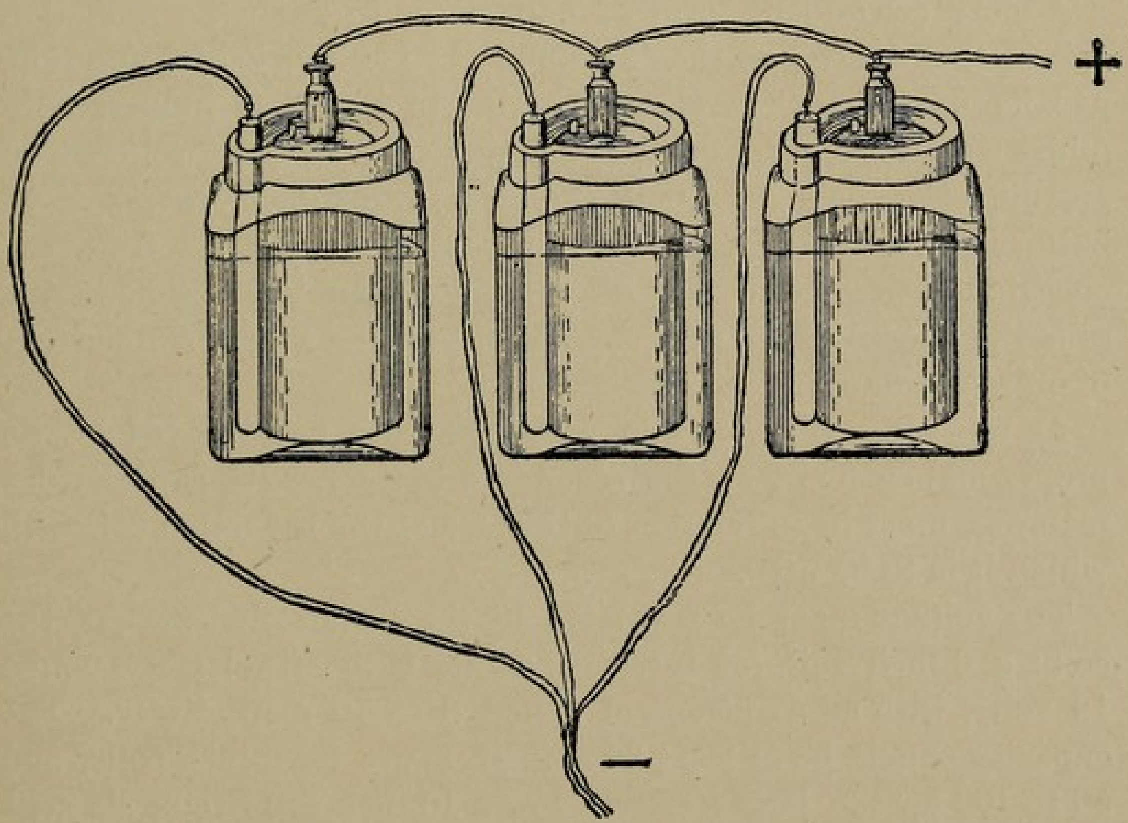


FIG. 5.—CELLS IN PARALLEL.*

bination that fulfils those conditions. Thus, to work a 10-inch coil, taking an E.M.F. of 12 volts and 6 to 8 ampères, would

* These and several of the foregoing figures are from Dawson Turner's 'Manual of Electricity.' (Baillière, Tindall and Cox. 2nd Edition.)

require seven or eight large Bunsen or bichromate cells arranged in series, the zinc of one cell being connected with the carbon of the next, and so on. The coil is coupled with the first carbon and the last zinc.

The modern forms of the primary battery are too numerous to describe here in detail. Each inventor claims for his own some special advantage. Whatever kind be selected by the operator, it ought to give a steady uniform current for at least an hour. The rate of the flow of the current generally required is not less than 8 ampères, at a pressure of 10 volts.

Dry batteries may be used. As a rule, two dozen cells are required, each dozen connected in series with the two end carbons and the two end zincs, carried to the coil by a single series.

(*b*) Storage or Secondary Batteries

A more convenient form of battery for exciting the induction coil is that known as the 'secondary.' It consists of lead grids, usually coated with a paste of oxide of lead, and immersed in dilute sulphuric acid of specific gravity 1·15 (136 volumes of arsenic - free acid to 1,000 volumes of distilled water). The battery is usually charged by a continuous current from the electric lighting main. By the storing of chemical action in the cells the charged battery is capable of yielding a powerful current of great constancy.

At the same time, certain points have to be observed in the proper management of the secondary battery. Its capacity, for instance, must be in relation to the size of the induction coil with which it is to be used.

The voltage must be regulated by the size of the spark of the coil : a 6-inch coil, for instance, wants 8 to 10 volts, a 10-inch 12 volts, with an ampèrage of 5 and 8 to 10 respectively. The capacity should be at least 30 ampère hours for 6-inch coils, and 50 to 100 for the larger sizes. For a 10-inch coil five or six cells will be wanted with a capacity of 30 to 60 ampère hours.

Each cell, whatever its size, when fully charged should indicate on the voltmeter about 2. Directly it falls below 1·9, the cell should be recharged, allowing in dealing with the whole battery 1·9 for each cell, *e.g.*, 19 volts for a ten-cell battery. If an ammeter be used, the wires from the cell should be firmly connected through a small resistance to the instrument. If the meter remain steady at any fair number of ampères, it is still well charged; but if there be a rapid, or even steady, fall, the cell requires recharging. It is never advisable either to discharge the cell altogether or to leave it uncharged, even if not in use. In the former case the plates buckle, and the cell becomes more or less choked by formation of an insoluble sulphate of lead. An invariable rule should be made that the battery must be recharged once a month, or preferably every three weeks. A constant 'leakage' of electrical energy is always going on from every storage battery, due to defective insulation, to impure acids, and to other conditions, and electricians have not yet been able to remedy this tendency to spontaneous, if so it be, slow discharge.

The charging of accumulators may be done by the continuous current from primary batteries, dynamos, and the ordinary lighting current, all that is required in the two last named being a suitable resistance and a fuse. The positive pole of the accumulator must be connected with the positive pole of the charging circuit. The polarity can be tested by means of pole-finding paper. The voltage of the source of charge should be about 10 per cent. over that of the storage battery when fully charged.

The positive terminals of the cells are painted red, and the negative black. In coupling up a battery, the + of one cell is connected with the – of the next, and so on. Great care must be taken to avoid short-circuiting of either the primary or the secondary cells.

For particulars of charging from primary batteries the reader may be referred to any standard electrical work. At least four cells in series of 0·9 voltage will be required for each accumulator cell. A similar reference may be made to charging from thermopyles and small dynamos. The medical man, wherever possible, will do best to arrange with the nearest electrician for the periodical charging.

Charging from a continuous lighting current needs between source and accumulator a resistance which may be either an adjustable rheostat or one or more incandescent lamps. The connection is kept up, usually a matter of ten or twelve hours, until gas bubbles appear and the acid turns milky. As the entering current should have a relation to the size of the battery, anyone proposing to charge for himself will do well, unless he have the requisite knowledge, to get the process thoroughly explained by the maker from whom he buys his battery.

Charging from an alternating current requires a special transformer.

The plates of the secondary cell should be kept covered with the acid.

A voltmeter and an ammeter are useful in determining if the cells are well charged. The former instrument consists of a bobbin of fine insulated wire, the ends of which are soldered to two binding screws on the outside of the case. In front of the bobbin is a magnetic needle, pivoted so as to move freely upon its axis. This instrument indicates in volts the pressure of the flow of the electric current. The ammeter is similar in construction, except that the bobbin is made of a much larger wire. It indicates in ampères the rate of the flow of the electric current. Behind one end of the magnetic needle of each instrument is a scale, indicating in volts or ampères the current that can be registered by the instrument. Messrs. Newton and Son have arranged the two instruments one above the other on the same stand for Röntgen ray work (Fig. 6).

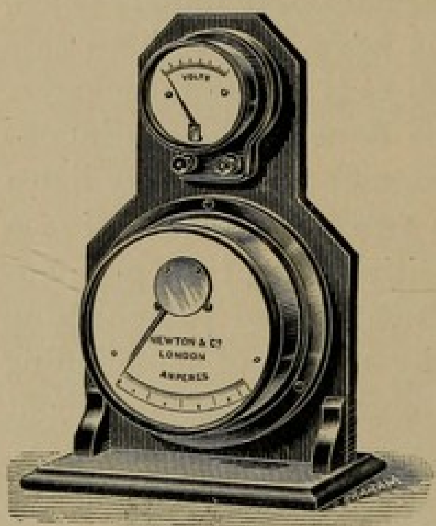


FIG. 6.—VOLTMETER AND AMMETER.

Another way of testing the cell is by means of a hydrometer. The specific gravity of the acid when put into the cell is about 1·190, and when fully charged about 1·200. A convenient hydrometer for testing sealed cells has been introduced by Mr. Hicks, of Covent Garden. A glass tube is passed into the vent, and the acid drawn into it by means of an indiarubber ball. Three beads of different colour float in the tube, and the one that comes nearest to the centre denotes the specific gravity of the acid.

For transport purposes most secondary batteries are heavy and cumbersome. To meet that objection, a small case has been devised for the writer by Messrs. Peto and Radford (Fig. 8). It contains six cells, giving thirty ampère hours at 12 volts pressure.

It occupies about a cubic foot only, and so is convenient for cases in which the operator must take his apparatus to the patient's house.

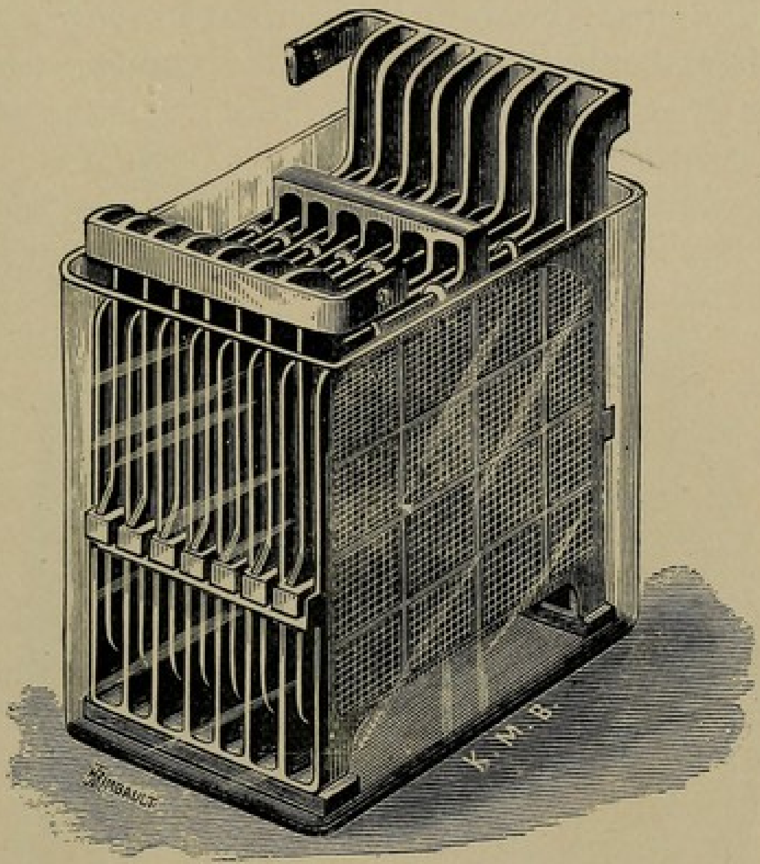


Fig. 7.—Secondary Cell.

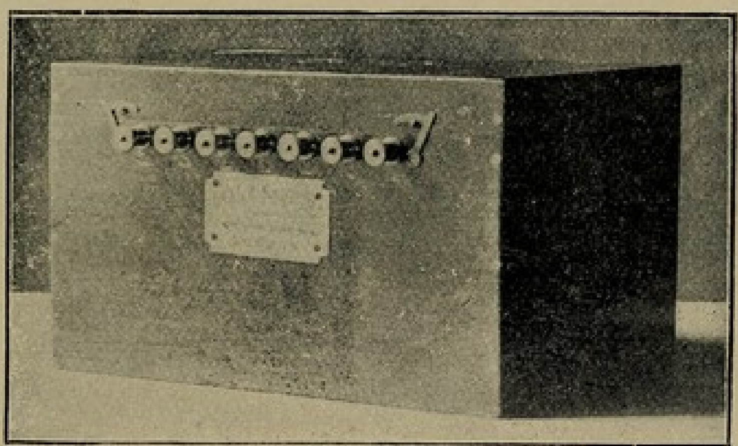


Fig. 8.—Secondary Battery.

B. Dynamos

This method of obtaining the electric current is open to those who have access to either a private or a public lighting supply. The *continuous* or low tension current, which is sent into the house with a voltage of 100 to 250 volts, is most convenient for running the induction coil. In order to reduce it to the necessary pressure—10 or 12 volts—a resistance coil, or a rheostat, must be placed in the circuit between the source of supply and the coil, and the wires should be attached to the ordinary terminals on

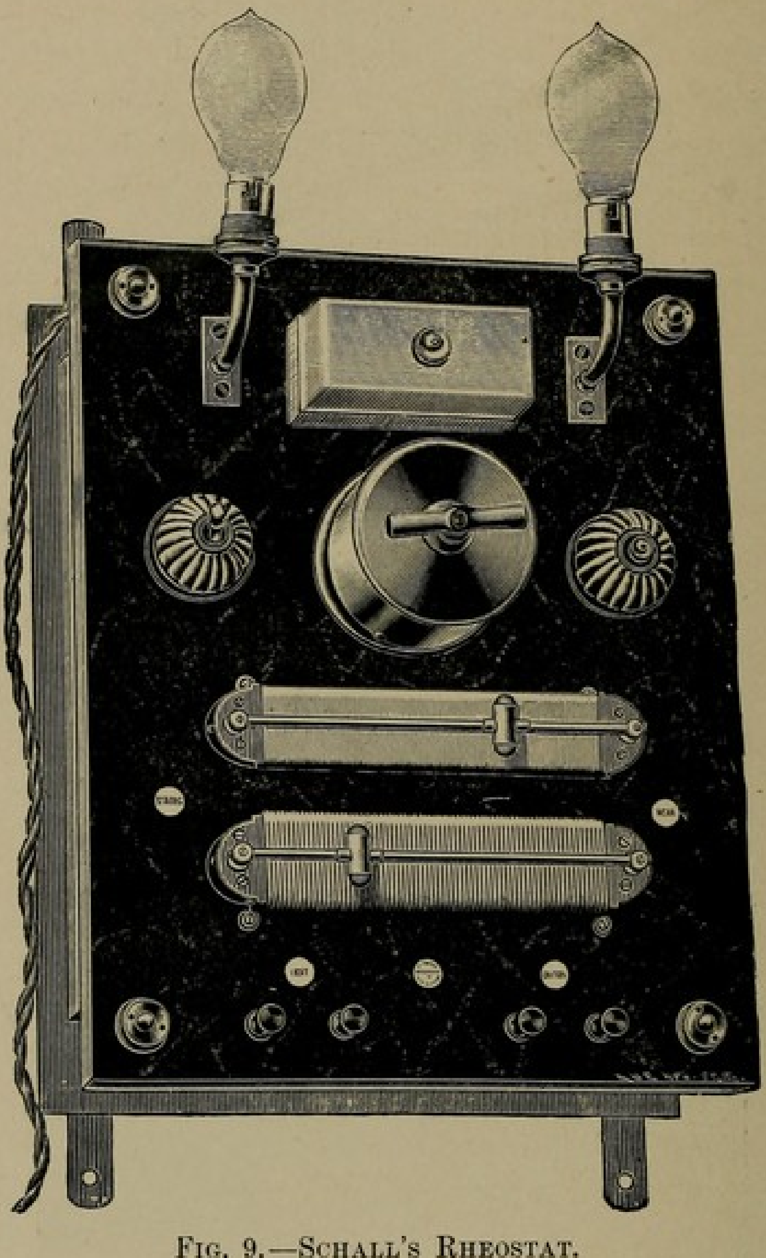


Fig. 9.—Schall's Rheostat.

the coil. A most complete rheostat has been made by Mr. K. Schall for Dr. Macintyre, of Glasgow (see Fig. 9). By its means the number both of volts and of ampères can be adjusted at will. This admirable rheostat furnishes a most satisfactory means of working the coil, and one that is cheaper and more convenient than any system of batteries.

Of the above-mentioned appliance Dr. Macintyre writes: 'The advantages of this rheostat are very great, because we can arrange the number of volts and the number of ampères for any size of coil from the 2 to the 18 inches spark. My work has not only been greatly facilitated by means of this new arrangement, but sparking across the platinum point of the contact-breaker has been diminished, and the risks to the Crookes' tubes have been considerably lessened, while the steadiness and constancy of current have been assured—points of great importance, as any fall in either ampèrage or voltage, as indicated on the meters, can be instantly corrected by the operator.'

A plan sometimes adopted is to work with the house-supply a small motor, which drives a dynamo so arranged as to send a suitable current straight to the coil.

The alternating current or high-tension current, between 2,000 and 5,000 volts in the street, on entering the house is reduced by a transformer to a voltage of 100 or 200. It can be used for running the coil direct, but in that case the coil must be suitably constructed, a point which should be attended to by the purchaser if he means to use an alternating source; both condenser and contact-breaker, for instance, require to be cut out. There are drawbacks, however, to the use of the alternating current in practice, or we may be sure that this convenient means of exciting the coil would have been widely adopted. It may be made to work an alternating current motor connected with a small dynamo, whereby a continuous current is supplied to the coil. The more usual way, however, is to attach the current in question to a Tesla 'step-up transformer,' by which the pressure is increased to about 6,000 volts, and passed into a Tesla coil. The insulating medium for coil, transformer, and condenser is oil. This last-mentioned method is noisy and destructive to tubes, and has never been much used for Röntgen ray work.

Several more or less successful attempts have been made to utilize the alternating current for the coil. One simple plan submitted to the present writer appears to promise well in its future developments, and there can be no doubt that some such contrivance would render the induction coil much more widely available in the houses of medical practitioners. Max Kohl, of Chemnitz, has recently patented an alternating-current interrupter, by which he claims that any coil can be worked direct from an alternating supply. He states that the cost of current by his method is extremely small, and that the interruptions take place with great rapidity (3,000 per minute).

Clearly, the use of an ordinary lighting supply as the source of electrical energy offers many advantages in Röntgen ray work. It is always advisable, however, in this and other electrical directions, for anyone who is not an expert in such matters to secure the advice and guidance of a skilled electrical engineer.

c. Statical Machines

The sources of electrical energy hitherto described all require more or less cumbersome apparatus to transform the charge of low

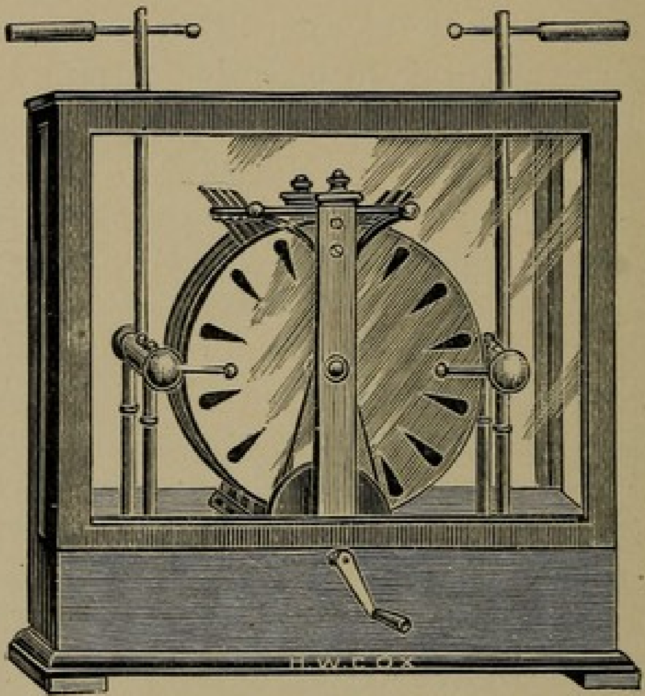


FIG. 10.—WIMSHURST MACHINE.

potential into the high potential discharge needed to excite the x-ray tube. Their great drawback in that direction is not shared by the influence or statical machine, whereby a current is produced of sufficiently high voltage to light any tube to which it is directly conveyed. These facts point to the simplification of means, a direction in which there can be little doubt that future advances in the method of producing Röntgen rays will lie. The Wimshurst machine is efficient in this class of work, and is the only type of statical machine that has stood the test of prolonged experience.

The special advantages are that it is at all times freely self-exciting and ready for use by merely turning the handle, while it produces a steady continuous flow of electricity of such a character that the charge may accidentally be passed through a patient without causing injury; the direction of the flow of electricity does not change when once started; the voltage is sufficiently high to excite tubes of the highest resistance; for screen work the lighting is constant; lastly, there is no need for a costly and troublesome system of accumulators, rheostats, coils, contact-breakers and other complicated appliances.

It seems tolerably certain that the apparatus of the near future, more especially for army and navy work, will be the Wimshurst machine, made probably with plates of vulcanite, instead of glass. There is, moreover, a growing tendency towards its use in ordinary hospital and clinical work. In America it has for some time past been spoken of in enthusiastic terms by various authorities.

The machine consists of several plates of glass or of vulcanite, fixed in pairs (except the outer plates of a series) to a boss or bulb; these bosses revolve upon a stout steel spindle, and are driven by pulleys and leather belts, the latter being alternately straight and crossed, so as to obtain opposite rotation of the bosses with their attached plates. Upon the outer surfaces of each pair of plates are fixed from twelve to thirty suitably-sized sections of stout tinfoil, which are lightly touched by fine wire brushes, and thereby excited. The charges are collected from the plates by means of metal combs placed horizontally at about the level of the spindle; the outer ends of the combs are fixed into a brass tube, which is carried upon insulating supports. The terminals of the machine usually spring vertically from these tubes, and are fitted with insulation handles, discharging-points, and so on, as may be required.

In order to shield the working parts of the machine from dust or from injury by inexperienced persons, it is always desirable that the frame of the machine be made in the form of a glass case; but the case is in no way necessary to the good working of a machine, beyond the protection it affords.

These machines have been made with plates not more than 2½ inches in diameter, and others so large that the plates were 7 feet across; but the intermediate sizes are the more useful and handy. Good work with either the screen or the photographic plate may be done with a machine constructed with twelve plates of 22 inches diameter. Dr. Macintyre fixes the lowest useful limit as eight plates of 18 inches diameter. He himself has, however, a machine with twenty-four plates of 36 inches diameter. All of these sizes can be driven by hand; still, when many exposures are made, a motor, a turbine, or a gas engine may be used with advantage.

The chief drawbacks urged against the use of influence machines are that (1) the excitement is not readily induced; (2) the current is not available in damp weather; (3) drying compounds are necessary to produce a 'false' atmosphere inside the case; (4) the direction of the current changes. With regard to these alleged defects, the author has had the personal testimony of Mr. Wimshurst, who states that with his form of machine he has not throughout a large experience known any instance either of reluctance to excitement or of difficulty with the current, although he has repeatedly used them in every possible bad condition of atmosphere. Moreover, he has never on any occasion used a drying compound inside the case; nor has the current ever changed its direction while the machine was at work. Then as to carriage: He has frequently sent his apparatus to Glasgow, Newcastle, Liverpool, Manchester, Southampton, and to learned societies in London, without a single case either of breakage or of failure in electrical results. At the same time, it is prudent to use a machine not only of approved modern type, but also of sound materials and good workmanship, and to keep it in an ordinary living-room atmosphere.

To connect the Röntgen ray tube to the machine, the 'leads' or connecting wires should be thickly coated with guttapercha, each being fastened to the terminals at one end, and at the other to a highly-polished brass ball. When the tube is working, the spark-gap between the ends of the tube and the brass balls should be adjusted until the best results are obtained. It will then frequently be found that tubes of little resistance may be made to give good results by allowing a long spark-gap between the ball on the end of the lead and the cathode end of the tube. The leads will, of course, be connected to the terminals of the machine, and to the tube after testing the positive and negative terminals.

The tubes, when once set in place, may be kept lighted so long as the plates are revolving; and as the quantity of electricity is proportioned to the speed at which the machine is turned, the tube may at any time be more strongly excited by a quicker turning of the handle.

Dr. W. Cotton, of Bristol, has done much good work with a 'sectorless' Wimshurst machine. In this form the apparatus is not self-exciting, but requires an initial charge, which may be communicated from a small ordinary machine or a Leyden jar. The latest development of the statical machine is a practically unbreakable one designed by Mr. Wimshurst himself, with a special view to army work.

II. TRANSFORMERS TO HIGH POTENTIAL

A. The Induction Coil

The Ruhmkorf coil is an instrument for transforming an electrical current of low voltage (or pressure) to one of high tension. Its action depends upon the fact discovered by Faraday that an electrified body is capable of inducing a similar condition in an unelectrified body lying within the field of its influence, but not in actual contact. It consists of a core of soft iron surrounded by a helix of thick insulated copper wire, known as the 'primary,' the ends of which are connected to two binding screws on a board that forms a base for the instrument. The thick wire is surrounded with many turns of a much finer insulated wire, called the 'secondary,' varying in length from a few hundred yards to several miles. A 10-inch coil, for instance, requires some ten miles of cotton- or silk-covered secondary wire of about 0·2 millimetre thickness. To secure a good and lasting insulation in this arrangement of primary and secondary is essential. The case is wrapped in varnished tape, and, after being wound with the primary wire, is usually enclosed in a thick vulcanite tube. On the latter the secondary wire is wound in layers, separated from each other by paraffin-paper. When finished, the whole is carefully soaked in melted paraffin. For large coils the secondary is wound, not in single layers along the length of the coil, like cotton on a reel, but in sections, like a row of reels on a spindle, with the ends of cotton carried from one to the other. If built on this principle, which is that adopted by Mr. Apps, the maker of some of our largest and best coils, a 10-inch coil should have seventy or eighty of these sections, and the core should project several inches on each side.* On the other hand, Mr. H. Cox uses no insulation whatever between the primary and secondary, and builds his coils in two sections only. A number of large coils made on this plan have been working for several years in a satisfactory manner. There are many other most excellent coils by various makers on the market.

In working a coil, it is well to feel it from time to time, and if it be found hot, to stop work and allow it to cool. Certain precautions are advisable. Thus, it is well to make an absolute rule from the first day of handling a coil to turn off the current before making any alterations or adjustment of the apparatus. This is usually done with a switch key, as in Apps' coil. When the handle points straight up in the air, the current is switched off. The spark from a 10-inch machine may have dangerous, or even fatal, results. The ends of the secondary wire are fastened to two discharging rods with sliding terminals, by which the length of the spark can be ascertained.

If a current of low voltage be sent into the primary wire, a current of extremely high voltage is induced in the secondary: between pointed terminals the estimate is about 10,000 or 15,000 volts per centimetre of spark, or some 100,000 volts for a 6-inch discharge. Sparks are generated in 'breaking,' and not in 'making,' the primary circuit, and hence complete and rapid interruption is necessary. Another essential to a good spark is the condenser. A key or commutator is also provided for turning the current into the coil, or for reversing it when in action.

The break or interrupter is an important part of the apparatus of the induction coil. It may be made on various plans, of which the simplest is that of the so-called vibrating hammer. A thin piece of steel armed at one end with a heavy piece of iron is fixed on the base, so that the head of the hammer is exactly opposite the centre of one end of the soft iron core, at a distance of about $\frac{1}{8}$ inch. Fixed in the centre of the hammer, on the face away from the core, is a piece of thick platinum wire, and opposite this, on a stout piece of brass fastened to the base, is a screw carrying in its point another piece of platinum. Connections are made underneath the base-board, so that the current must pass through

* These coils are now made by arrangement with Messrs. Newton and Co., and sold under the name of 'Apps-Newton.'

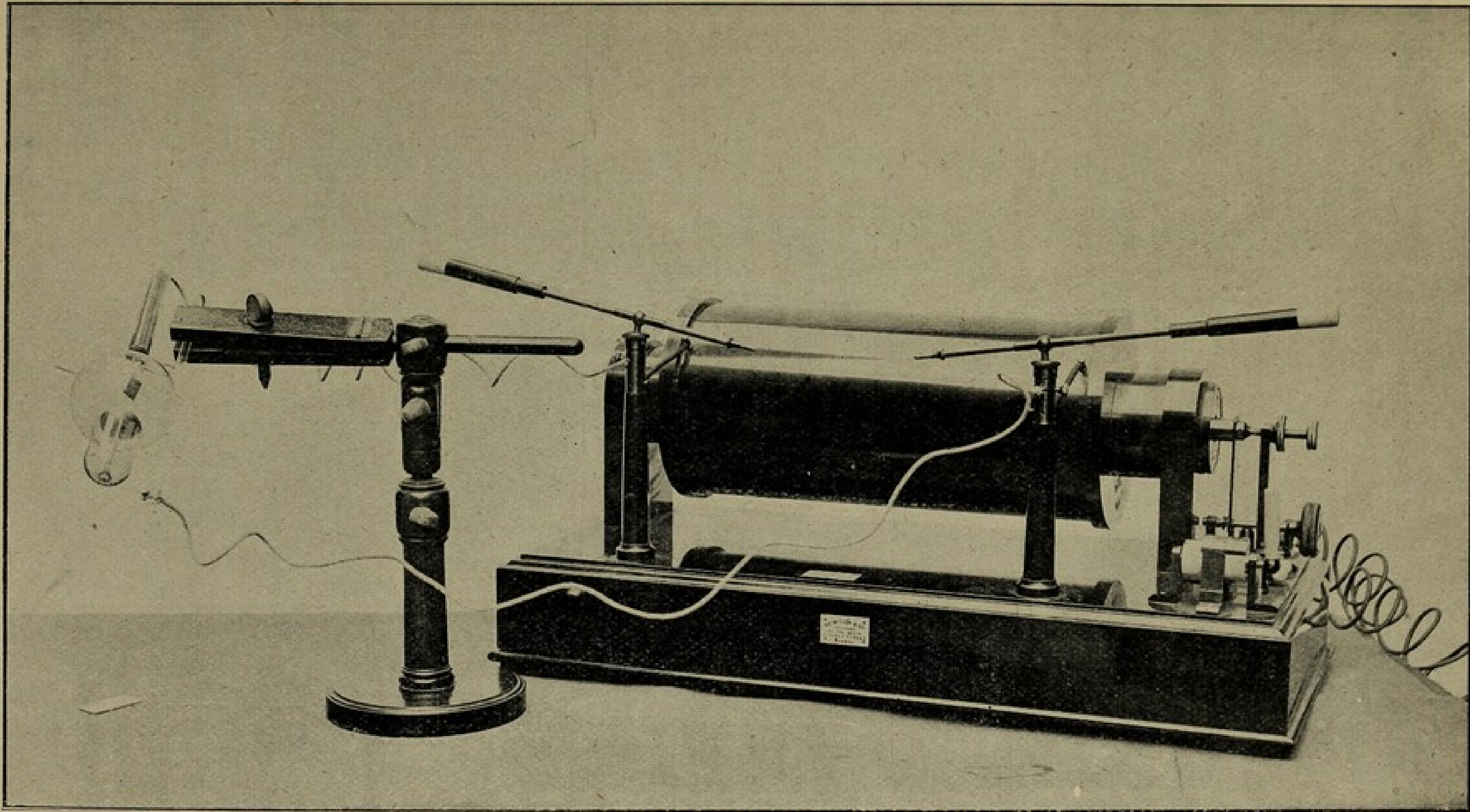


Fig. 11.—Apps-Newton 10-inch Spark Coil, Apps' Contact Break, Tube with Special Indiarubber Protector (Webster's).

the two pieces of platinum when touching each other, into the primary wire. The current immediately changes the soft iron core into a magnet which attracts the iron hammer on the vibrating steel, and the two platinum points are separated. The current ceasing to flow, the core is demagnetized, and no longer attracts the hammer, which falls back to its original position, when the current flows again into the primary and the process is repeated. There must be an arrangement for adjusting the distance of the hammer from the iron core, and this has been pro-

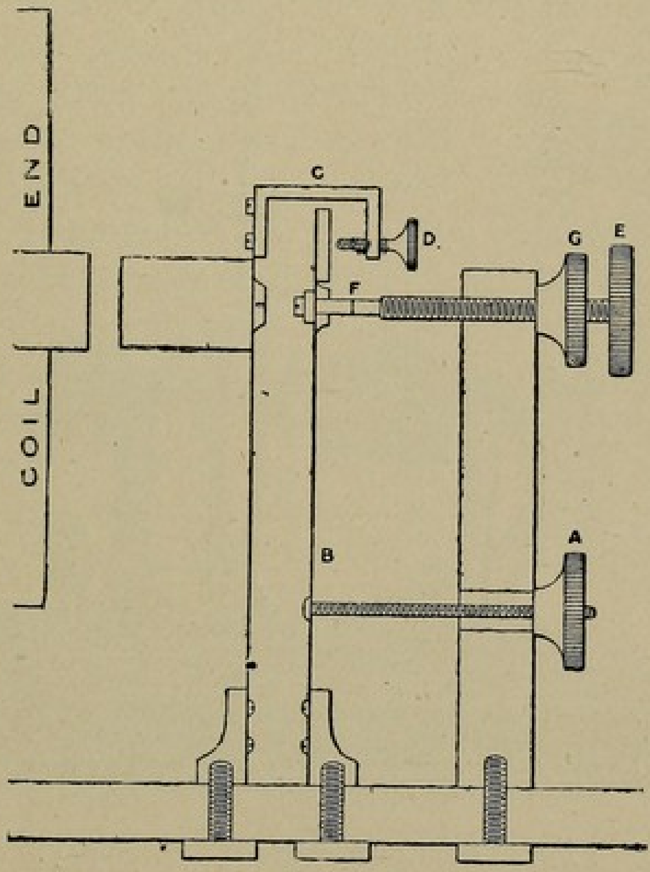


Fig. 12.—Vril Contact-breaker.

vided for by Mr. Apps with a simple but efficient contrivance, in which the rate of the break is regulated by a screw that can be made to stiffen the hammer-spring, and thereby slow the vibration, or vice-versâ. The top screw regulates the amount of current, and the lower the speed.

The Vril Contact-breaker is a modification of the foregoing. It was devised by Mr. J. King, A.M.I.C.E., and is made by W. Watson and Sons. It will be seen from Fig. 12 that the iron hammer is mounted as usual, and the platinum contact carried by an intermediate spring, B.

The action consists of the attraction of the hammer, by the magnet, to the coil, causing the point of screw D to impinge on the top of the spring B, so causing a separation of the platinum points, F. The advantages claimed for this system are that a prolonged contact is afforded, giving time for the thorough magnetic saturation of the core; that in consequence much less battery power is required than with ordinary patterns; and that the liability to heating of the platinum contacts is greatly diminished, while 'sticking' is almost impossible. This is an excellent break, capable of a wide range of adjustment.

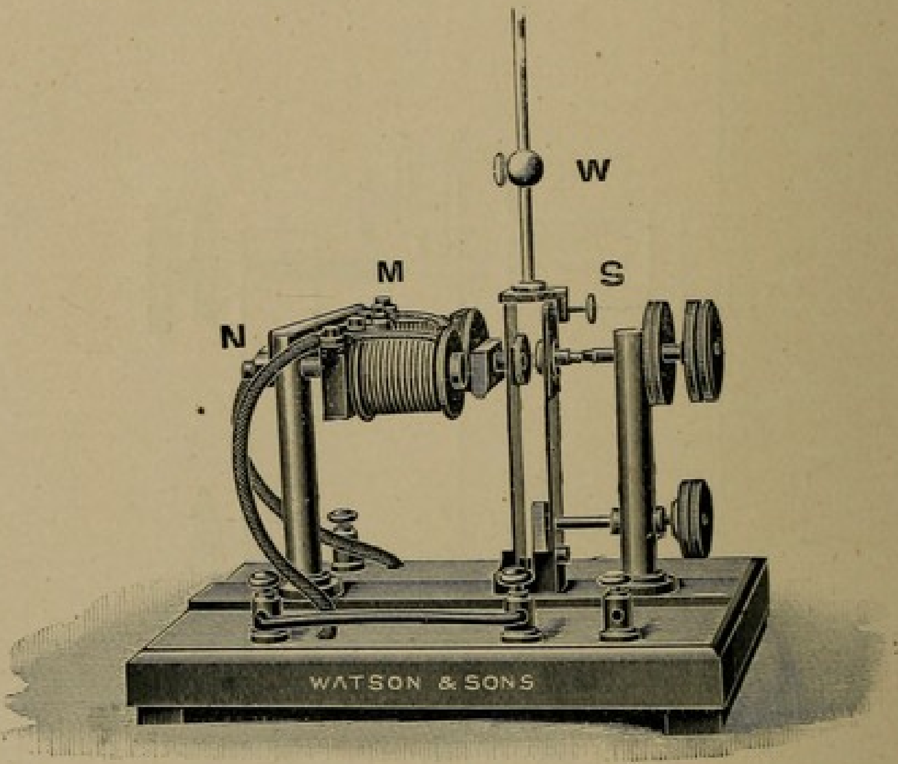


FIG. 13.—ELECTRO-MAGNETIC BREAK.

Some of the best Röntgen ray workers keep to the top contact spring break, and produce excellent results therewith. On the other hand, many prefer a mercury break, or a mechanical form driven by a motor. With a rapid mercurial break there can be little doubt that a more constant fluorescence can be excited upon the screen. It is claimed by some observers that it produces better photographic results in dealing with deep-seated tissues. There are many excellent forms of mercurial breaks upon the market, perhaps one of the best being that made by Max Kohl, of Chemnitz. Contact is made by metallic rods that are made to dip alternately into cups containing mercury by the action of a rotary interrupter, which is driven by a separate battery. The rate of breaking can be regulated at will, and is recorded by a speed-indicator (tachometer). The inventor considers from 1,300 to 1,600 interruptions per minute a good average for photographic and screen work.

An electrolytic interrupter has recently been adapted to this work by Dr. Wehnelt, of Charlottenburg. The break which it induces appears to be so complete that no condenser is required. It is worked from the direct current, and requires from 50 to 100 volts to produce the best results. It consists of a containing vessel (see Fig. 14) with two electrodes of unequal surface (the cathode commonly of platinum foil and the anode of platinum wire), and the current is sent by means of these electrodes through an electrolyte of dilute sulphuric acid of specific gravity about 1·205. This interrupter gives a break of high frequency, at a rate, say, of 1,300 or 1,500 per minute, and a screen light of great steadiness and brilliancy is afforded. It destroys a 'hard' tube in a few minutes by fusing the platinum anti-kathode. Dr. Macintyre says this difficulty can be surmounted by regulating by means of a rheostat the strength of the current which it sends to the primary. Mr. Cox, however, has shown that 50 volts can be run safely on a tube of medium resistance. In spite of some drawbacks, Wehnelt's invention appears to mark a distinct advance in methods, and further developments will be looked forward to with interest. The great advantage is the brilliant and steady illumination of the tube and the fluorescent screen. Osmium withstands the current, although it gets white hot.

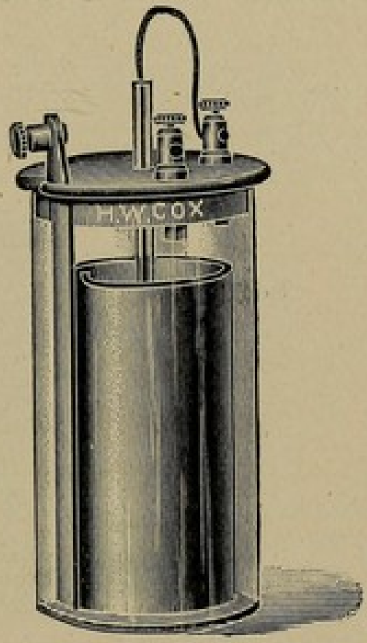


FIG. 14. — THE WEHNELT ELECTROLYTIC CONTACT BREAK.

In practice it is desirable to keep a spare break at hand, as the platinum points are soon worn away by the action of the current, and the coil cannot be worked again until they are renewed. Before using the coil these points should always be examined, and if found uneven a fine watchmaker's file should be passed over them until the surfaces are rendered perfectly plane.

Beside the contact break is usually found a commutator or key for making contact or for changing the direction of the current It will be found desirable to alter the direction of the current at times, or one platinum point will wear out much faster than the other.

In a box below the base, and forming part of it, is placed the condenser. This consists of a number of sheets of tinfoil insulated from each other by sheets of paraffined paper. The alternate metallic sheets are connected in two sets, the even

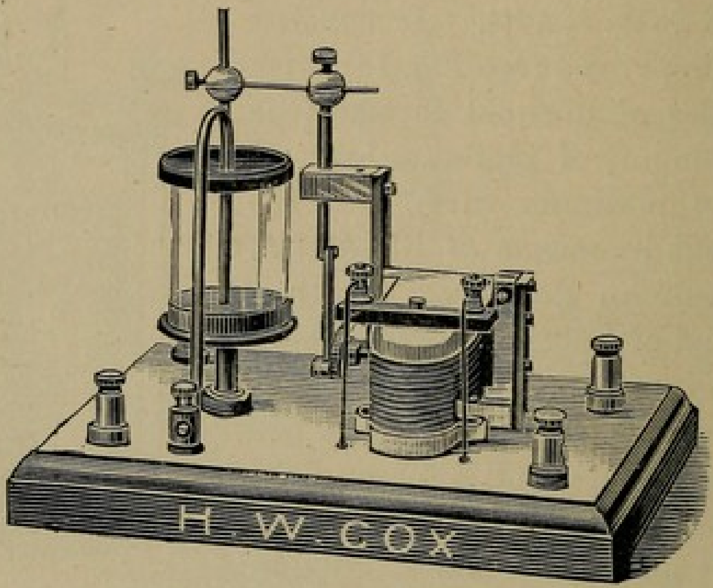


FIG. 15.—MOTOR MERCURY BREAK.

numbers on one side to one of the two supports armed with the platinum contact points, and the odd numbers on the other side to the second support. The object of the condenser is to demagnetize as quickly as possible the soft iron core, as the length of the spark depends upon the suddenness with which this is accomplished. On breaking contact a current is induced in the primary wire in the same direction as the primary current, which would tend to prolong the magnetization of the iron core if it were not directed into the condenser. The condenser immediately discharges, and produces a reverse current in the primary wire, resulting in the instant demagnetization of the core.

The Rochefort and Wydt induction coil was shown in the summer of 1898 before the Röntgen Society of London. The chief points are the small size of the secondary wire and the insulation, which is dependent on a special solid hydrocarbon.

It is claimed to possess certain advantages over the old form of induction coil, such as heavy sparking and economy in the amount of initial energy required.

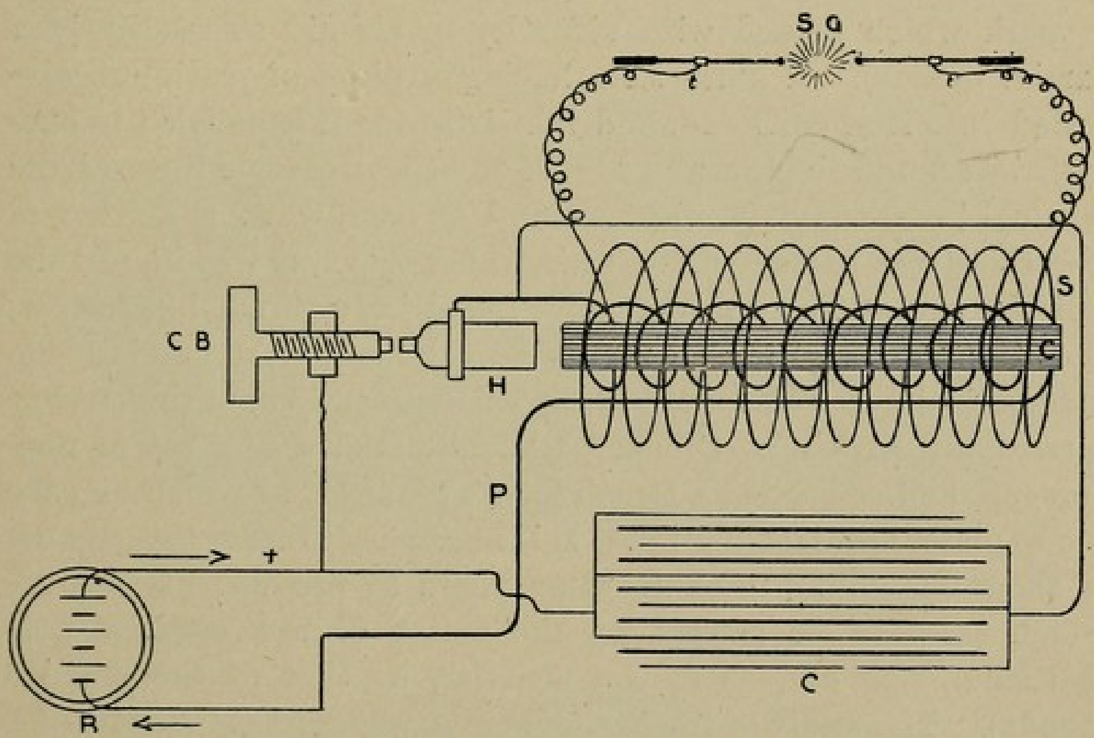


Fig. 16.—Plan of Coil: C B Contact Break. R Battery. P Primary. S Secondary. C Soft Iron Core. H Hammer. C Condenser. S G Spark Gap.

B. The Tesla Coil

This is a high-frequency coil with an alternating current, which yields good results with the focus tube. It can be charged from an alternating house-supply, and the current is first passed through a transformer with oil insulation. As the secondary current is alternating, a special kind of tube is required. This apparatus is less convenient and cleanly than the ordinary induction coil.

C. The Tesla Oscillator

first shown by Professor Silvanus Thompson at the inaugural meeting of the Röntgen Society of London. It is a converter of electrical energy, which produces a number of extremely rapid oscillatory discharges. From a practical point of view, it is open to the serious objection that the resulting secondary current is alternating.

III. THE VACUUM TUBE

Soon after the invention of the induction coil, it was found that a spark which passed with difficulty in air did so readily in a partial vacuum. A glass tube having a piece of platinum wire sealed into it at each end, and the air inside it exhausted to one-half, was found to glow and to give the spectroscopic lines of the residual gases, namely, nitrogen and oxygen, when a current of electricity was passed through it. This apparatus was named the Geissler tube. The phenomena of the striæ, or brush-like sparks, and the relative condition of higher exhausts, were carefully investigated by De la Rue and Spottiswoode. The exhaust was carried still higher by Crookes, who observed a new set of phenomena, and suggested a fourth form of matter, to which he gave the name of 'radiant matter.' It is necessary to carry the exhaust to about one-millionth of an atmosphere to produce his results, which seem to be caused by the action of the negative pole (kathode), and not, as in the Geissler, by that of the positive (anode). The study of the kathodic rays was pursued still further by Lenard and Röntgen, who showed that they could be reflected and refracted just as ordinary light, and in addition could be deflected by a magnet. It was while investigating these that Röntgen made the discovery that there were other rays, to which he gave the name of x-rays. The latter appear not to conform to the laws of light, but they have the special property of penetrating substances opaque to ordinary light. On this fact depends their interest and great utility. The x-rays, or, as they are now more generally named, the Röntgen rays, like the actinic rays, produce fluorescence and photographic action, but do not possess the properties of refraction, regular reflection, and polarization.

By carrying the exhaust of the Crookes' tubes still further, Röntgen rays of great penetrating power are produced in abundance. The tubes themselves are made in endless variety, the differences being chiefly in the shape and position of the anode and kathode. Originally the kathodic rays were projected on the inner surface of the glass tube opposite the kathode, with the result of an irregular fluorescence of the tube and a diffuse production of the invisible x-rays. The form now adopted in all tubes is that introduced by Mr. Herbert Jackson, who focussed the kathode rays on a platinum target inside the tube, and so procured x-rays in greater abundance and yielding much better photographic definition. By his plan the main part of the Röntgen rays is directed to one side of the tube, and hence may be readily thrown upon the object to be investigated, whether by

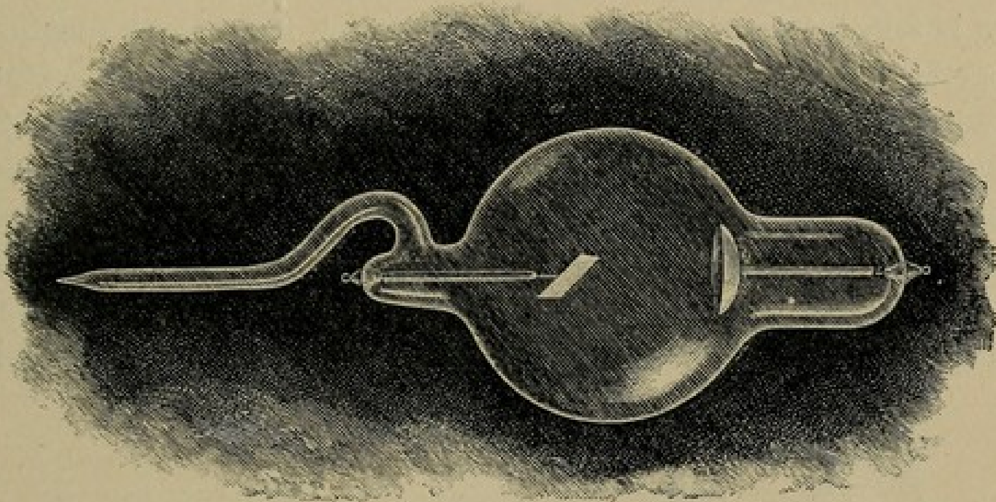


FIG. 17.—FOCUS TUBE FOR CONTINUOUS CURRENT.*

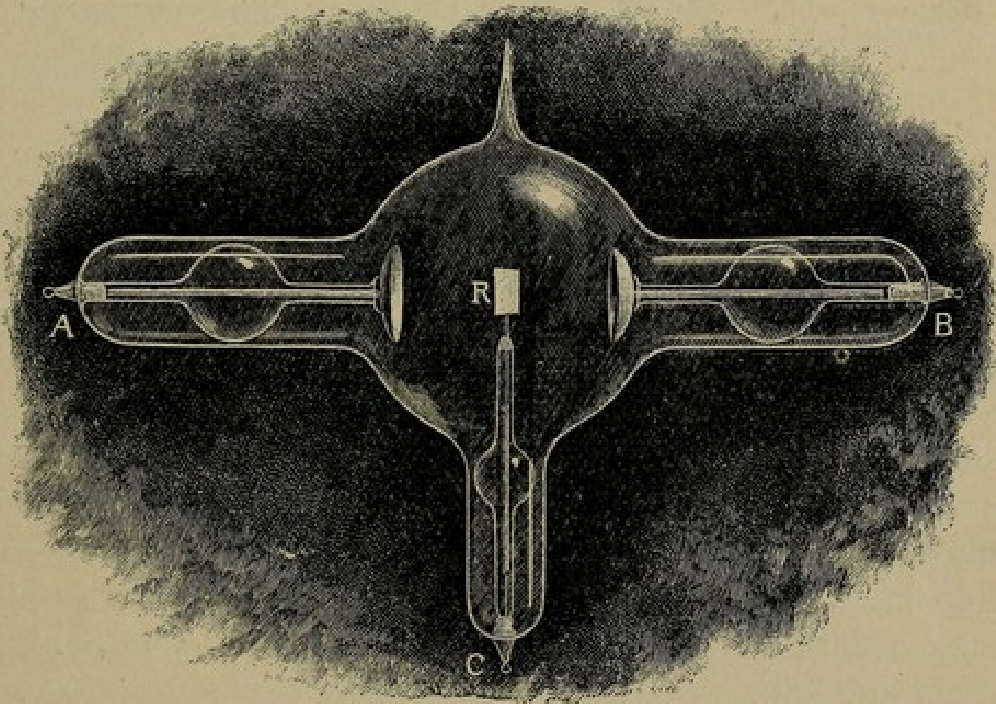


FIG. 18.—FOCUS TUBE FOR ALTERNATING CURRENT.*

the fluorescent screen or by a sensitized photographic surface. Jackson's tube, known as the 'focus' tube (Fig. 17), consists of a hollow sphere of glass from 2 to 4 inches in diameter. In one

* Both these drawings are from 'The Induction Coil in Practical Work,' by Lewis Wright. Macmillan and Co., 1897.

part of its circumference is fused a small straight tube, with a platinum wire current terminal carrying at its free end an aluminium disc, which projects into the globe. The diameter of the disc varies from ¼ inch to 1 inch, but the smaller is found to produce equally penetrative rays. At the opposite side of the globe is another small straight tube, in which is sealed a platinum wire. On the free end of the latter, and projecting into the globe, is a square piece of platinum foil, fixed at an angle of 45° to the kathode. A branch from this anode end of the tube serves as a holder, and is left open for the purpose of exhaust. The aluminium disc is the negative (−), or kathode; the platinum is the positive (+), or anode. Sometimes the piece of platinum is not used as the anode, which is attached to another terminal, forming

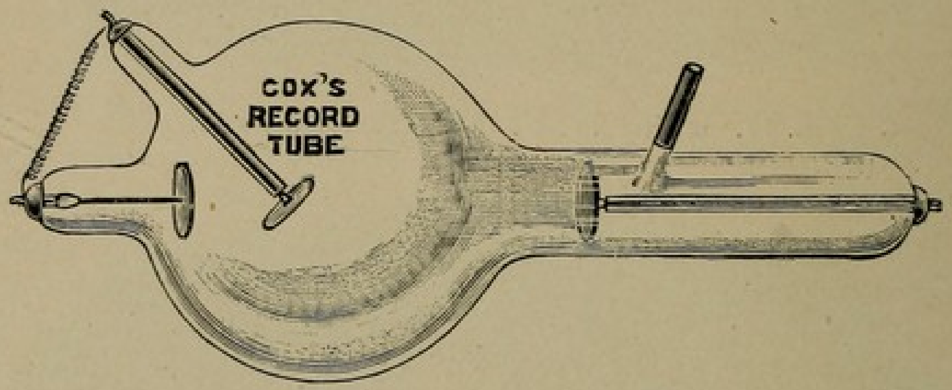


FIG. 19.

the bianodal form of tube (Fig. 19). In any case, the platinum target is often spoken of as the anti-kathode.

For exhaustion the tube is attached to a pump, and the air withdrawn to something less than the millionth of an atmosphere. With a good pump and with an operator who understands high exhausts, a moderate-sized tube may be prepared in half an hour. A special tube is required for use with an alternating current; it has two kathodes (A and B, Fig. 18), and the anode or anti-kathode (C) is placed midway between the two.

The tube is a most important part of the Röntgen outfit, and when suited to the coil and of good definition will yield satisfactory results to the worker; but otherwise his time will be wasted. Unfortunately, it is not possible to say what are the exact conditions that make a good tube, so that another like it can be produced at will, although, on the other hand, the excellences of a tube, its definition and penetration, can always be tested before purchase. The resistance should be proportioned to the size of the coil, and if wished can be reduced for a time, either by heating the tube with a spirit lamp or by reversing the current for a few moments. Mr. A. A. Campbell Swinton's adjustable focus tube is devised upon a sound principle, and one can only wonder why it has not come into more general use among practical workers. He has shown that the kathodal rays are projected from the aluminium cup-shaped anode in a hollow cone merging into a beam that strikes the anti-kathode. By a sliding kathode (which may be adjusted by Dawson Turner's method from outside by a magnet) he regulates the distance between kathode and anti-kathode, so that the tube may be independent of alterations of resistance, and be fitted for various

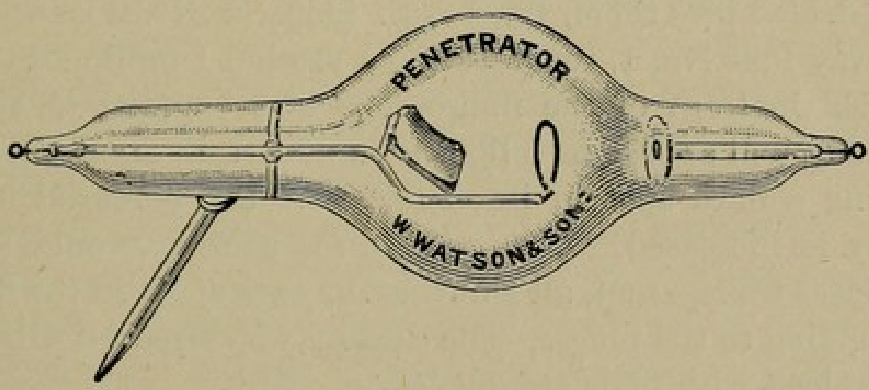


Fig. 20.

kinds of work. An excellent tube for high-resistance coils and for deep tissues is the Penetrator of Messrs. Watson and Co.

There yet remain two methods of reducing the resistance in a tube. The first, by heating some substance contained in an annex, such as potash or palladium, whereby the vacuum is lowered. One of the latest types of this kind is the Queen tube, which is so arranged that when the tube resistance reaches a certain point, the current passes by an alternative route into a communicating potash bulb, whereby vapour is driven off and the vacuum of the main tube lowered, so that it is again brought into action. This result depends on the fact that some free gaseous molecules are needed to form a path for the electrical current; but those left in the original state of the tube appear to become gradually occluded, and are set free again by the heat.

The other method alluded to depends on the theory that the outer side of a focus-tube in action becomes inductively charged with electricity, which acts upon the inside current. To counteract this tendency, some observers have placed a ring of tinfoil or a strip of wet cotton-wool round the kathodal end of the bulb. Mr. T. C. Porter, of Eton, has replaced the foil by a ring of wire connected with the earth. The present writer reported at the Röntgen Society the fact that a finger placed on a tube in action rendered the fluorescence of the screen steadier and brighter.

The testing of a tube is managed in various ways. The ordinary rough plan is to examine a hand with a screen or fluoroscope. A more accurate test of penetration has been devised by Dr. Kolle of Brooklyn, which he describes under the name of a radiometer, as follows:* 'It consists of a small mahogany frame, grooved to contain eight sections of sheet aluminium, ranging from 1 to 12 millimetres in thickness. The sections have a consecutive number of holes drilled into them, filled with plugs of No. 8 lead wire in such a way that No. 1, representing a section 1 millimetre thick, being held in front of the fluoroscope and exposed to the ray emanations, will appear as a light area of certain dimensions, and containing a dark spot in its centre. As the potential or tube efficiency is increased, one section after another would become more or less transparent, all showing the dark spots in the number corresponding to the plugs. The dots may be replaced with small figures of lead with little trouble.'

Several sciameters have been introduced upon this principle of figures through graduated sheets of metallic foil projected upon a screen. One of the first was that of Messrs. Reynolds and Bransom, and among the later may be mentioned those of Max Kohl and Mr. K. Schall. The value of such a test is that good penetration is absolutely necessary to get through deep structures, such as the pelvis or the skull, for the screen and for photographic purposes. At the same time, it should be borne in mind that, broadly speaking, the higher the penetrative power of a tube, the less its photographic action.

The action of a tube is subject to changes not only from week to week and day to day, but also while being worked even a few minutes. Each tube, as a matter of fact, has its own peculiarities. To the worker with the Röntgen rays a really good tube is a priceless possession, to be cherished and protected in every way. Unfortunately, sooner or later the tube refuses to

* 'The *X*-Rays,' by F. S. Kolle, M.D., p. 13. New York: Ogilvie Publishing Company, 1897.

work any longer, and then almost the only hope is to admit air and re-exhaust. It is a curious fact that a tube may benefit greatly by being laid aside for several weeks or months.

IV. THE EXHAUST PUMP

The form of pump varies almost as much as that of the battery. The mechanical pump, capable of giving a high exhaust, demands special knowledge and aptitude on the part of the operator to be successful. The various kinds of mercurial pump, although fragile, are much easier to work. They are devised upon two methods: the Sprengel, by which the rapidly-interrupted fall of a stream of mercury carries the air out of the pump; and the Toepler, in which, by the lifting of the mercury, air is forced out of the apparatus (Fig. 21). Mr. Wilson Noble* has introduced some important modifications in the latter form which, amongst other things, do away with all indiarubber tubes, and permit the reintroduction of any desired quantity of air.

If the Sprengel be selected, it should have at least six fall-tubes, otherwise it will be found exceedingly slow. From 10 to 20 lbs. of mercury are required to work either form. A drying tube—two if possible—should be attached to each pump, as it rapidly absorbs all moisture, the great enemy of high exhausts. An elementary knowledge of glass-blowing is essential to the use of the apparatus. The Röntgen ray tube should be fused to an outstanding branch of the pump; if attached by any other means, it will be found almost impossible to prevent leakage. There should also be a tube with a tap for connecting a small mechanical pump to the mercurial pump. By means of a few strokes of the former, an exhaust of one-thousandth of an atmosphere is quickly reached. If the coil be attached to the tube before starting the exhaust, the spark will pass exactly as in the open air. As the exhaust increases, however, the spark widens out, and forms a ribbon-like discharge. Now the mercury pump must be put in operation.

Assuming that the Toepler form has been selected, the vessel containing the mercury is gradually lifted from the floor-level, so as to raise the glass valve gently to its position, and to fill the large reservoir by forcing the air out through the barometer tube.

* See paper read at Röntgen Society, January, 1899.

When no more bubbling of air is to be seen, lower the vessel containing the mercury, taking care to keep it upright, so that no air can enter, and return it to its first position on the ground-level. Directly the mercury has flowed back into the vessel, lift

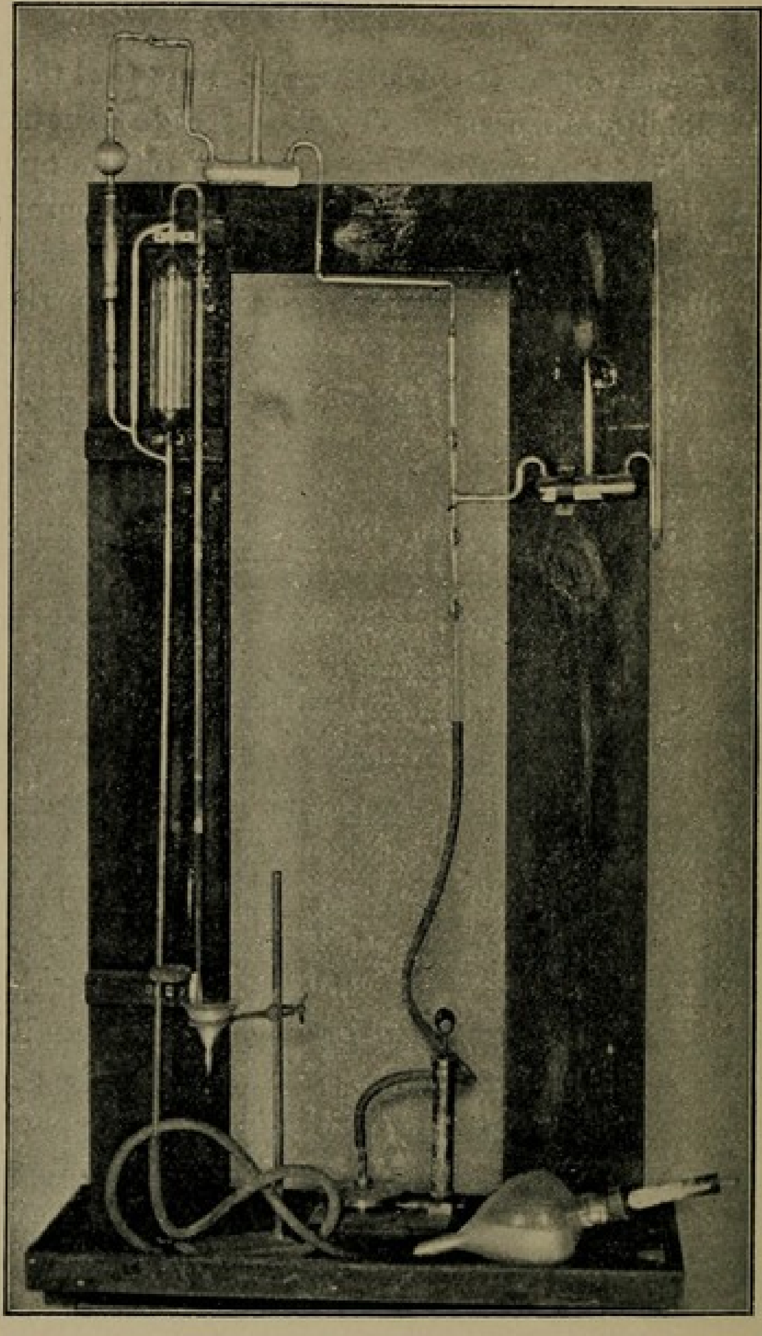


FIG. 21.—TOEPLER MERCURY PUMP.

the latter and continue the process of lifting and lowering until the required exhaust is reached. The higher the degree of the exhaust, the more care is required in filling the reservoir, as by any sudden lift the mercury rushes up with force sufficient to break the strongest pump. If while exhausting the spark be allowed to pass continuously through the tube, it will be noticed that the ribbon discharge breaks away from the kathode and gradually shortens until a glow surrounds both anode and kathode; later on the glow surrounding the anode gradually disappears, while that of the kathode spreads until it fills the whole tube. A dark space begins to appear round the kathode, and as this increases a green fluorescence is seen here and there in the tube.

The kathodic glow is focussed by the aluminium disc into a distinct stream striking the anode, which it gradually makes red-hot. At this point it is desirable to heat the tube by placing underneath, and almost close to it, a piece of asbestos board, below which is a good Bunsen flame. When the tube is thoroughly heated, another Bunsen flame may be applied directly to the glass; it must not be allowed to rest on one spot, but should be passed quickly to and fro, so that the flame may play equally over the whole tube. This second burner should be used occasionally for two or three minutes at a time. Unless these points are carefully attended to, there will be danger of overheating some part of the glass bulb, which will soften and be driven in by the pressure of the outside air, causing the instant collapse of the Crookes' tube. When the dark space reaches as far as the anode, the resistance to the passage of the current increases rapidly, and the whole of the front of the tube is filled with a beautiful golden-green fluorescence, and if the hand be now placed between the tube and the fluorescent screen, its shadow can be seen on the latter. If the tube is to be used with a 6-inch coil, the exhaust should be continued until a 3-inch spark passes with some difficulty; then the tube should be disconnected by melting in a blowpipe flame, and drawing out the glass junction of the Crookes' tube with the pump. As the resistance of the tube continues to increase with use, it will gradually exceed the power of the coil, as already stated. It may then be opened, attached to the pump, and once more exhausted.

Another method of exhausting the Crookes' tube has been suggested recently by Professor Dewar. Taking advantage of the intense degree of refrigeration that can be attained by liquid hydrogen, he applies that material to a small secondary bulb, and in that way condenses the whole of the air in the main tube as a liquid in the annex, which is then sealed off with the blowpipe. A tube can in this way be exhausted in about a minute.

V. THE FLUORESCENT SCREEN

The screen depends upon the property possessed by the Röntgen rays of causing fluorescence in certain bodies, such as platino-cyanide of potassium, platino-cyanide of barium, calcium tungstate, and many other salts. A thin piece of cardboard is covered with three layers of collodion varnish. Before the last coating is dry, either of the above-mentioned salts is sprinkled in a fine powder evenly over its surface. Everything necessary should be at hand, as the varnish dries rapidly. The best sprinkler is a fine wire strainer, held some distance from the cardboard. It is well to practise on a piece of dry cardboard several times, as the operation is by no means as simple as it looks. The efficiency of the screen largely depends upon the evenness with which the cardboard is covered. The following sizes are recommended: 8 inches by 5, 12 by 10, and 18 by 12.

The eye is not readily affected by the fluorescent light. It is advisable, therefore, to have the room perfectly dark, to place a cloth over the break of the coil, and to enclose the Röntgen tube in a black paper wrapper. After remaining a few minutes in darkness, the tube may be put into operation, and in dealing with the human body the experimenter will gradually learn to distinguish any abnormal conditions of the bones or the presence of any foreign opaque substance. The object to be examined should be placed between the tube and the screen, the latter being put upon it with the fluorescing salts outward—that is to say, on the side facing the operator. The screen when not in use should be kept away from dust and damp; and it is often advisable to protect it with a layer of celluloid or other transparent material, especially for campaigning purposes.

The value of the screen seems to be not yet fully appreciated in medical and surgical work. In both branches of practice an immediate diagnosis is often imperative, a result that can be more reasonably expected from the direct visual evidence afforded by the fluorescent screen than by a photograph for which the surgeon or physician has perhaps to wait for a week or a fortnight. For the consulting-room, where the greatest possible amount of accuracy has to be combined with the least expenditure of time, the screen will probably sooner or later take a foremost place. By its means a diagnosis that would baffle an hour of careful ordinary examination might be laid bare in an instant by a glance through the fluoroscope. This promptness has commended the screen to the enthusiastic praise of the army surgeons who have used it in actual warfare.

The cryptoscope, or fluoroscope, does away with the necessity of a darkened room. It consists of a dark chamber, shaped like an ordinary stereoscopic hand-camera. At one end is fixed the fluorescent screen, and at the other one or two apertures through which the observer looks (see Fig. 22).

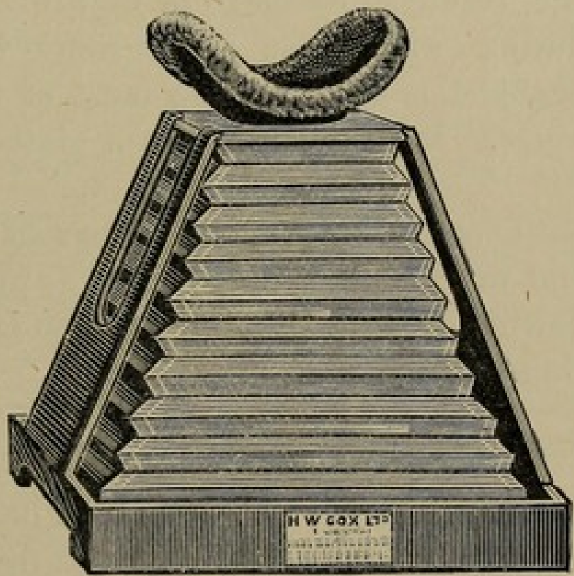


FIG. 22.—THE CRYPTOSCOPE.

Many attempts have been made to photograph direct from the screen, but hitherto without much success. Tracings may be made upon transparent paper laid on the screen surface, or with a pencil on paper placed against its cardboard back.

VI. PHOTOGRAPHY

A knowledge of photography is essential to the experimenter who wishes to carry out the whole process with his own hands. All the usual dry plates of good makers seem equally sensitive to the focus tube rays, but amongst them may be specially mentioned the Cadet Lightning, the Paget XXXXX, the Imperial Rapid, and the Lumière plates. With the last beautiful results may be obtained, at the cost, however, of a slow development. Dr.

Dawson Turner has, however, found that slow plates are just as good and as quick as extra rapid ones (*Electrician*, February, 1897). Plates must be transferred from their boxes to the black paper envelopes in a photographic dark-room. It is better to enclose them in two layers of coloured paper—an inner one of orange and an outer of black. After exposure the plate is taken back for development to the dark-room, from which all except ruby light has been rigorously excluded. Where light-tight envelopes are used the invariable rule is to place the sensitive surface of the plate beneath the plain or 'address' side of the envelope. Some workers use plates coated on both sides, and speak well of the results. Special dishes are needed for their development, during which the plate must be occasionally reversed. Their object is to make the most of the x-ray image with deep structures. Printing from these plates is done in the usual way.

Developing solutions may be prepared of pyrogallic acid, hydrokinone, metol, and various other materials. If pyrogallic acid be selected, the following formula will be found to give good results with almost all kinds of dry plates:

STOCK A.

Pyrogallic acid	1 oz.
Potash metabisulphite	2 drs. 10 grs.
Ammonium bromide	2 drs. 10 grs.
Water to 10 oz.	

B.

Ammonia, strong solution ...	5 drs.
Water to 10 oz.	

C.

Pyrogallic acid solution (Stock A) ...	$2\frac{1}{2}$ drs.
Water to 10 oz.	

To develop a whole plate, take 2 oz. of C and 1 dr. of B, but do not mix them until you are quite ready to proceed with the development.

The developer may be divided into three solutions, of which one gives density (A), while the others act as accelerator (B) and restrainer (C).

A.

Pyrogallic acid	$2\frac{1}{2}$ drs.
Metabisulphite of soda	$2\frac{1}{2}$ drs.
Water	20 oz.

B.

Carbonate of soda (crystals) ...	3 oz.
Sulphite of soda	1 oz.
Water	20 oz.

C.

Potash bromide	1 oz.
Water	9 oz.

Mix equal parts of A and B, and add a small quantity of C.

Dishes—the lighter the better—will be required to match the various sizes of plates. They may be made in the smaller sizes of ebonite or of xylonite, and in the larger of papier-maché or of enamelled iron. Having taken the exposed plate out of the envelopes, place it in the developing-dish, mix the developer, hold the dish slightly inclined from you, and pour the developing solution quickly along the upper edge of the plate, so as to cause it to flow rapidly over the whole surface. Keep the liquid slightly moving, but not so quickly as to produce bubbles. The picture, if properly exposed, should show within a minute after pouring on the developing solution. The more gradually it appears the better the result is likely to be. If after two or three minutes it still lacks contrast, pour off the developer and add to it a little more of solution B, and once more flood the plate. In from five to ten minutes the picture will be fully developed. Practice alone will enable you to decide when this important part of the process has been effected. The plate must now be taken out, well washed, and placed in the fixing solution, which consists of

Hyposulphite of soda	16 oz.
Water	80 oz.

The plate should remain in this until all traces of opalescence have disappeared. It may then be exposed to the ordinary light, and should be washed in running water, if possible, for about an hour, and afterwards placed edgewise and allowed to dry.

The methods of development are legion, and one or two of those that have yielded the best results in x-ray work will be described immediately. Most of the makers of dry plates and of sensitized paper print on the cover of the packets a formula suitable for developing and toning. One drawback to the use of a "pyro." developer is the way in which it stains the hands. To avoid that inconvenience such substances as rodinal and hydroquinone have been substituted by many photographers. Metol does not stain the hands, but is apt to cause a troublesome sloughing of skin.

Many good results have been obtained with hydroquinone, which is a slow developer. The image begins to appear in about four or five minutes, and development must be continued for half an hour or more—indeed, until the whole surface has become blackened. To secure detail slow development appears to be the rule, and the plate may be immersed in a weak solution of developer, and placed upon a suitable 'rocking' bath for forty minutes or more, when the strength of the solution is gradually increased. Metol gives a dense black negative, and combined with hydroquinone is a favourite combination with many Röntgen photographers, and has been well spoken of in the following formula :

Metol	80 grs.
Hydroquinone	45 grs.
Sodium sulphite (crystals)	640 grs.
Sodium carbonate (crystals)	640 grs.

Water to 20 oz.

A good formula for metol is : Metol, 5 parts, dissolve in distilled water, 50 parts, and then add sulphite of soda (crystals), $\frac{1}{2}$ part.

In an excellent little book on the subject, Messrs. Isenthal and Ward* recommend a rodinal solution as efficacious and convenient, especially for double-sided films and plates. The writer has found this developer give excellent results, especially as regards detail, but it is slow in action. One part of rodinal is used to 30 parts of water. The image quickly appears, but development must be continued until it has such density that no details are discernible in transmitted light (twenty to forty minutes). In case of over-exposure the solution may be further

* 'Practical Radiography,' by A. W. Isenthal and H. Snowden Ward, London, 1898, p. 102.

diluted; for under-exposure a few drops of the following solution should be added:

Rodinal	...	...	...	... 1 oz.
Water	...	...	...	... 1 oz.
Bromide of potassium	...		...	... $\frac{1}{2}$ oz.

Excellent results have been reported by development with hydroquinone until the image shows a fair amount of density; the plate is then immersed in a rodinal solution, in which a further slow development brings out the more delicate details of the picture.

The operator will do well to master the capabilities of one set of plates and of one developing solution. To procure good results, every part of the process should be performed thoroughly.

Intensification of negatives is often necessary to strengthen a faint image, especially in the case of deep tissues taken with a high-resistance or 'hard' tube, when the bulk of the rays is penetrative rather than photographic. It is carried out by first washing the plate, and then immersing it in a solution of corrosive sublimate of a strength of 20 grains to the ounce of water, rendered soluble by the addition of an equal quantity of ammonium chloride. The negative is left thus covered until its whole surface turns light gray or white; it is then well washed, and blackened in a solution of strong ammonia—10 drops to the ounce of water. Negatives intensified in this way print more slowly, owing to their density.

Reduction of an over-dense negative may be effected by washing and then placing in clean hyposulphite solution; to the latter is then added a few drops of the following solution:

Potassium ferricyanide ... ... 1 oz.
Water to 10 oz.

Reduction at once commences, and when sufficiently advanced the plate should be well washed and dried.

Printing from Negatives

As soon as the plate is thoroughly dry, it may be placed in the printing-frame, with the film side inwards. On the latter is laid the sensitized paper, which is in turn fastened on with the wooden back. The frame is then exposed to the light (not direct sunlight) until the picture appears in deep tones, a fact that may be ascertained by raising half of the back and looking at the paper. Owing to the density of the negative, the process is often slow, sometimes extending over a week. Good results are obtained by some workers by printing through green glass. The print when taken out is placed in running water until all cloudiness of the water disappears. It is then put in a toning solution consisting of

Chloride of gold	20 grs.
Acetate of soda	1 oz.
Water	20 ozs.

One ounce of this stock solution should be added to 10 oz. of water for use. Keep the print constantly moving, so that the toning may be even; and when the required tone appears, take it out and wash, if possible in running water, for some time. Then immerse in the fixing solution, consisting of

Hyposulphite of soda	2 oz.
Water	20 oz.

and let it remain about ten minutes. Once more wash thoroughly and hang up to dry. It is advisable to carry out the washing and toning in subdued light. When dry, the print should be mounted on cardboard. The kind of mount is a matter that will repay attention, as nothing sets off a photograph more effectively than a good-sized mount with a border of subdued tint and a white centre, either plain or 'sunk.'

A combined toning and fixing solution may be used, and, although results are hardly so satisfactory as those obtained by ordinary methods, yet, on the other hand, time is saved, and if the process of washing be carried out thoroughly, good enough prints are obtainable.

With regard to photography in relation to Röntgen work, it may be observed generally that the roughest negatives and prints often afford all the information needed by the surgeon or the physician; still, it is clearly desirable to have good results in photographs that are to be kept, and now and then detail is absolutely essential, as when small splashes of lead or fragments of necrosed bone are buried in deep tissues.

Rapid results may be obtained in various ways. Thus, the negatives may be hardened by immersing them in 2 per cent.

solution of formalin, and dried after soaking in methylated spirit, or, better still, in absolute alcohol. When dry, the negative may be put in the printing-frame, and a snap-shot print taken on Elliott's bromide paper. This is done by exposing the negative for five seconds at a distance of about a foot from the flame of an ordinary fish-tail gas-burner. The print is then immersed in a rodinal developer—1 drachm to 3 ounces of water; and when the image has reached the desired degree of blackness, it is removed, washed, placed in a weak fixing solution of hypo., again thoroughly washed, and dried. By this means the surgeon may be presented within a few hours, say, of an accident or of a condition demanding urgent operation, with a photographic record, somewhat lacking in detail, it is true, but likely to afford all the information desired.

Röntgen photographs may also be taken direct on sensitized paper. Eastman's *x*-ray paper, and that of other makers, is used in exactly the same way as the dry plate; but the most rapid paper is not yet equal to the most sensitive plate, and hence longer exposure is required. Moreover, it does not give anything like the detail of the sensitive plate; but, on the other hand, its advantages are so numerous and so obvious that improvement in the production of it is still eagerly awaited. In using paper, the operator must take care he presents an absolutely flat surface to the Röntgen rays, otherwise the image may be distorted in a remarkable way, and thus give rise to pictures that may entrap the unwary into all kinds of fallacious readings. A good plan is to place the sensitized paper between two sheets of stout pasteboard.

In the Greek war many Röntgen photographs were taken direct as positive images on Eastman's special paper. In this way, although there is not the clear definition in the resulting photographic record as that obtained by the use of negatives, yet, on the other hand, there is a great saving in time and also in risks of the carriage of fragile glass plates.

Intensifying Screen

Various attempts have been made to multiply the photographic effects of the focus tube. To take deep structures requires a tube of high resistance, a condition in which there is great penetration but little photographic action. In order to increase the latter the 'intensifying screen' was devised. At first it consisted of a fluorescent screen, the surface of which was in contact with the sensitive plate, which thus had the double action of the focus-tube rays and of the fluorescent screen image. Messrs. Watson were the first to introduce a flexible screen, the coating of which would not crack when bent. Two such screens were used, one on each side of the plate. The intensifying material most commonly used is tungstate of calcium, but hitherto it has been found impossible altogether to avoid the mottled appearance known as 'grain' which is produced upon the negative. Although theoretically sound, this method of manipulation has not been widely adopted, and, given sufficiently powerful apparatus, equally good results can be obtained in other ways. At the same time, it should be noted that by the use of the intensifying screen the exposure may be much shortened. Moreover, it enables a small coil with a longer exposure to penetrate deep structures, and to approach a large coil in efficiency. In order to make the most of the photographic action of the focus-tube rays in dealing with deep tissues, some operators use double plates and two intensifying screens.

Messrs. Watson supply a neat mahogany frame which carries the sensitive plate and intensifying screen; the face is of ebonite, and on the other side is a sheet of thick glass, according to the plan of insulation adopted by Mr. Webster in his exposures of the fractional-part-of-a-second duration.

Most of the plate-holders, whether for use with the intensifying screen or otherwise, are made so that the holder can be conveniently centred in its position against the patient's body, by white lines on the outer surface which correspond with the underlying plate.

Definition*

Clearness of definition depends upon a number of conditions.

First, with regard to the tube: The best definition would obviously be given where the rays were emitted from a single point, and this in turn will depend upon the relative position of the anti-cathode to the cathode. If the platinum plate is fixed exactly in the focus, it is apt to become overheated and perforated or detached from the support. These drawbacks may be to some extent avoided by using either a thick platinum plate, about one-sixteenth of an inch thick, or platinum backed with aluminium,

* This section has been kindly revised and rewritten by Mr. Ernest Payne.

for the anti-cathode. Osmium and iridium, especially the former, have been found useful for the anti-cathode, a small piece of the metal being fixed on a block of aluminium. Professor Röntgen used a 'pinhole,' consisting of a sheet of metal with a small hole in it, through which the rays passed, thus obtaining almost the same result where the platinum plate was not in the focus, and the 'surface of emission' was comparatively large.

The phenomenon of diffusion and the action of secondary rays tend to spoil definition more, perhaps, than an imperfect tube. Placing the tube at a long distance from the plate and object does not prevent the effects of the secondary rays. Professor Röntgen investigated this phenomenon, and gave the results to the Berlin Academy of Sciences.* A lead screen or cover has been tried to keep off these secondary rays, with an aperture at the upper side or end to admit the rays from the tube. But this does not, of course, do away with the diffusion of the rays which pass through the subject and act upon the plate. It is, perhaps, in radiographs of the pelvis that this defect becomes most obvious; it also shows when examining the thorax with the fluorescent screen. A coin, for instance, placed on the surface of the body next to the screen gives a clear, definite shadow, but if placed on the other side of the body, away from the screen, the shadow becomes lighter, and much less distinct than would be the case when compared with the shadow cast by an ordinary lamp. It has been stated that these diffusion effects are not so strong with a new tube as with one that has been worked for some time.

To test the definition of tubes, Dr. Mackenzie Davidson employed a network of fine wires crossing each other at right angles, and about 1 cm. apart. If the *x*-rays come from a small point, the shadow of the wires cast on a fluorescent screen will be correct. 'Anything larger than a small point will show astigmatism in the shadow—in other words, the wires parallel with the nearest edge of the anode will cast dark shadows, while the cross wires will cast blurred and ribbon-like shadows, or even be invisible altogether.'† In any tube the rays which will probably give the best definition will be those coming off the anti-cathode at the widest angle to the axis between cathode and anti-cathode.

* *Archives of the Röntgen Ray*, vol. iii., No. 3.
† *Ibid.*, vol. iii., No. 4, p. 68.

The distance of the tube from the plate and from the parts to be radiographed is an important question. If possible, it is no doubt best to have the tube at a comparatively great distance, and give a longer exposure where good definition is wanted.

If a picture of the upper part of the spine be desired, the tube may be placed nearer the sternum than if a general view of the heart and lungs were wanted; the bones nearest the tube will then be given only in indistinct masses. These facts were pointed out in the early days by Dr. Macintyre.

Some of the plates specially recommended as most sensitive to x-rays do not give the best definition. This may be due to some fluorescent effect excited in the glass plate or in the sensitive film, but it is probable that these plates are more sensitive to the secondary rays than others. Some developers—or, perhaps, methods of development—are better than others. Long development in a weak solution will sometimes bring out details more completely than a quick development with strong solutions. Some workers recommend a weak solution of rodinal (1 : 64) and water, and leave the plate in the developing bath for two or three hours. Fading and indistinctness of the negative is sometimes due to imperfect washing.

Intensifying screens seem to improve the picture in some cases and to spoil the effect in others. In some instances they appear to exaggerate the light and shade of the picture, as, for instance, when taking a radiogram of the elbow from front or back, always more difficult to show clearly than the same joint in profile. They no doubt shorten the exposure, and bad definition may be due to over-exposure. Care should always be taken that the screen is kept close up to the sensitized film; if not, misty patches will often appear here and there on different parts of the negative.

Movement on the part of the apparatus should be guarded against. If the tube is standing on the same table as the coil, and if the former be not very steady, the vibration of the contact-breaker may be quite sufficient to shake the tube and perhaps cause the tube-holder to shift its position slightly. A similar disturbing effect may be produced on the plate and on the hand or arm of the patient if they are resting on the same table on which the coil is standing.

Movements on the part of the patient often produce hazy pictures, even where there are no defects in the apparatus. These movements may be voluntary or involuntary. The operator should always insist on the patient always being in a suitable and comfortable position. When taking the hand, wrist, or elbow, the whole arm should rest on the table, and the patient sit back in the chair, especially when the elbow is concerned. The movement of the shoulder with respiration will cause a slight amount of indistinctness, and the clearest pictures of that part will be obtained when the patient is lying on a suitable couch. Pillows, cushions, and rugs may be placed under the parts not to be radiographed, but the board on which the plate rests should be as rigid as possible. Folds and creases are a great source of discomfort, and become intolerable in cases of long exposure. It is often better to remove a garment altogether than to fold or roll it.

Involuntary nervous tremors will sometimes cause bad definition, especially in the case of children. If the patient feel cold, a couple of large silk squares may be thrown over the body without diminishing the radiographic effect.

With regard to the movements of the heart and lungs, radiograms of the thorax must always be more or less indistinct on this account. Clearer pictures of the thorax might possibly be obtained in some special cases if the patient could hold his breath for short intervals, during which the tube would be running, the current switched off for a few seconds during each fresh inspiration.

To carry out this method in the case of the heart would be still more difficult; it would be necessary for the operator to sit with the hand on some part of the body where the pulsation of the heart could be felt, instantaneous single flashes being sent through the coil with each movement or every other movement of the heart. Whether the pictures of the heart thus obtained would be of any value or not it is hard to predict. The experiment is one, however, which might be tried.

Localization

This important branch of Röntgen work should perhaps be considered here, as photography is intimately concerned with its chief methods. For the sake of convenience, however, the subject has been placed in the second part of this book, under the heading of 'Foreign Bodies' (p. 89).

Stereoscopy

X-ray or radio-stereoscopy furnishes a means of visual inspection and localization, but it is not likely, so far as one can see, to come into general use, owing to its somewhat complicated processes. Beautiful results are thereby obtainable, especially for purposes of demonstration, and the worker who wishes to undertake this particular branch of the subject will gain a good idea of its principles and methods from the following description by Mackenzie Davidson :*

STEREOSCOPIC RADIOGRAPHY.

It is only necessary to look at two good stereoscopic radiographs in a Wheatstone's stereoscope to realize at once how thoroughly practical and important this method is in surgical work. A single skiagraph is often confusing, if not misleading, but with two properly taken and viewed in a stereoscope, the picture stands out in true relief, and shows clearly the relation of the parts.

I will now describe the method and apparatus† I employ. It is that which up to the present time I have found to be the best.

1. *The Crookes' Tube.*—A tube giving the best possible definition, and at the same time allowing the shortest exposures, is essential. The tube with an osmium anode (introduced by the writer) answers these requirements well. Mr. Cossar has made these tubes admirably, but unfortunately the supply of pure solid osmium seems to be exhausted. It can be obtained in fine powder, but in small lumps it cannot now be procured, and no one seems to care to make any more in the solid form.

2. *Horizontal Bar.*—Two radiographs must be taken from two different points of view. The Crookes' tube after one has been taken must be displaced and then another taken. I use the horizontal bar of my localizing apparatus. Any desired displacement may be given to the tube, but it seems best to displace it about 6 cm., which may roughly be taken as the distance between our eyes. The two skiagraphs thus taken from two different points of view, and the necessary marks made on the patient's skin to guide the surgeon, give data sufficient to localize the position of any foreign body or other part accurately ; while the same skiagraphs give a stereoscopic picture enabling the surgeon to have a correct view of the parts in relief. This method, if correctly carried out, is so accurate and complete that the surgeon can have little cause for complaint.

3. *Changing Box.*—This consists of a frame over which is tightly stretched some calf-skin. This is stout enough to support a considerable weight, and at the same time is thin and transparent to *x* rays. The photographic plate, wrapped in black paper in the usual way, is placed beneath the skin, and supported against it by some suitable arrangement. Fig. 23 shows the apparatus, and if it be viewed with a stereoscope, its construction will be readily seen and understood. The horizontal bar shows the tube-holder displaced to one side, and the clip on the right side is the limit to which it must be displaced for the second photograph. A wire is seen stretched on the nearer end of the box, and the bar is

---

* 'On the Value of Stereoscopic Skiagraphy,' etc., by Mackenzie Davidson, M.B. (*British Medical Journal*, December 3, 1898).

† The apparatus is made by Messrs. Muirhead and Co., Elmer's End.

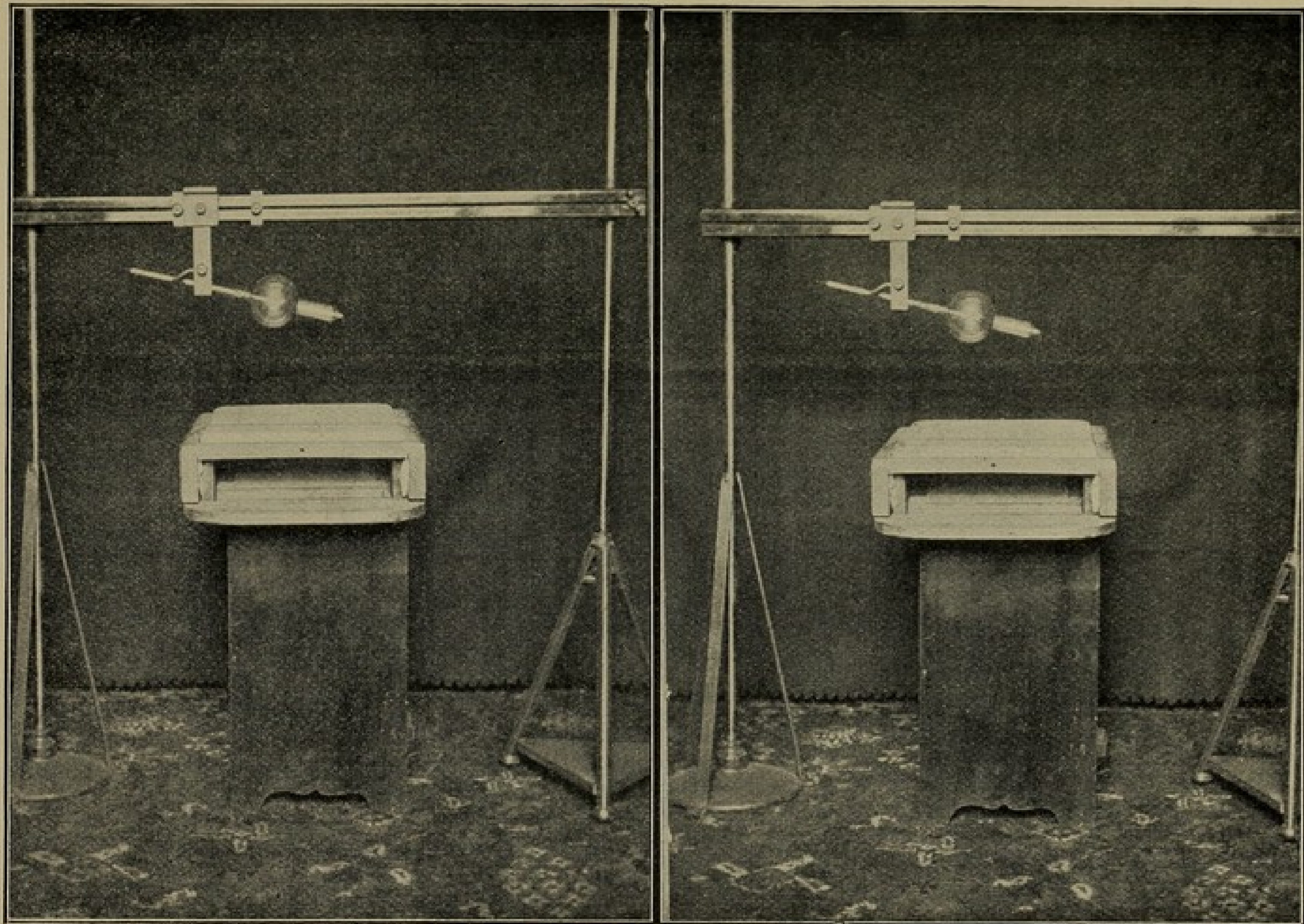


Fig. 23.—After a Stereoscopic Photograph showing Horizontal Bar with Crookes' Tube and "Changing Box" arranged for taking Stereoscopic Radiographs.

arranged parallel to this wire. This leaves a white line at the edge of each negative, and this enables the photographs to be mounted correctly in register. A board is seen below, and upon it will be noted the photographic plate wrapped in the black paper. By means of a lever worked by a screw at the far end of the box, not visible in the illustration, this board is raised so that the plate is brought firmly up against the calf-skin. The part of the patient to be skiagraphed is placed upon the top of the box. It will be easily seen how two photographs can be taken on different plates without disturbing the position of the patient ; we are thus sure of obtaining correct stereoscopic pictures. This method can, of course, be carried out by having a table made with calf-skin covering a space cut out of the top ; or, again, an operating-table can have a window, so to speak, covered by the calf-skin upon which the patient can lie. This has the further advantage that it will allow a Crookes' tube to be placed below this part of the table, so that the patient could be examined by a fluorescent screen while lying on the couch.

4. *Wheatstone's Stereoscope.*—Two plane mirrors, about 4 inches square, are so fixed on a vertical support that their backs form an angle of 90° with each other. When the observer puts his face close to the edge where the mirrors meet, so that this edge lies vertically between his eyes, it follows that his right eye can see only what is reflected in the right mirror, while his left eye can only see what is reflected in the left mirror. Now, if the two skiagraphs, taken as already described, are placed so that the right eye image is opposite the right mirror and the left image opposite the left mirror, each eye will recognise its own picture, and they will combine, as usual, and give rise to a single image in perfect relief.

There are several devices for supporting the skiagraphs, and also for simultaneously making them approach or recede from the mirrors. The simplest of all arrangements is to have two mirrors mounted on an upright block of wood, which can be placed upon a table, while the skiagraphs can be supported by any simple means in the proper positions. The writer has devised a form of revolving Wheatstone stereoscope shown in Fig. 24.* A four-sided box, which can be revolved on a vertical rod, is placed opposite each mirror. Upon each of its four sides one of a pair of stereoscopic skiagraphs is placed. The corresponding pictures are similarly placed on the other box. In this way the boxes can be rotated, and two corresponding skiagraphs brought simultaneously in correct position opposite the mirrors. This prevents the necessity of adjusting each pair separately, and saves time in demonstrations. The block supporting the mirrors is attached to a small base with bevelled edges, which slides in a broad groove, and enables the observer to slide the mirrors towards or away from his eyes. In this way he can adjust the mirrors to the position which enables him to combine the pictures most comfortably. Each revolving box is fixed by its vertical support to its sliding board. This allows the distance of the skiagraph from the mirrors to be altered at will.

The Wheatstone stereoscope is peculiarly adapted for x-ray photographs ; first, because, as everyone knows, a print from an x-ray negative is reversed—for example, if a skiagraph of a right hand be taken, when printed it appears to be a left hand. Now, if such a print be viewed in a Wheatstone stereoscope, it is reflected in one of the mirrors, and is thus reversed to its original position by the reflection. Therefore, if opposite the right mirror is placed the print from the negative produced when the Crookes' tube was displaced to the right side, and opposite the left mirror the print from the negative taken when the tube was displaced to the left, the observer will then see the parts in correct stereoscopic relief, as if he had been looking at them with his eyes placed so that the right eye was at the point occupied by the anode when displaced to the right, and the left eye at the point occupied by the anode when the tube was displaced to the left. If the skiagraphs be viewed under the same angle as they were taken, the

* The Wheatstone stereoscope is made by Messrs. Curry and Paxton, Great Portland Street, W.

stereoscopic picture would show the parts of the true or actual size, and the exaggerated distortion of the single *x*-ray photograph is overcome. The importance of such a result to a surgeon is great.

There is no limit to the size of the pictures which can be seen in a Wheatstone stereoscope. The largest size the writer has as yet taken stereoscopically is 12 by 15 inches.

If the right picture be placed opposite the left mirror, and the left picture opposite the right mirror, a stereoscopic picture will be seen as before, only reversed. For example, in one case a hand will appear as seen from the dorsal aspect ; if the prints are transposed, it will appear as a hand seen from the palmar aspect. The same transposition can be effected by turning each print upside down.

The negatives, while wet, can be seen in a stereoscope if they be held in proper position by upright frames, and each illuminated by a strong light diffused through ground glass or white paper, but the effect is not so good as viewing prints.

If it be desired to reproduce the skiagraphs as illustrations in a book or periodical, they can be reduced and mounted alongside of each other.

INSPECTION OF STEREOSCOPIC SLIDES WITHOUT THE STEREOSCOPE.

By practice it is not difficult to acquire the power of combining stereoscopic pictures without an instrument of any kind. There are two ways of doing this :

1. By looking beyond the photograph, so that each eye sees the picture opposite it.

2. The most easily acquired and most important for *x*-ray work, as it enables skiagraphs of any size to be seen at once, consists in crossing the visual axes. This may be accomplished as follows : The photographs or radiographs are placed correctly in front of the observer ; he then holds up his finger in the middle line between his eyes and the skiagraphs, and while looking at the top of his finger he will observe double images of each radiograph ; by a little perseverance he will learn to make two of the images in the centre combine, and he then will have a beautifully clear stereoscopic image apparently in the air. Behind to right and left will be two images, but these he soon learns to ignore, or he can cut them off by bringing his hands cautiously from the outer side of each eye towards the middle line, stopping the moment the two side images are cut off. It is, of course, very convenient in this way to see negatives in stereoscopic relief immediately after development.*

---

* See Wheatstone's papers already referred to and Leconte's Sight' (the International Scientific Series, Kegan Paul and Co.).

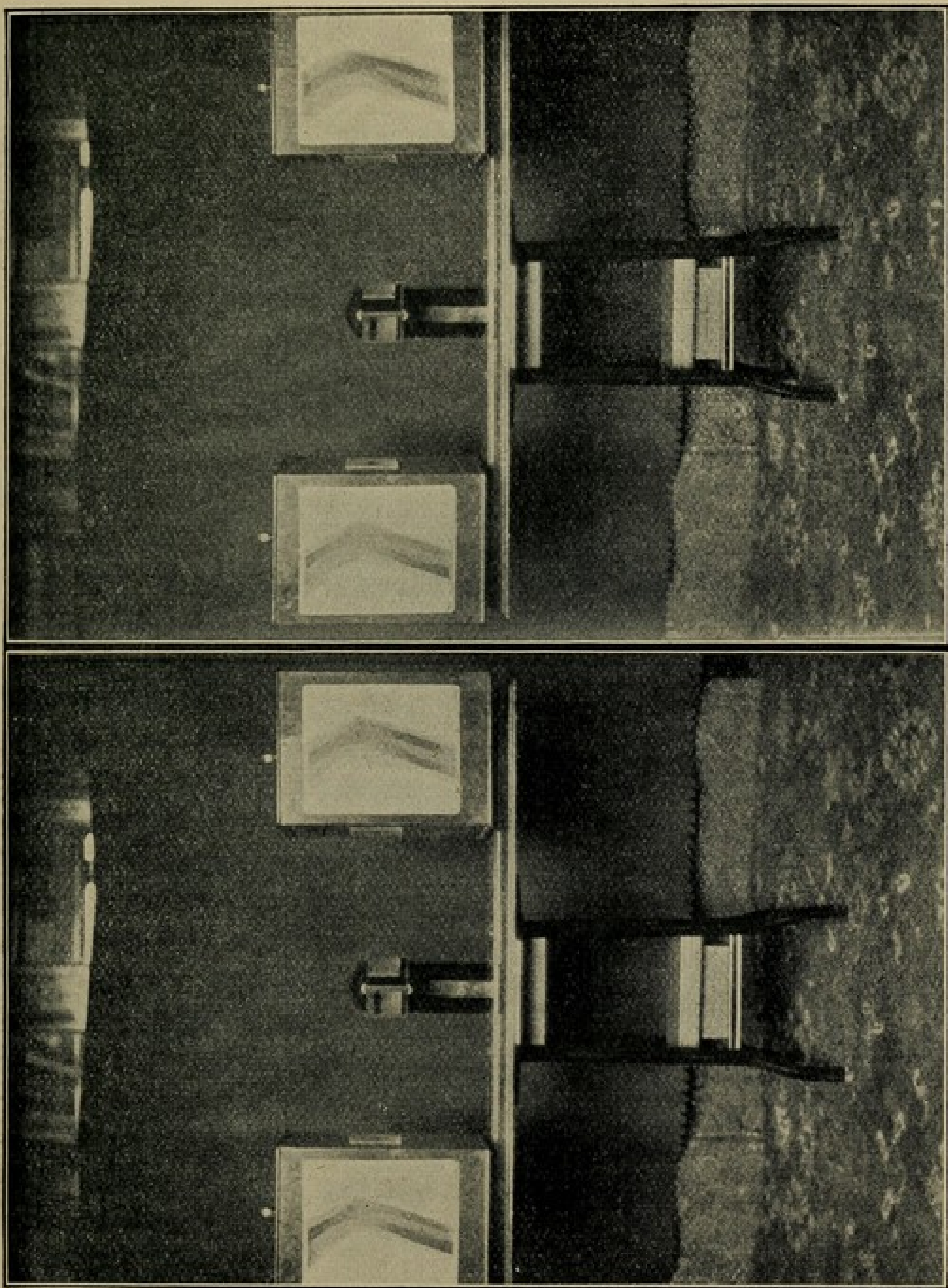


FIG. 24.—AFTER A STEREOSCOPIC PHOTOGRAPH OF A WHEATSTONE'S STEREOSCOPE.

VII. STANDS AND OTHER ACCESSORIES

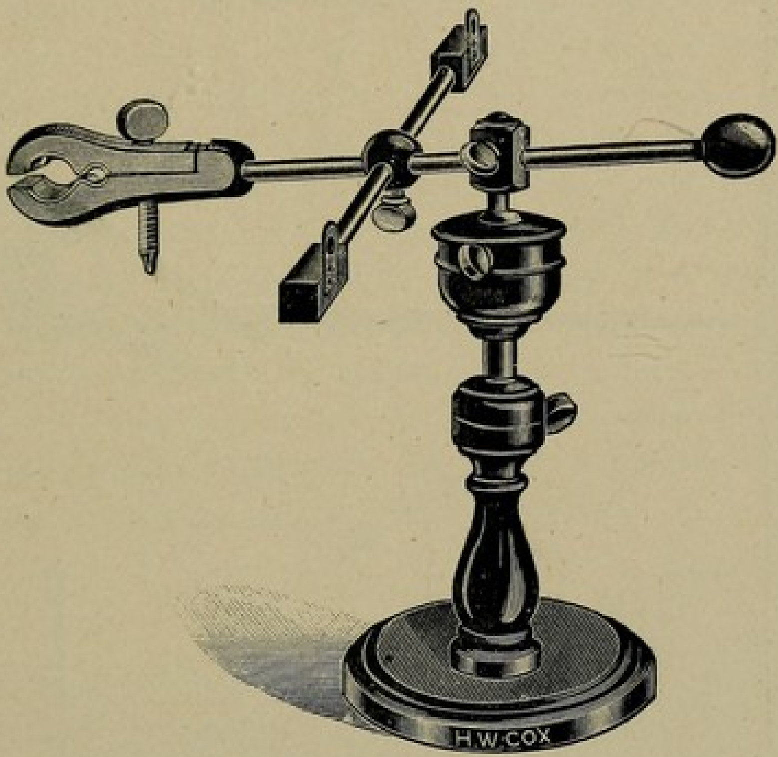


FIG. 25.—TUBE-HOLDER.

A stand for the tube is necessary, and can be easily constructed by anyone possessing a little mechanical ingenuity. An ordinary laboratory wooden retort-holder will be found to answer most purposes. When a patient is lying on a bed or couch, however, a larger holder will be required, such as the one shown in Fig. 25.

Many other excellent stands are in the market. The chief requisites are a firm, heavy base; easy joints, capable of tight fixing and of ready extension in every direction, with arms of some non-conducting material, *e.g.*, hard wood. The stand is one of those details careful attention to which will be found essential to the production of good work. As the tube hangs from the end of a long lever, it is readily made tremulous by the multiplication of any motion communicated to its support. Clearly, a shaky tube means a blurred photograph.

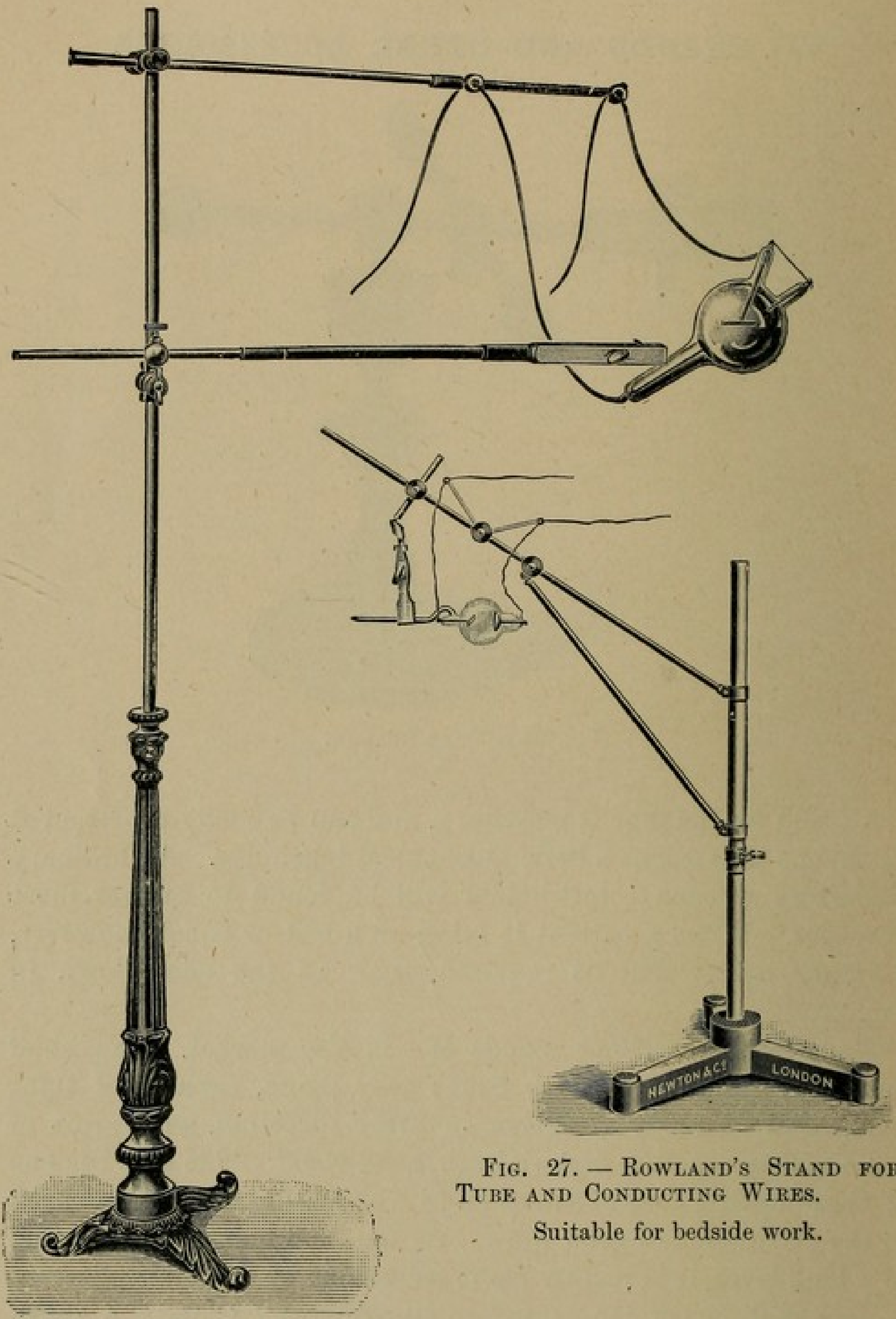


FIG. 27. — ROWLAND'S STAND FOR TUBE AND CONDUCTING WIRES.

Suitable for bedside work.

FIG. 26.—STAND (WATSON'S).

Operating-Table

A simple operating-table can be made of a piece of board 6 feet long, 2 feet broad, and 1 inch thick, mounted on firm supports about 18 inches high. The coil and tube-stand can be placed on the floor, or on a second table close to the patient. By using the small mounted screen occasionally, it will be seen if the tube is emitting rays of good penetrating power—a simple precaution whereby much subsequent disappointment may at times be prevented. If the process can be conducted in a dark room, the ordinary screen will be available; but if it be in a lighted room it is difficult for the inexperienced eye to determine whether the tube is at its best or not. In the latter case the fluoroscope, which, as already explained, is simply a screen mounted in a stereoscopic camera, will be found of service.

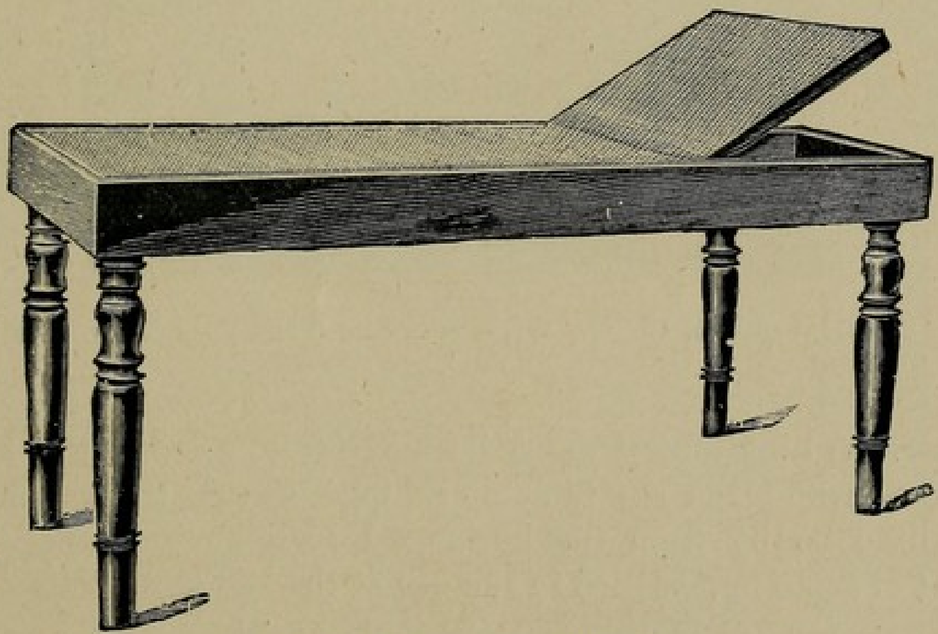


Fig. 28.—Operating-Table.

An operating-table may be extemporised from an ordinary box-couch or deal table without drawers, and in the latter case the screen can be used beneath the table-top. Numerous special couches have been constructed, many of them with canvas tops. The accompanying illustration shows a simple one of modern type, made by Watson and Sons.

Davidson has a useful couch (Fig. 29) which allows the tube to be shifted into any position in the length or breadth of the table. There is also a window fitted with a convenient sheepskin tympanum for screen observations and for stereoscopic or ordinary photography.

By exercising a little ingenuity the Röntgen ray worker will be able to adapt any ordinary deal table to meet his require-

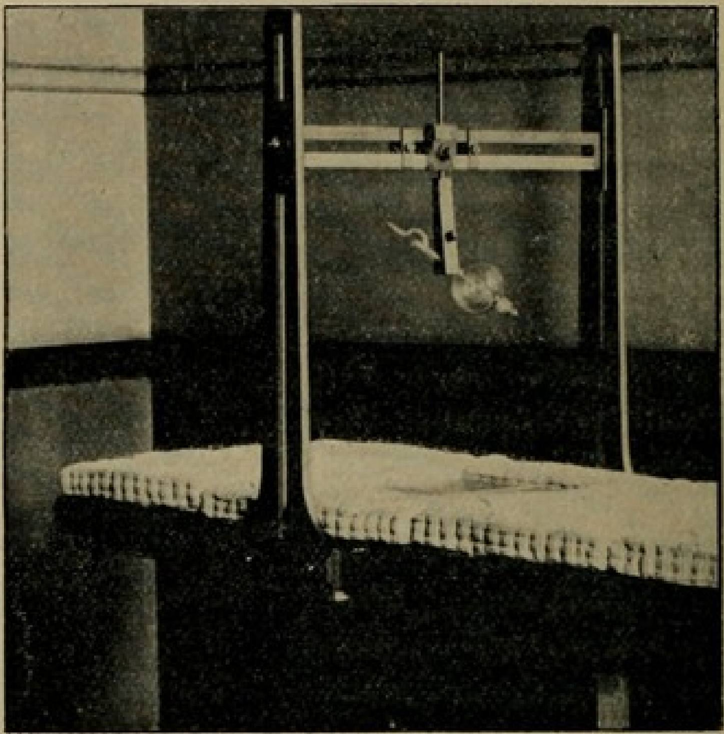


FIG. 29.—DAVIDSON'S COUCH, WITH SHIFTING TUBE-HOLDER, FOR RÖNTGEN RAY WORK.

ments. A hint may perhaps be taken from some of the French makers, who place the table on a hinge, so that the patient may be tilted bodily from the horizontal to a reclining position, a point of some importance in the use of the screen.

VIII. PRACTICAL APPLICATION OF THE RAYS

The proper management of Röntgen ray work involves attention to a number of details. It can be acquired only by a careful study of the various parts of the apparatus and also of methods; unless these be mastered the operator may produce nothing but poor results, and may speedily ruin the best and most costly coil. In the following description an attempt has been made to describe the process in a systematic manner, much as it would be carried out in actual practice:

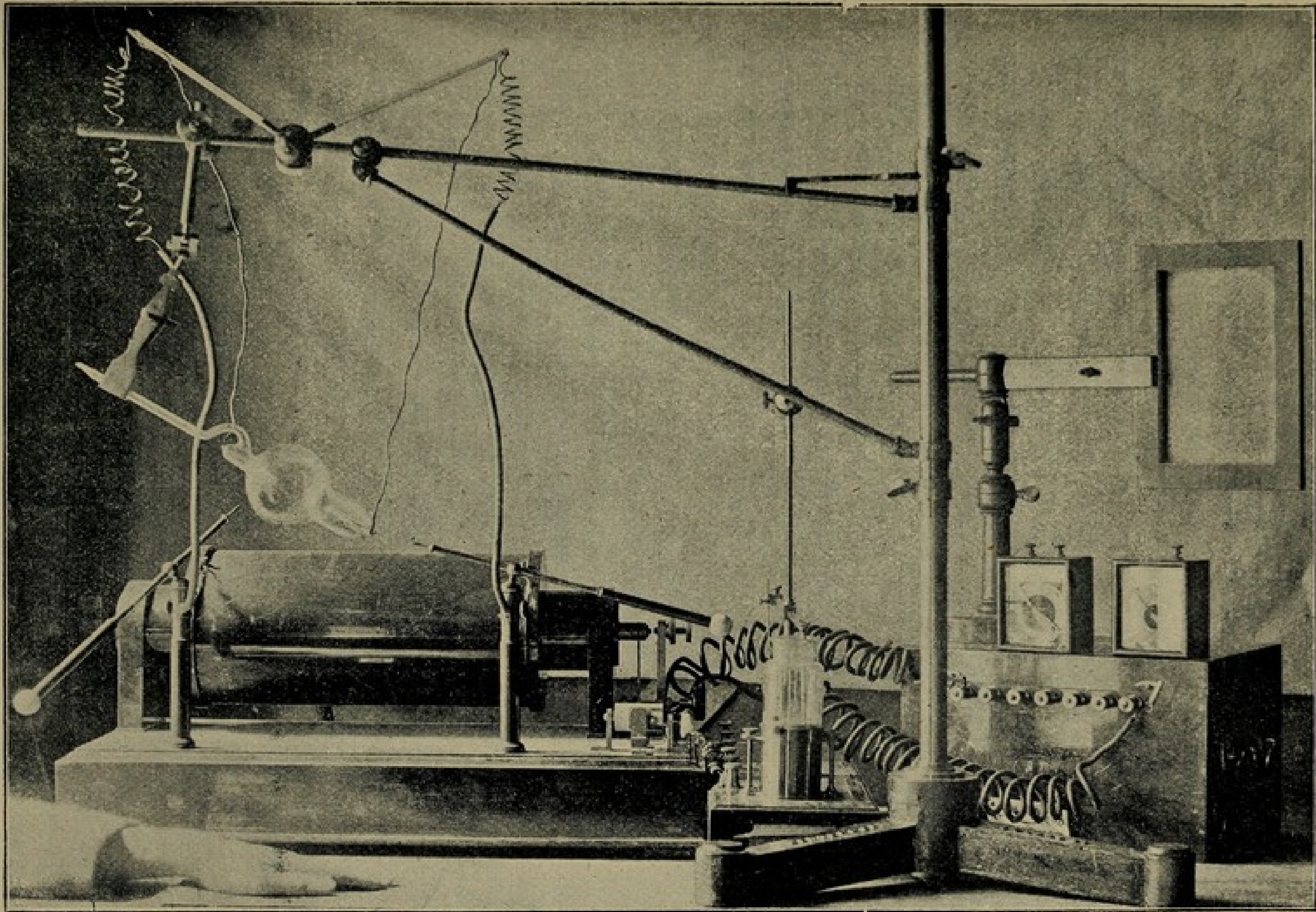


Fig. 30.—Complete Apparatus for Röntgen Ray Work, consisting of Secondary Battery, Voltmeter, Ammeter, Apps-Newton Induction Coil with Ordinary and Mercurial Break, Focus Tube, Fluorescent Screen on Stand, and Hand in Position upon Photographic Plate.

First examine the platinum points of your coil; see they are not in contact, and are perfectly smooth and even; also notice that the arm of the switch which passes the current into the 'primary' of the coil points upward. If the condenser be connected to the coil by means of wires fastened to binding screws on the base of the coil, see that the wires are firmly screwed down. Place the discharging-points of the coil opposite each other, about $\frac{1}{2}$ inch apart.

The source of supply of the electric current having been tested as already described (p. 24), one end of a piece of thick, well-insulated copper wire, No. 12 B.G., should be firmly fixed in the + terminal of the battery, and the other end securely fastened to the binding screw on the coil; a second piece of wire should be similarly fixed on the – terminal of the battery, and led to the other binding screw on the coil. Examine all the connections of your battery, and see that the wires are clean and firmly screwed down. Every weak or bad connection means leakage of current.

Now turn the handle of your switch to the horizontal position, and bring the platinum points gently together by means of the regulating screw attached to the contact break. A spark will at once commence to pass between the discharging-points; withdraw these until the distance between them is a little more than the spark required to produce the Röntgen rays in the tube. Next increase the pressure of the platinum points by means of the regulating screw until the spark passes once more between the discharging-points. The battery and coil are now in working order and ready for use. Turn off the current by means of the switch. The latter should move stiffly in its socket, otherwise it is liable to fall and set the coil in operation at a moment when unpleasant, if not serious, results might follow—that is to say, by communicating a shock to the operator or to any other person who might be in contact with some part of the circuit. Two pieces of copper wire well insulated, about No. 24 B.G., should now be fastened, one end of each to the supports carrying the discharging-rods, and the other two ends to the terminals on the focus tube. It is important that the direction of the current between the discharging-points should be recognised. If when the switch is turned on the space between the aluminium disc (kathode) and the piece of platinum (anode or anti-kathode) is filled with an apple-green light with a dark shadow behind the plane of the platinum, then the current is in the right direction; but if the green light seems stronger below the platinum and whirls round the inner surface of the tube, the direction is wrong. In the latter case, turn the switch in the opposite direction, and at once the space between the anode and kathode will glow with the characteristic apple-green colour. By the use of the screen all doubt may be set at rest: with right direction it will fluoresce brightly, and the flesh of the hand placed behind the screen will be easily penetrated, and show the shadow of the bones distinctly; with wrong direction scarcely any Röntgen rays are produced, so that only a feeble fluorescence of the screen can be perceived. Having once found the right direction, make a note of the binding screw of the coil to which the + of the battery is fastened, and also the direction of the handle of the switch. Change the wires of your battery to the opposite binding screws, and you alter the direction of the current; change the direction of the switch handle to the opposite side, and you alter the direction of the current; change both the direction of the wires and the switch handle, and the current flows in the same direction.

Take care that the wires leading from the coil to the focus tube are not near each other, for otherwise the spark will pass between them, instead of through the tube. Much caution is also required to avoid shocks, both from the coil and from the wires leading to the tube. The golden rule for the operator is never to touch any part of the apparatus while the current is 'on.' If any readjustment be required, switch off the current first, and then make the required alteration. The current from a single wire may give a smart shock without causing any serious results, but if the body form a part of the secondary circuit, by contact with both wires at the same time, the consequences might be of an alarming, or even fatal, nature. Too great care, therefore, cannot be taken to prevent the current entering the body either of the operator or of his patient; the longer the spark used, the greater are the precautions necessary. The focus tube should be fastened firmly in the insulated holder so that the flat terminal of the platinum anode lies parallel to the photographic plate or screen. If the platinum get red-hot, the current used is too powerful, and should be lessened by reducing the pressure between the platinum points by means of the regulating screw. The tube is in the best working condition when the upper surface of the platinum is covered with a green velvety glow, and the under surface shows just a faint redness.

The distance of the tube from the object to be photographed is important. As the Röntgen rays radiate from a point, the near approach of the tube exaggerates the shadow projected upon the plate. For objects not more than an inch thick, a foot is a good distance, but for the thicker parts of the human body from 20 to 30 inches is desirable. The length of the exposure will vary according to the distance, the penetrating power of the tube, and the thickness and opacity of the object. With a tube exhausted to work with a 4-inch spark and placed 1 foot from the plate, a good photograph of the hand of an adult should be obtained with an exposure of one minute. If the distance be doubled, probably four minutes would be required. It need scarcely be urged upon the beginner that he should become thoroughly acquainted with the apparatus and the methods by which the best results are to be obtained before taking photographs of patients. He will find in his own person a convenient subject for experiment. When he has succeeded in taking every part of his own body, he will be prepared for the ordinary difficulties of Röntgen ray photography.

If the plate be not already placed in the protecting envelopes, it will be necessary to go to the dark-room to do so. The film should be placed towards the address side of the envelope. It may be recognised in the dark-room by its dull, non-reflecting surface, whereas the plain-glass side shines and reflects light sharply. Do not bring more plates than the one to be used into the operating-room, as they would in all probability be affected by the Röntgen rays, even if standing a long way from the tube. They may, however, be kept in the same room if shielded in a metal box.

A. EXAMINATION OF PATIENT

At this point it may be useful to describe the exact methods pursued by the writer, and to cite actual examples. For instance, the case of a fractured forearm, in which both radius and ulna were broken a few inches from the wrist: The limb was placed upon the same table that carried the coil and tube-stand. The patient sat on a chair at a convenient distance, and his splints and bandages were not removed. The sensitive plate, duly wrapped up in black paper, was put on the table with the film side upwards. The arm was next arranged on the plate with the palm downwards and the fractured part as nearly as possible over the centre of the plate. The focus tube was placed 12 inches above the centre of the plate, according to the instructions already given. The switch on the coil was turned in the right direction to produce the rays, and an exposure allowed of five minutes. The tube was examined by means of the cryptoscope, to ascertain if it were working properly, and the plate afterwards taken to the dark-room and developed.

The second case was that of a little boy with supposed double congenital dislocation of the hips. The plate here chosen measured 15 inches by 12, so as to include the whole of the pelvic region and a good part of both femurs. The part to be photographed was relieved of all clothing,* and a warm flannel cloth spread upon the operating-table. The little patient was placed on his back, with a low pillow for the head to rest upon. His legs were placed so as to give the toes a slight outward turn, and care was taken that both were in an exactly similar position. A support was then placed on the outer side of each foot, and a small wedge of cloth between them. An 8-inch spark tube was selected and fixed in the stand at a distance of 24 inches above the plate, exactly over its centre, and an exposure made. The plate was then taken to the dark-room and developed. The boy, a bright, intelligent little fellow, was kept interested in the apparatus and various other things. As a rule, children are amused rather than alarmed by the Röntgen ray process. In this case a perfect result was obtained, but a condition was revealed not coinciding with congenital dislocation.

The third case was that of a man who had been thrown from his horse, and who, amongst other injuries, had fractured the right ramus of the lower jaw. He was placed on the operating-table on his right side, with cushions to support the back. A plate, 15 inches by 12, was placed in the protecting envelopes, the film towards the address side. The injured side of the face was then laid upon the plate, so as to bring the broken bone as near as possible to the sensitive surface. Lastly, the plate was slightly

* Although the removal of clothing is not absolutely essential, yet it is desirable when taking a Röntgen photograph through a thick part of the body, as the pelvis, to remove superfluous clothes, as they offer some resistance to the rays both by their material, and also more especially by their dyes.

raised, so that the head might be in a comfortable position. A 9-inch spark tube was chosen, as it was necessary to penetrate the left jaw to reach the right. It was placed 24 inches from the plate, exactly over the sigmoid notch of the inferior maxillary bone, during an exposure of twenty minutes.* The resulting Röntgen photograph showed not only two fractures in the jaw and displacement of teeth, but also injury to the superior maxillary bone.

The fourth case was that of a patient suffering from stone in the bladder. The plate, 15 inches by 12, having been prepared, the clothing was removed, and the patient placed on the table prone on his belly, with the body inclined slightly to the right. The tube, worked by a 9-inch spark, was placed 30 inches from the plate over the left side of the sacrum. An exposure of thirty minutes was given. The plate was then developed and yielded a print that plainly revealed the shadow of the calculus.

In the application of the rays to the teeth, special means must be taken to meet the requirements of the case. As the sensitized surface must be placed in the mouth, glass is almost out of the question. A good celluloid film should be chosen, and cut in pieces about 1 inch by $\frac{1}{2}$ inch. The latter may then be wrapped in black paper, and the whole fastened up securely in thin rubber,† so as to keep out all moisture while in the mouth. The tongue should be pressed firmly against the rubber, in order to keep the plate close to the teeth. The patient should, of course, be placed in a comfortable position, yet so that it is impossible for the head to move during the operation. An exposure of five minutes or more will be required to get good detail. The tube should be placed not less than 12 inches from the face. For the sake of precaution, the hair can be shielded by means of a thin sheet of lead held in a clamp and placed a few inches from the head. After exposure, the plates are developed in the usual way.

It is obvious that the value of the Röntgen results can be best appreciated by the skilled anatomist. Yet even to him this new method of investigation presents many difficulties. As a rule, he is not an expert in practical photography. Every stage of that process is liable to produce spots and blurs which may

* This refers to the earlier days of x-ray work, and would now take a quarter or less of the time mentioned.

† The rubber may be fixed on by a few turns of ordinary sewing cotton.

mislead the most careful, but which are reduced to a minimum in the hands of a good photographer. Hence it is a distinct advantage, where possible, to leave the development of the exposed plates to such skilled hands. The professional photographer, however, will require some experience in order to obtain the best results, for the development of a portrait or a landscape differs widely from that of a Röntgen ray negative. Much depends upon knowing what ought to appear upon a plate; that which at first seemed a failure may, if properly handled, prove a great success. Then, of course, it must be borne in mind that the surface of the object or subject close to the plate receives the sharpest definition, and is nearest its natural size, while the farther the parts are from the plate, the more exaggerated and the more indefinite the record that is obtained.

Whatever kind of contact break is used with the coil for the purpose of taking a photograph, a rapid one is needful for screen-work, otherwise the flickering light produced renders it impossible to obtain any useful or trustworthy information. A highly-exhausted tube should be selected and fastened in the stand, with the platinum anode facing the observer. All light should be excluded from the room, the tube itself covered with black paper, and a dark cloth placed over the contact break. The subject or object to be examined should be placed as near the tube as possible—not more than an inch away from it. As on the sensitive film the parts nearest the plate are most sharply defined, so with the screen. If it be necessary to examine the sternum, the tube should be placed at the back, and the screen on the front of the body, with the fluorescing material towards the eye. At first nothing appears distinctly on the screen, but after a time, as the eye grows accustomed to the feeble vibrations caused by the fluorescing surface, it also begins to distinguish the strong and sharp shadows of opaque objects nearest the screen. It is practically useless to go direct from strong sunlight to the examination of any fairly thick object like the human body. The eye of the observer, about a foot away from the screen, should take first a general and afterwards a more specific view. Every bone and every articulation should be systematically examined, commencing with the thinner members, such as the hand and arm, the foot and leg. Needles may be fixed in the arm in various directions, both on the side near the screen and on the opposite side, so that an idea may be formed of their relative appearance.

The thorax should next be explored. With the screen on the front of the body, the shadow of the heart is distinctly seen, its pulsations may be counted, and anything abnormal in its position noted. The cavities of the lungs appear bright, and the respiratory rise and fall of the diaphragm are conspicuous. The dark shadows cast by the liver and spleen are plainly outlined in the abdomen, but, curiously, the convolutions of the adult intestines furnish no readable record by the Röntgen rays. The pelvic cavity, although more easily examined than the abdominal, still presents a limited field. To examine it, the tube should be placed either between the ilium and the dorsal vertebræ or below the sacrum. As in astronomical photography the sensitized plate reveals thousands of stars invisible through the telescope to the eye, so too the eye fails to perceive on the screen many interesting and important points that are distinctly photographed on the plate. With our present knowledge and apparatus, the screen is useful in the examination of most fractures, both before and after 'setting,' also for detecting and localizing any foreign opaque substance in those parts of the body which the Röntgen rays can readily penetrate. The screen also aids our investigation of the organs contained in the thoracic cavity.

B. Fallacies

Many fallacies may arise from an unusual relative position of the focus tube towards the part under examination. By shifting a limb up and down and from side to side, its shape upon the screen may be distorted so as to resemble a variety of deformities. It is well in all cases of supposed injury to make à routine examination of the correspondingly sound side of the body under exactly similar conditions as to relative position of parts and of focus tube.

Flaws in the sensitive plate or in its development may sometimes lead to an error; and when *x*-ray paper is used, a small crease or inequality of surface may result in a perplexing record.

Buttons, coins, or other objects about the person of the patient may cause confusion.

Seiz has pointed out the mistakes that may arise from a misinterpretation of the results of the fluorescent screen. In one case an outward dislocation of both bones of the forearm took place in a girl of thirteen. A radiogram taken twelve days after reduction showed a normal position of joint, but an apparent separation of the tip of the olecranon, of which, however, there was no trace to be found on clinical examination. In a second case the *x*-ray photograph showed what appeared to be a shortening of three inches in a fracture of the femur, whereas the clinical measurements proved there was not more than one inch of shortening. As Seiz points out, such false impressions might now and then have the greatest importance, especially in actions for damages.

Callus may be pervious to the rays some months after a fracture, and may thus give an impression that there is non-union, whereas the parts may be firmly united.

A fracture without displacement may not show on the *x*-ray photograph, but may often be recognised when viewed from a fresh aspect. Hence it is well to examine first with a screen, so as to determine on the best position for securing an effective record.

IX. THEORY

Part I. of this little book is intended to be a brief practical treatise, yet a few words concerning the history and the various theories explanatory of the *x*-rays may be acceptable to the reader. The interesting phenomena obtained by the discharge of an electric current in a glass tube from which the greater part of the air has been exhausted have been already referred to. They are associated with the names of Geissler and Gassiot. Crookes carried the exhaust much further, and opened up a new world to scientific explorers. Working in this direction, he produced one of the most wonderful inventions of modern times, the radiometer. But an electric discharge in his higher exhaust revealed fresh phenomena caused by the rays proceeding from the negative or kathode terminal, and hence named kathodic rays. Hertz, Lénard, Röntgen, and others, investigated the special properties of these rays, which, while responding to the tests applied to ether vibrations, were found to possess additional characteristics. It was while studying the latter that Röntgen discovered what he modestly named the x-rays. These new rays, which we prefer to call after the name of their discoverer, as already stated, do not respond to the tests applied to transverse vibrations of the ether. From the fact that they penetrate material opaque to light rays, and that they affect a photographic plate in the same way as light, Röntgen conceived the idea that the waves might be longitudinal, of very great length, yet of high frequency. This theory has never found much acceptance by leading English physicists.

M. Tesla has suggested that the so-called rays consist of minute particles of matter, but this explanation has gained even fewer adherents. It is now generally believed that Röntgen's rays are transverse ether vibrations of exceedingly short period and wave-length.

Whatever ultimately may prove to be the true explanation, the discovery of the Röntgen rays has enabled us to take one step higher on the vast ladder of vibrations which Nature has planted between the finite and the infinite.

In concluding Part I., it may be remarked that the outlines of this portion of the work will be to some extent filled in by many practical hints scattered throughout the pages of Part II.

PART II

MEDICAL AND SURGICAL APPLICATIONS

The advantages of Röntgen ray work to the medical man are not confined to purely clinical purposes, but are here and there extended to other branches of professional study, such as forensic medicine, anatomy, and physiology.

In order to deal with the subject systematically, it may be split up into various sections. The following rough classification will be found to cover most of the ground broken by this modern means of accurate investigation :

A. Surgery.
- I. Foreign Bodies.
- II. Bones :
  - (*a*) General Remarks.
  - (*b*) Fractures and Dislocations.
  - (*c*) Separation of Epiphyses.
  - (*d*) Congenital and other Bony Deformities.
  - (*e*) Diseases of Bone.
  - (*f*) Other Surgical Points.
  - (*g*) Action of Rays upon Micro-organisms.
- III. Mapping of Skin Surfaces.

B. Dental Surgery.

C. Nasal and Throat Surgery.

D. Medicine.
- IV. Regional.
  - (*a*) Thorax and Abdomen.
  - (*b*) Heart and Great Vessels : Aneurism, Cardiac Enlargement, etc.

(*c*) Lungs and Lung Diseases: Pleurisy, Phthisis, etc.

(*d*) Abdomen.

V. Other Medical Points.

VI. Action on Skin and Deeper Structures.

VII. Therapeutics.

E. Obstetrics and Gynæcology.

F. Legal Medicine.

G. Anatomy.

H. Physiology.

I. Veterinary Uses.

A. SURGERY

When the first Röntgen photographs were published, scientific surgeons all over the world became keenly alive to the possibilities of the situation. So far, they have gained the lion's share of practical help from the new science, but the process has also proved of great and increasing value to the physician. As methods improve, they will both assuredly derive a still greater amount of precise and valuable information from the same source. Their future success, however, will most likely depend upon the definition not so much of substances that are relatively opaque to the rays, but rather of the more translucent structures, such as soft tumours, gall-stones, abscess cavities, internal organs, and so on. So long ago as February, 1896, Adolph and Leng recorded the fact that they had obtained a Röntgen ray picture of ordinary connective tissue.

I. FOREIGN BODIES

In nothing have the Röntgen methods proved of more immediate practical use to the surgeon than in the finding of foreign bodies. The nature of the embedded substance is of importance, for, in order to yield a readable record, it should offer a resistance to the rays considerably greater than that of the tissues in which it lies. Thus, a bullet buried in translucent muscle would cast a deep and clear-cut shadow on the sensitive plate or screen, whereas it would be obscure if lodged in more opaque structures. Fragments of glass can be readily photographed, because they resist the rays, but such penetrable materials as leather, clothing, paper wads, and wood cannot, as a rule, be demonstrated by radiography.

All surgeons know that at times it is impossible by any ordinary method to detect the presence of a foreign body in the deeper tissues. A familiar instance of this uncertainty is met with in the palm, where a fragment of needle may elude not only careful and skilful manipulation, but an extensive cutting operation as well. The help that can be given by the Röntgen rays under kindred circumstances may be judged from the following cases that have been brought under the writer's notice:

A lady, who some time previously ran a needle into her hand, had her palm explored by a surgeon, with negative results. A little later a radiogram, taken through splint and dressings, revealed a piece of broken needle lying in the first interosseous space, close to the distal end of the thumb metacarpal. From the information thus obtained the foreign body was readily removed by a second operation. In other words, the process furnished the surgeon with a method of diagnosis which denoted not only the presence, but also the shape, nature, and position of the body to be removed.

In another case a child suffered for several weeks from a swollen foot, for which no cause could be ascertained. A radiogram, however, showed fixed in the astragalus a broken needle, the removal of which was followed by speedy recovery.

These facts suggest a useful application of the Röntgen rays—namely, to locate a hypodermic needle broken off beneath the skin. As everyone knows, such an accident may be caused by an abrupt movement on the part of the patient. Further, the fragment is apt to wander about freely, so that few surgeons would feel justified in undertaking a cutting operation unless the foreign body could be fairly well localized. The danger to the host of a wandering object of the kind in the tissues is obvious. Suppose it to be small and buried, say, beneath periosteum or in the sheath of a tendon, it would almost certainly elude the exploring finger of the surgeon, unless he be guided by the exact information now available in all cases by means of a localizing Röntgen photograph.

The opacity of glass* to the rays, probably due to the contained lead and other metals, makes it easy to detect fragments buried in the soft tissues. It is, of course, well known that such objects may remain embedded for many years, and often give no sign

* Potash glass is more translucent to the Röntgen rays than lead glass.

of their presence beyond some slight enlargement and pain or discomfort on deep pressure. By the Röntgen method, however, a foreign body of that sort may be so exactly defined that the surgeon can cut down upon and remove it without a moment's hesitation. After any injury of the kind, indeed, it would be well as a routine practice to examine by the rays, in order to ascertain whether any glass has been left in the wound. In the next case negative evidence was obtained as to the presence of glass, but positive testimony as to joint mischief.

A. B——, a milliner, admitted to the Metropolitan Hospital with the following history. Two months previously her little boy, whom she was nursing, by a sudden kick broke a wineglass in her hand. The left forefinger was cut, and severe pain followed, reaching up the arm to the shoulder. A piece of glass was supposed to be in the wound, which had been explored before the patient came to the hospital. On admission the wound was found to be cicatrized, and the end-joint of the finger stiff. The accompanying radiogram (Fig. 31) proved the absence of glass, but disclosed various changes in the joint. Absorption of the distal end of the second phalanx had taken place, and fibrous anchylosis was diagnosed from (*a*) the appearance on the photograph of a faint line between the phalanges, and (*b*) the clinical condition of the joint.

FIG. 31.—FINGER SHOWING ABSORPTION OF BONE AND FIBROUS ANCHYLOSIS.

Lead is exceedingly opaque to the rays, and hence the new method does yeoman's service in gunshot wounds. The erratic course taken by bullets after entering the body often renders their discovery, under the conditions of ordinary surgery, a matter of impossibility. By means of a Röntgen ray examination, however, the surgeon may in many cases acquaint himself as to the exact whereabouts of the missile, and that without undressing the patient and without taking off splints and dressings. In that event, moreover, the shock entailed by prolonged manipulation will be avoided. The Röntgen method may also be of service in this class of wounds by proving the absence of a bullet. In doubtful cases the value of such negative evidence, both to the surgeon and to the patient, is so obvious that it need not be enlarged upon.

The difficulty of gaining exact evidence as to the presence of a rifle-bullet was well illustrated in the classical case of Garibaldi. Day after day his medical attendants, surgeons of European fame, endeavoured in vain to find out whether a ball was or was not embedded in the ankle of their illustrious patient. At length Nélaton settled the point by means of the ingenious probe that bears his name, an instrument tipped with porcelain, on which the leaden bullet traced an unmistakable billet. Röntgen, however, has far surpassed Nélaton's plan as regards ease, certainty, and simplicity. Had this method been available in the case of Garibaldi, a few minutes' exposure would have sufficed to clear up the diagnosis. A similar localization might possibly have saved the life of the late United States President, Garfield. It is interesting to add that in 1896 the presence of a Japanese bullet in the head of the distinguished Chinaman, Li Hung Chang, was demonstrated by the Röntgen rays during his visit to Europe.

Military Surgery

In military surgery the Röntgen processes have proved of great value. On a campaign, where baggage is naturally cut down to the last ounce, some difficulty is presented by the cumbersome nature of the necessary apparatus. However, the electrical engineers have already to a great extent met the wants of the case. As it is, an ordinary field ambulance waggon may be calculated to carry a ton burden, a weight that would more than accommodate an *x*-ray installation with dark-room and photographic requisites. In the British army the Engineers already possess a photographic waggon, which might be adapted to such work. However, the Röntgen apparatus would not as a rule be located in the front, but at a base hospital, where bulkiness would not be so positive a hindrance.

Hitherto the chief appliances for detecting deeply-placed bullets have been based on (*a*) simple and (*b*) electrical contact.

Of the former, the two best are Lecomte's *stylet-pince*, made to bite away a morsel of the metal, and Nélaton's probe, which, as already stated, is marked by the lead. Electric probes, on the other hand, are constructed to show, by means of bell, galvanometer, or microphone, when the circuit is completed by a bullet touching the end of the probe. The two first-mentioned instruments, however, are useless when dealing with modern hard-mantled projectiles: the stylet-pince fails to bite, and Nélaton's probe to indicate the latter-day small-bore ball with its steel or cupro-nickel envelope. Clearly, no such difficulty awaits the method of Röntgen diagnosis, which will at once demonstrate, not only the position, but also the exact size and shape of a missile in any part of the body.

The first opportunity of the trial of the new discovery in actual warfare was afforded by the Græco-Turkish war. The *Daily Chronicle* sent off a complete outfit to the seat of the war in connection with its national fund for the wounded.

Surgeon-Major Beevor carried out the Röntgen methods successfully on the Indian frontier during the Chitral campaign in 1898. His work was often carried on in a temperature that registered 22° of frost and over. The only damage to his coil was on a train journey in Central India, when the insulating wax melted out owing to the intense heat. He was able to repair the damage, however, and after that wrapped the coil in damp blankets. He found that the method was valuable in many surgical conditions other than the presence of a foreign body, as, for instance, in abscess, necrosis, undetected partial fractures, and injury to internal organs. In one case the spleen was penetrated. In another a round bullet passed at low velocity through the liver (driven by poor native powder): but the missile did not injure the plexus of nerves and vessels through which it passed across the body to a position between the ninth and tenth ribs, where it was located by the rays. This diagnosis could not have been attained by probing or other ordinary surgical procedures.

In the brilliant campaign brought to a close at the latter end of 1898 by the Sirdar, now Lord Kitchener, the value of the Röntgen methods was demonstrated under different climatic circumstances. In the face of great difficulties Major Beevor, R.A.M.C., applied them in the cold and mountainous districts of Northern India, whereas Major Battersby, R.A.M.C., in the Nile expedition encountered the not less trying conditions of sand-storms and tropical heat. The latter distinguished officer, who was in charge of the Röntgen ray apparatus in the Soudan, related his experiences in a graphic manner in a paper read before the Röntgen Society of London, January 10, 1899.* The chief points raised may be thus summarised :—

First of all, it may be noted that the work was carried out in a climate where the temperature varied from 100° to 120° F. The destructive effect of that degree of heat upon insulating materials, upon fluids of batteries, and upon the processes of photography, may be readily imagined.

Between Wady Halfa and Abadieh the Soudan outfit had to travel for two days and a night in an open truck, exposed during the daytime to the fierce heat of a blazing sun. By keeping the casing of felt wet, however, the journey's end was reached without mishap, and a thermometric observation showed that the temperature in the interior of the coil did not exceed 85° F.

It may also be noted that Battersby is clearly of opinion that the more perfect appliances for war purposes will dispense with batteries and coils. 'An ideal apparatus,' he writes, 'would consist of a statical or friction machine—some modification, for instance, of Mr. Wimshurst's, by which the focus tube could be excited directly. For such a design many physical difficulties confront us, but they are not insurmountable."

Portability must always be a first essential in field work. So far as the coils were concerned, Battersby had one constructed in two parts, so that they could be slung one on each side of a mule or a camel. Each portion was packed in a teak box—the coil in one, and in the other condenser, commutator, break, and stand. These boxes were cased in thick felt, and also those containing the storage batteries, so that they could be constantly wetted, and their interior temperature thereby reduced by evaporation.

The generation of electricity was managed in a highly ingenious way, which may be described in Battersby's own words: 'The pulley of a small dynamo is connected by means of a leather strap with the back-wheel of a specially constructed tandem bicycle. The required velocity for the dynamo is thus obtained, and our procedure is as follows: Having carefully adjusted the circuit with the storage battery, and also with the voltmeter

* See *Archives of the Röntgen Ray*, February, 1899.

and ammeter, my warrant officer took his position on the seat of the bicycle and commenced pedalling. When 15 volts and 4 ampères were registered, the switch close to the handle of the bicycle was opened, and charging of the battery commenced. As the resistance became greater, a sensation of riding uphill was experienced, and the services of an additional orderly were requisitioned for the front-seat. This bicycle practice was generally carried out in a shade temperature of 110° F., so that at the end of half an hour we unanimously agreed that some other form of scientific amusement was desirable. Then the switch having been turned off before pedalling ceased, in order to avoid any discharge from the battery, the machine was brought to a standstill.

'Our cells were the ordinary E.P.S. cells, 40 ampère hour type, with a voltage of 2 volts per cell, and discharge of 4 to 6 ampères. The cells while being charged required the dynamo to give a current of 15 volts and 6 ampères; this multiplied together gives an electro-motive force of 90 watts, and as 760 watts equal 1 electric horse-power, $\frac{1}{8}$ horse-power was necessary to drive the dynamo for charging. It was also necessary to have an extra $\frac{1}{8}$ horse-power to overcome the resistance of the working parts and the opposing force contained in the full batteries, hence the necessity of tandem seat for extra man.'

Primary batteries are for various reasons unsuitable for military purposes. The small dynamo above alluded to was readily transported by rail and river, but was unsuited for carriage by mule, camel, or by bearers. One of the 10-inch coils and its accessories packed in an oak box was found too heavy for mule or camel transport, but when slung by ropes on a long pole could be carried, like an Indian dhoolie, on the shoulders of four men. Beevor advocates bearers above all other means of transport.

The insulated wire for the various parts of the apparatus should be specially made to withstand hot climates.

The tubes were ordinary bianodic focus tubes. Their platinum terminals were protected at the ends of the tubes by a thick ferrule of indiarubber. Each tube was wrapped in cotton-wool and packed in a small wooden box, which appears to have secured safe transit.

The fluorescent screen was most useful at night, but unsatisfactory during the day, owing to the intense glare of the sunlight. Its surface was protected by celluloid, a most necessary precaution in a hot and dusty climate. This appliance is looked upon by Major Battersby as of surpassing importance in military surgery, where rapid diagnosis is everything.

Battersby used glass plates to the exclusion of celluloid films and sensitized paper. Those plates that had the thinnest film were most suitable for the intense heat, and an alum-bath was essential in all cases. The water available for developing was comparatively hot, and no ice was to be got, so that the more delicate shades of development had to be sacrificed. The developers used were rodinal, hydroquinine, metol, and "pyro." There was a marked tendency for development to proceed at a very rapid pace, often making the picture flash up at once. As a rule, this part of the work was done at three in the morning, that being the coolest part of the day.

After the Battle of Omdurman 121 wounded British officers, non-commissioned officers, and men were brought to Abadieh. Of that number there were 21 cases that could not be diagnosed accurately by ordinary surgical means, and of these the presence or absence of a bullet was proved by the Röntgen rays in 20 instances. The odd case was that of a shot in the lung, so severe that it was not considered justifiable to examine at the time. The focus tube was used about sixty times in all.

Spent bullet wounds are of common occurrence in fighting with natives whose powder is not of very good quality. In former days it was difficult to ascertain whether a bullet had lodged in such a wound or not, and consequently a good deal of probing was resorted to. All that is now changed, as shown by several of Battersby's cases. In one of the latter a private had gunshot wounds on the outer and the inner side of the left arm, and a third near the lower angle of the shoulder-blade. Three pieces of lead were shown by the rays at the outer side of the humerus. No bullet was seen in the chest, the wound in which was consequently not probed. Another soldier was shot near the tip of the right shoulder behind the acromion. The bullet was localized at right angles to the axillary border of the scapula, 2 inches below the glenoid cavity, and readily extracted.

In several instances where the foreign body could not be made out by the screen, owing to the flickering of the tube or the glare of diffused sunlight, a diagnosis was nevertheless afforded by a photographic plate, even when the latter was much damaged and imperfect. In this way a bullet was found flattened out like a shilling at the lower end of a leg, and an injured hand was shown to have the metacarpal of the ring-finger fractured.

The supply of focus tubes taken out by the two officers quoted above seems to have been far too small; thus, Beevor took only three, and Battersby only four. When we consider the great risk of damage in transit, to say nothing of perforation during work, to which these delicate tubes were exposed, we would imagine it safer to take, say, several dozen, and to distribute them at various bases of supply. Beside the greater safety ensured by such distribution, it is now pretty well agreed that better results can be obtained by reserving certain tubes for those purposes to which they are best fitted, as, for instance, for penetration or for screen work, instead of attempting to get a number of diverse effects from one or two tubes by varying the spark, current, break, and other conditions.

The experiences of the Röntgen method in the Græco-Turkish War, in the British expeditions to Chitral and the Soudan, as well as in the Spanish-American War, prove conclusively that it may be applied under all conditions likely to be met with in campaigns. Localization seems to be satisfactory, but much remains to be done in the generation of electricity, in the introduction of portable machines of the Wimshurst type, in the improvement of photographic films and sensitized papers, and in the perfecting of screen appliances. In short, the army surgeon, taught by the experiences of the field, must look to mechanical and scientific experts for advances in the direction of portability, simplicity, strength, accuracy, and durability.

Gunshot Wounds in Civil Practice

Apart from military surgery, however, there are numerous gunshot wounds to be met with in civil practice. It is surprising the number of injuries of this kind, accidental and otherwise, that come under treatment in the course of a single year at one of the great general hospitals of the Metropolis. Many practitioners will readily recall the long and fruitless search for the missile that usually took place in their student days. Now all that is changed, and if a bullet be present, it may as a rule be located within a few minutes by the Röntgen ray apparatus which is now attached to every well-appointed hospital.

One great advantage of the new method is the avoidance of the risk of introducing harmful micro-organisms into the wound by means of the probe. In fact, the method may be regarded as an addition of prime importance to aseptic surgery, and it must infallibly lessen the mortality that has been hitherto incident to gunshot injuries. A further gain is that, with a knowledge of exact location, the surgeon can minimize the extent of his operative measures. The latter point is well illustrated in the following

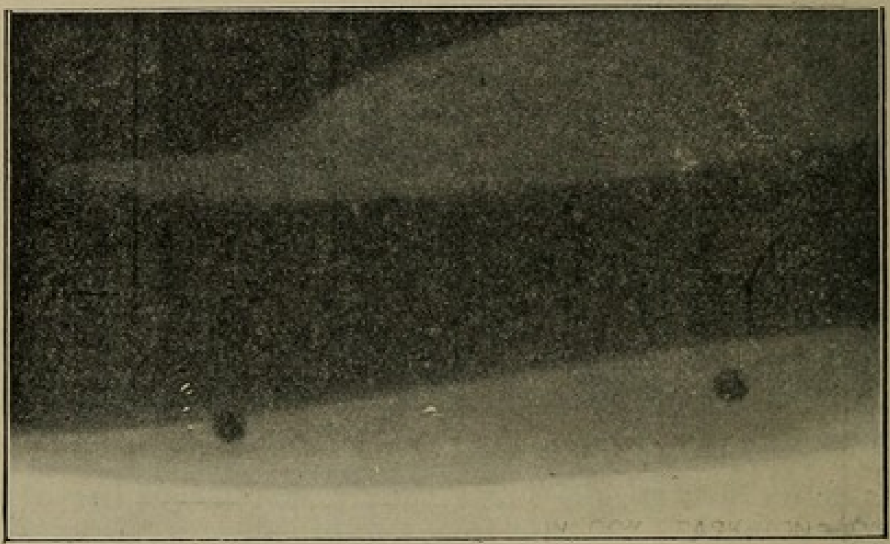


Fig. 32.—Shot embedded in Muscular Forearm.

case, reported by Dr. E. H. Lee to the Chicago Academy of Medicine :

'The removal of foreign bodies by means of skiagraphs,' he remarked, 'has opened up a great field of observation in that line. I have in this connection an interesting case, which was that of a policeman who, in pursuing a burglar, shot himself in the heel. The skiagraphs show the bullet embedded in the upper portion of the os calcis. I located the bullet before removing it by Girdner's bullet-probe. By the skiagraph it is seen that the bullet is not located in the joint. This is a point which was of the greatest importance, for the joint was not opened during the operation. It was supposed that we could not remove the bullet without opening the joint, and it could hardly have been avoided had we not had such accurate knowledge of the location.'*

It will be seen, therefore, that the Röntgen methods furnish, as it were, an absolute chart upon which the surgeon may found,

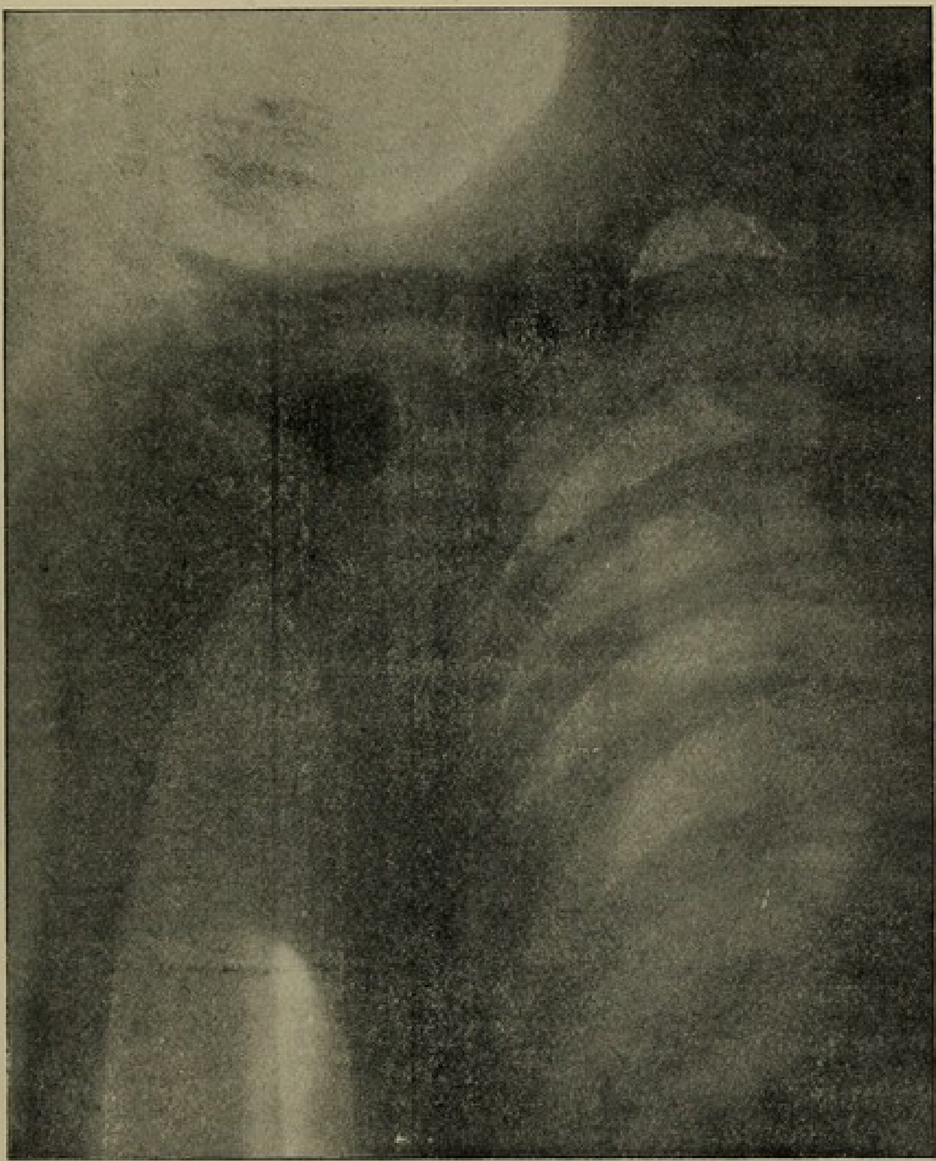


FIG. 33.—BULLET IN SHOULDER, LYING ON SCAPULA. FIRED FROM FRONT. (Dr. Scott, *American X-Ray Journal*, July, 1899.)

not only his diagnosis and plan of operation, but also the hardly less important point of prognosis.

Fig. 32 gives a good idea of the record obtained from small shot. It was taken from the arm of a gentleman who had been accidentally shot twelve months previously. Two pellets lie

* *The Journal*, Chicago, January 16, 1897, p. 124.

close to the ulna, a small portion of which is portrayed. They caused no trouble, and as the patient was strong and muscular, their presence could hardly have been detected by any other means. In cases of this kind, where a foreign body has been embedded for a long period of time without giving rise to any inconvenience, it need scarcely be remarked that few surgeons would counsel removal.

Fig. 34.—Thumb showing Leaden Débris and Absorption of Bone (Distal End of Metacarpal) after Impact of Bullet. (Mandras.)

The above print is from a photographic film, and reverses the light and shade of an ordinary *x*-ray, just as happens when the positive print is taken on sensitized paper.

The radiogram of a bullet-wound may help diagnosis in various ways. In the following case, related by Dr. Mandras, of Paris, it threw light upon an injury of the kind long after its infliction :

'M. B—— was struck about fifteen years ago by a bullet from a revolver a little below the distal end of the dorsal surface of the first metacarpal. There was no fracture, but the ball glanced round the bone, and caused an extensive laceration of the tissues at the lower and inner part of the thenar eminence.

'Forty days after the accident the wound was healed, but there was complete loss of power of the thumb. Professor Dubreuil extracted a disc-shaped fragment of a bullet the size of a franc. Soon after a second piece, as large as a lentil, was taken away, followed by a third two and a half months later, but it was a year before the thumb regained its movements.'*

A radiogram of the hand by Messrs. Joubert and Bertin-Sans showed (1) a slight depression upon the metacarpal bone, doubtless due to the destruction of the periosteum by the projectile, and (2) the presence in the ball of the thumb of much metallic débris. By the courtesy of Dr. Mandras, the photograph is reproduced in Fig. 34.

Localization of Foreign Bodies

In order to localize the exact position in the tissues of a foreign body, it is often needful to take a second *x*-ray observation at right angles to the first. For instance, let us take Fig. 35,

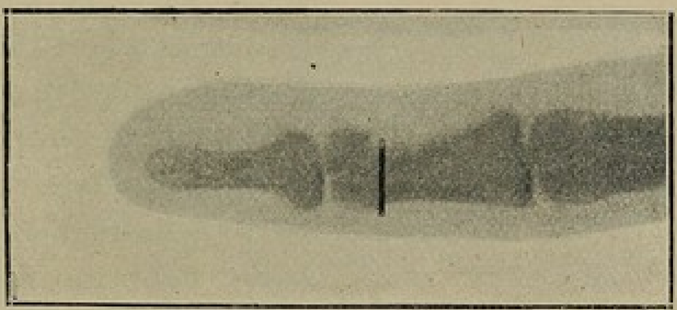


Fig. 35.—Needle in Finger, showing Eye.

which shows a needle to be imbedded in the finger. With so small an object, the surgeon has no clue as to whether it lies back or front of the digit. A cross-photograph, however, will at once settle the point.

When the fluorescent screen is used, the surgeon might in some cases be able to localize by means of acupuncture needles. Thus, he might take two views at right angles, and in each pass across the field a needle until it apparently touched the foreign body, or he might first accurately fix the shadow and push an acupuncture needle straight into the tissues in the direction indicated, and then, by a cross-view, ascertain the exact depth to

* 'Radiographie en Médecine,' par V. Mandras, M.D., Baillière, Paris, 1896, p. 28.

which the needle should be carried. Such a proceeding would obviously be confined in its application to the less vital regions.

Other aids to the correct reading of the record of a foreign body are furnished by (*a*) the sharpness of the shadow outline, and (*b*) its size in relation to the original object. These points are both shown in the following experiment of Mr. Greenhill's. A radiogram was taken of a hand with two sections of bullets exactly corresponding in size, placed, the one on the back of the hand, away from the plate, and the other on the palmar side next to the sensitive surface. The difference in the resulting images was striking. That of the lower one was clear, sharp, and almost of the same size as the original section; the other, on the contrary, was darker, larger and more diffuse. This difference in the size of the recorded shadows is explained by the fact that the rays issue from the focus tube in radiating straight lines; the diagram (Fig. 36) will serve to show what is meant. Let F represent a focus tube in action, P the sensitive photographic plate, and A and B two objects of similar shape and size, such as two halfpenny pieces, but A being near the focus tube and B near the plate. It follows, then, as the Röntgen rays radiate in straight lines from F to P, that the shadow *a* will be larger than *b*, inversely to the distance of A and B from the focus tube. In fact, given the distance of tube from plate, and the size of the shadows, the relative position of the intervening objects could be determined by a simple mathematical calculation. Upon this principle, indeed, the chief localizing methods are based.

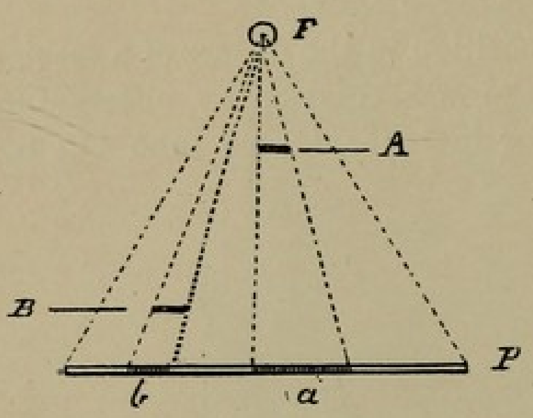


Fig. 36.

It need hardly be pointed out that the ordinary localizing signs and symptoms, such as pain, tenderness, swelling, dyspnœa, and difficulty of breathing or of swallowing, together with the history of the case, will retain their former value to the medical attendant. Such aids to diagnosis, however, are often altogether wanting, and it is then that the surgeon will call in the aid of the Röntgen rays. In short, the philosophical observer will find therein an additional means for conducting exact investigation into regions hitherto inaccessible to either direct or indirect visual inspection.

In practice, the location of an object buried in deep tissues or in the larger cavities of the body often presents peculiar difficulties. Suppose a bullet to be lodged near the surface of the lung, there would be a better chance of finding its exact position than if it were more deeply embedded. In investigating the brain, the photographic field is somewhat obscured, as the rays pass through a large mass of soft material and two surfaces of bone, of varying thickness and density, which under present methods are more or less recorded on the plate.

In the case of a foreign body in the brain, the action of a cross-record may be explained by the following diagram (Fig. 37):

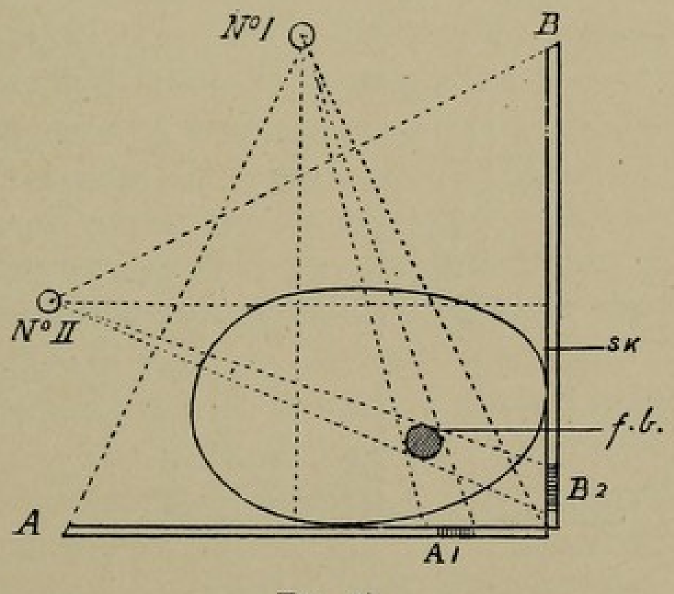


FIG. 37.

Let *sk.* represent the skull; *f. b.* the foreign body; No. I. the lamp, and A the sensitive plate used for the first position; No. II. the lamp, and B the plate for the second position. Then the shadow A1 will fix the plane between No. I. and A in which *f. b.* lies. The exact point of *f. b.* on that plane is determined by the shadow B2 on the second plate B, which fixes the plane of *f. b.* between No. II. and B. In other words, the foreign body lies at the point of intersection of the two planes obtained by the two radiograms taken at right angles the one to the other. In taking the second or cross photograph, the lamp should be placed at exactly the same distance from the plate as in the first exposure. It should also be over an exactly corresponding part of the plate, as, for instance, the centre. In dealing with an oval object like the skull, it will be better to leave the latter in one position and to move the lamp, placing the plate A on the table, and B at right angles. In practice, however, the results are not so easily obtainable as might be inferred from the foregoing explanation. In the above case, for instance, there would be greater difficulty in penetrating the long axis of the skull, and a somewhat longer exposure would be needed for that position.

In one instance, referred to a few pages later, a bullet inside a skull was located by two radiograms: a cross or trans-frontal exposure of eight, and a fronto-occipital of twenty minutes.

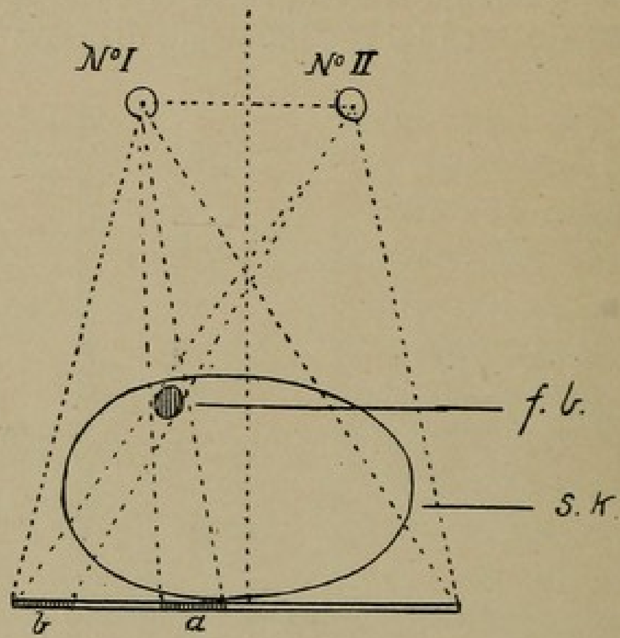


Fig. 38.

Another method, which takes both views in the short axis, is on the principle shown in Fig. 38. Two views are taken by shifting the focus tube, but the body to be penetrated and the sensitive plate remain in exactly the same relative positions. The lamp is put at the same distance from the plate in both views, and also in some known relation to a given point, say the centre or the edge of the plate. By comparing the resulting shadows, a conclusion can be formed as to the intersection of the planes, Ia and IIb. This is the exact principle of the localizing apparatus devised by Mr. Mackenzie Davidson, who places threads on the lines between No. I. and *a*, and No. II. and *b*, and by shifting the focus tube takes two images on one sensitive plate.

Mackenzie Davidson's Localizing Apparatus

The two positions of the anode are secured by sliding the focus tube along a horizontal bar, marked with a millimetre scale, which runs both ways from a central point at zero. Beneath is placed the sensitive plate, or, better, film, protected with black paper in the usual way. On the photographic envelope are laid two wires at right angles to each other, so placed that one of them runs in the same direction as the horizontal bar that carries the tube above, and their point of intersection lies beneath zero on the scale. The cross-wires may conveniently be fastened to a thin board or sheet of vulcanite, and kept in place over the sensitive plate by means of drawing-pins. The wires are painted with aniline ink so as to leave a mark on the body of the patient, and it is convenient further to 'orientate' or identify one of the corners of the plate by some opaque object, as a small coin, with a corresponding sign (in aniline) on the adjacent skin surface. Two equidistant points are marked off by clips at each side of zero on the horizontal slide bar, say at 5, 10, or 15 millimetres, as may be decided by the operator. The focus tube is then drawn up to one side-clip and an exposure made, after which it is pushed over to the opposite clip and a second exposure made of equal duration. The distance from the centre point of the anode to the plate is accurately measured. The operator is then in possession of a number of accurate data from which he may find the exact relation of a foreign body in a patient's tissues to the cross-wires and photographic surface, or, what amounts to the same thing, to the aniline cross mark upon the patient's skin.

In order to work out the problem readily and accurately, Mr. Davidson has devised a 'cross-thread localizer.' The apparatus consists essentially of an adjustable horizontal bar, marked with a millimetre scale starting from a central zero, and notched correspondingly on its upper edge. A plate-glass stage marked with a cross, of which the point of intersection lies exactly beneath zero on the horizontal bar. Beneath the stage is a hinged reflecting mirror.

The developed negative is placed film upwards on the glass stage, and the shadow of the wires made to correspond with the cross mark on the stage. The bar is next raised or lowered so as to bring the zero of the scale to the same distance from the scale as that of the centre of the anode from the sensitive plate when the exposures were made.

Two fine silk threads are next passed over the horizontal scale bar. Each thread has a weight at one end to keep it taut, and is fixed in a notch on the scale corresponding with the distance of the anode from zero during the original exposure. The other end is threaded into a fine needle fixed in a piece of lead. This part of the thread between the notch on the scale and the eye of the needle represents the x-ray, and is movable. With two such threads, then, it will be easy to trace the path of the rays in relation to a body interposed between the focus tube and the sensitive plate as shown in the diagram (Fig. 38).

One threaded needle is placed upon any particular part of one of the photographic shadows of the foreign body, and the other needle upon a corresponding part in the second shadow. The point where the threads cross and touch each other will represent the position of the part of the foreign body chosen for location. A perpendicular is then dropped from the intersection of the threads to the negative below, and a mark made where the perpendicular touches the negative. The distance of the spot thus marked out from the cross-wires is measured by a pair of compasses.

The operator is then in possession of the required measurements. Suppose the distances to be 3 centimetres and 1 centimetre as in the diagram, and the depth from the crossing of the threads to the plate to be 2½ centimetres, then he knows that the foreign body lies at 2½ centimetres from the surface of the patient's skin, at a distance of 3 centimetres and 1 centimetre from the cross-wires, in a quadrant that is easily determined by reference to the distinguishing mark (*e.g.*, coin) placed there when taking the double-exposure photograph.

Mr. Davidson's own words may be quoted: 'The height of the point where the threads cross gives one co-ordinate—that is, the depth of the foreign body below the skin which rested on the photographic plate. The other two measurements give the other two co-ordinates. It will be obvious that these measurements can be noted thus (see Fig. 39).

'As the mark of the wires is left on the patient's skin, all that is required is to measure the two co-ordinates on the skin that give the point below which the foreign body will be found, at the depth given by the third co-ordinate.'*

If the reader have grasped the foregoing description, he will readily perceive that by gauging opposite sides of shadows it

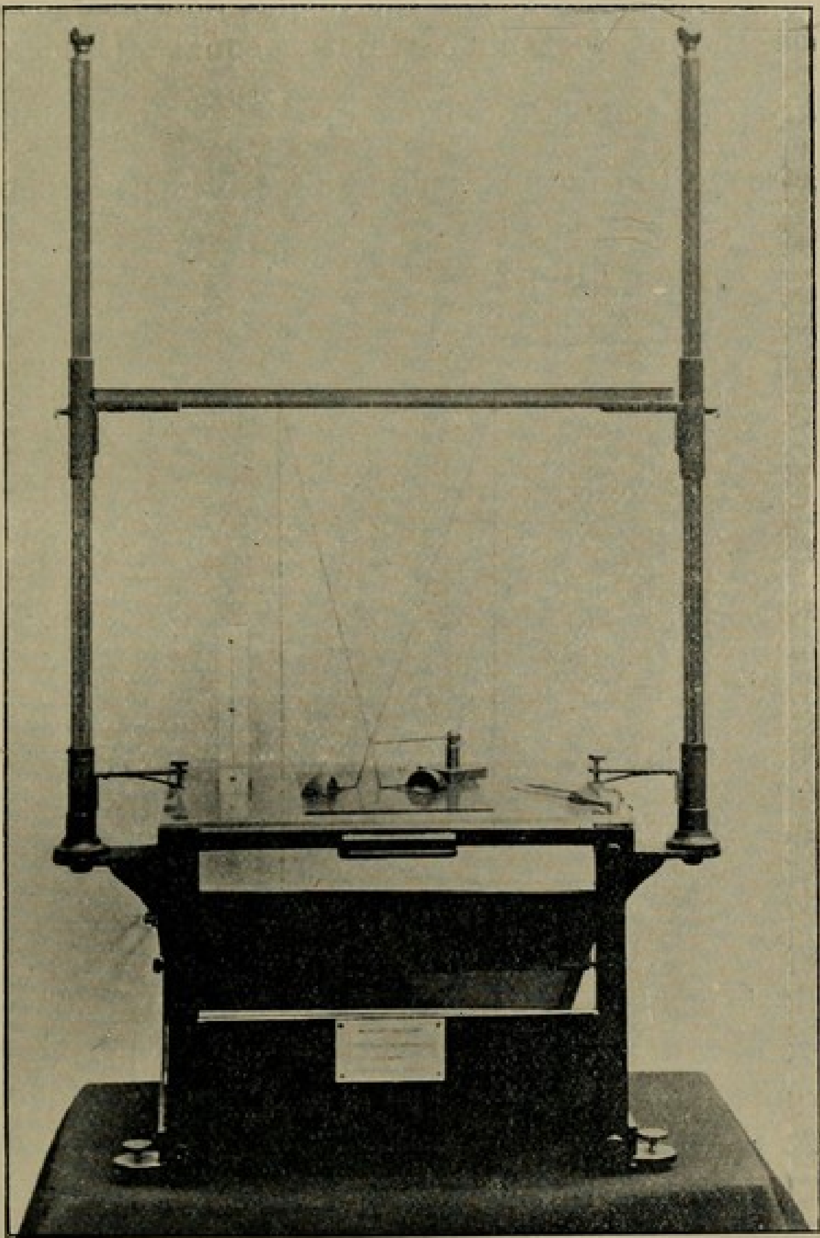


FIG. 39.—MACKENZIE DAVIDSON'S CROSS-THREAD LOCALIZER.†

will be possible to measure the size of the foreign body. As a matter of fact, such a conclusion can be drawn with quickness and precision. A little practice, however, is necessary, and the

* *Archives of the Röntgen Ray*, vol. ii., No. 1, May, 1898, p. 65.

† Made by Messrs. Muirhead and Co., Elmer's End, Kent, and Westminster.

beginner will find it a good plan to localize small objects, such as bullets or shot buried in a turnip or a block of paraffin.*

Dawson Turner and others have published a simple formula for localizing.† Two photographs are taken on one plate by shifting the focus tube. The distances are measured from tube to plate a, between the two positions of the tube b, and between the two shadows on the photograph c. Let x equal distance of the foreign body from the plate. Then $x = \frac{a \times c}{b + c}$. Supposing a to be 33 centimetres, b 10 centimetres, and c 1 centimetre, then

$$x = \frac{33 \times 1}{10 + 1} = 3 \text{ centimetres.}$$

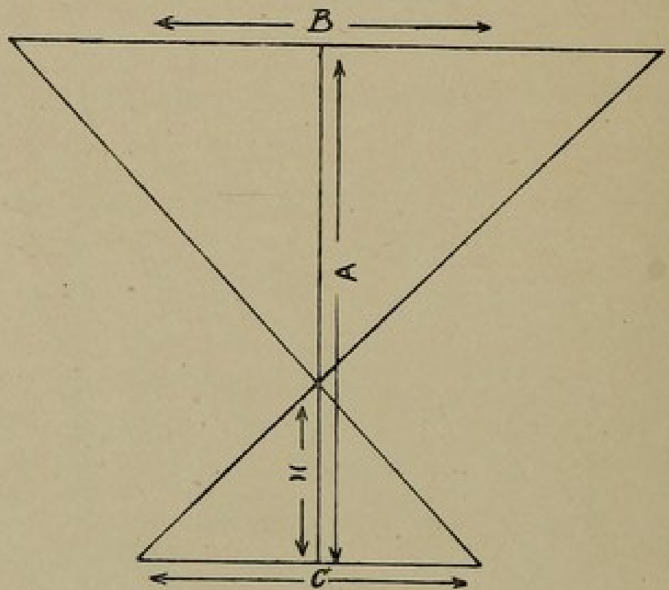


FIG. 40.

Dr. Hedley's combined localizer and vacuum-tube-holder is a modification of Mr. Mackenzie Davidson's apparatus. It serves a double purpose, and is designed with a view to portability and simplicity. It consists of an upright steel bar screwed into a collapsible tripod stand, and carrying a shifting horizontal bar made of wood and graduated, and armed with a travelling clamp that grips the focus tube. A wire cross dipped in an aniline dye is laid on the plate to mark the patient's skin, and the path of the rays is traced by silk threads attached to the scale at points corresponding with the focus tube during the two exposures and carried down to the images on the developed plate, where they

* The apparatus is made by Messrs. Curry and Paxton, of Great Portland Street, London, W. It is kept in two sizes.

† *Scottish Medical and Surgical Journal*, April, 1898.

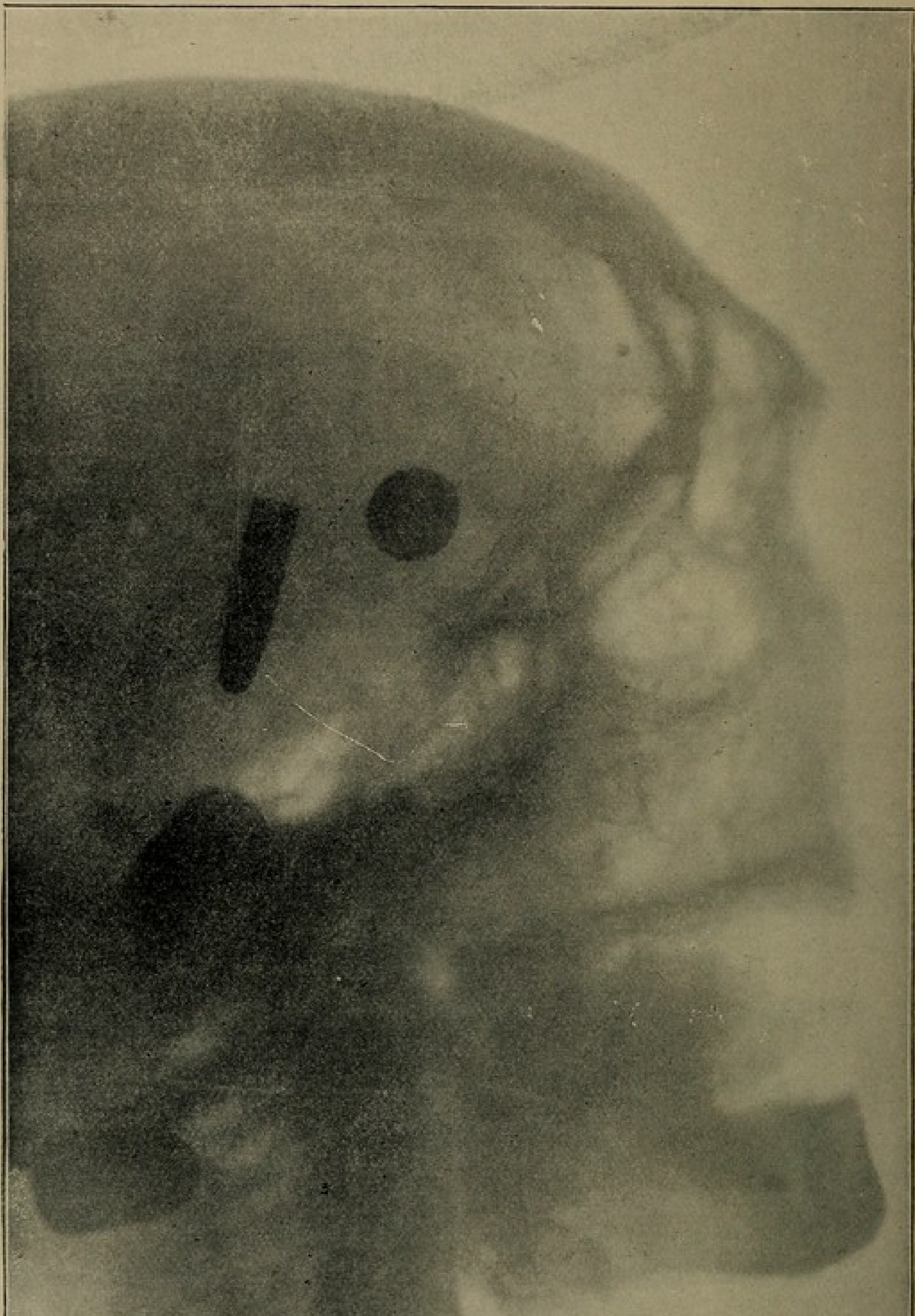


Fig. 41.—Three Bullets in Head of a Cadaver; One in Neck; reduced about one-third.

are fixed by small weights. The point of intersection of the threads marks the position of the foreign body.

Mr. Hall-Edwards has a good localizer, in which a chequered grid lies flat over the sensitive plate and beneath the shifting tube. In America the 'Dennis Fluorometer' is in vogue. It consists of an upright grid attached to an operating table, and was used exclusively in the recent Cuban war, where it was found to work rapidly and well, especially in screen-localization.

Foreign Bodies in Brain

By the kindness of Mr. Davidson the writer has been enabled to reproduce the accompanying illustration (Fig. 41), showing bullets artificially introduced into the head and neck of a cadaver. Commencing from above downwards, the round ball at the top was placed in the right frontal lobe of the brain, and the conical bullet next to it also inside the brain, close to the right parietal bone. As the right side of the head was placed next the sensitive plate, both these bullets were brought close to the film, a fact which accounts for their clear definition. For a like reason their shadows in the original photograph correspond nearly in size with those of the foreign bodies. Their sharpness of outline is wanting in the third bullet (from above downwards), which was placed in the centre of the lower portion of the skull cavity, over the basilar process of the sphenoid. The radiographic record of the last missile, moreover, would be larger than the original, owing to its comparative distance from the sensitive plate. Much the same may be said of the remaining bullet, which is deeply embedded in the middle line of the muscles of the back of the neck.

In the absence of definite information as to details, it may be conjectured that the tube, acting strongly from both a photographic and a penetrative point of view, was placed close to the skull, and that the exposure was fairly long. Under those conditions, the side of the skull next the lamp would be reproduced only faintly, if at all, and a reference to the figure will show that it represents mainly one side of the skull, namely, that next to the plate. It will be noticed that the frontal sinus is displayed, the gums are toothless, the tongue well defined, and, lastly, that the excellence of the result is to some extent accounted for by the thin bones, and the fact that the photograph was obtained from a dead subject.

The subject of clearness of definition is admirably handled by Mr. Lewis Wright in his work on the 'Induction Coil.' He states that sharpness can be increased in two ways only: (*a*) by increasing the distance of object and plate from the tube, which, of course, lessens photographic power, but is useful in some cases; and (*b*) by reducing the radiant* almost to a point. The following passage is so clear and practical that the intending operator will do well to study it carefully: 'As Dr. Macintyre has pointed out, the problem confronts us, when we deal with subjects of great depth, in a more complicated way. Suppose we want a radiograph through the entire human body, or through the entire cranium. We have now to consider *what* we want. If we remove the focus tube to a distance proportionate for the much greater thickness, to 9 or 10 inches for the thickness of the hand, our shadow of all the structures would be of approximately equal sharpness. But in the first place, such a distance will afford far too feeble radiation; and in the second place, even supposing that we could thus get shadows of all the structures superimposed, these would only confuse each other. What we want is some definite portion, the less confused by images of the rest, the better. These objects are best attained by placing the focus tube as close as possible to the structures we do not want. If we seek for a suspected injury or disease of the bone on one side of the cranium, therefore, we bring the tube close to the other side, and the photographic plate close to the side we wish to photograph. Then the shadows of the side next the tube are so diffused and dispersed and enlarged that they practically disappear; while the details are sharp of the side in contact with the plate.'

An admirable instance of ingenious intracranial localization has been kindly furnished to the present writer by Professor Waymouth Reid, of Dundee. Owing to the shedding of hair that followed the first exposure to the Röntgen rays, he found it impossible to procure a cross-photograph. Although the plan he adopted does not stand comparison with more recent methods, it nevertheless has a distinct historical value; and the case presents features of great clinical interest, so that a short account may be here inserted:

The patient, a young gentleman, from whom the radiogram

* 'The Induction Coil.' Lewis Wright, p. 150. Macmillan and Co., 1897.

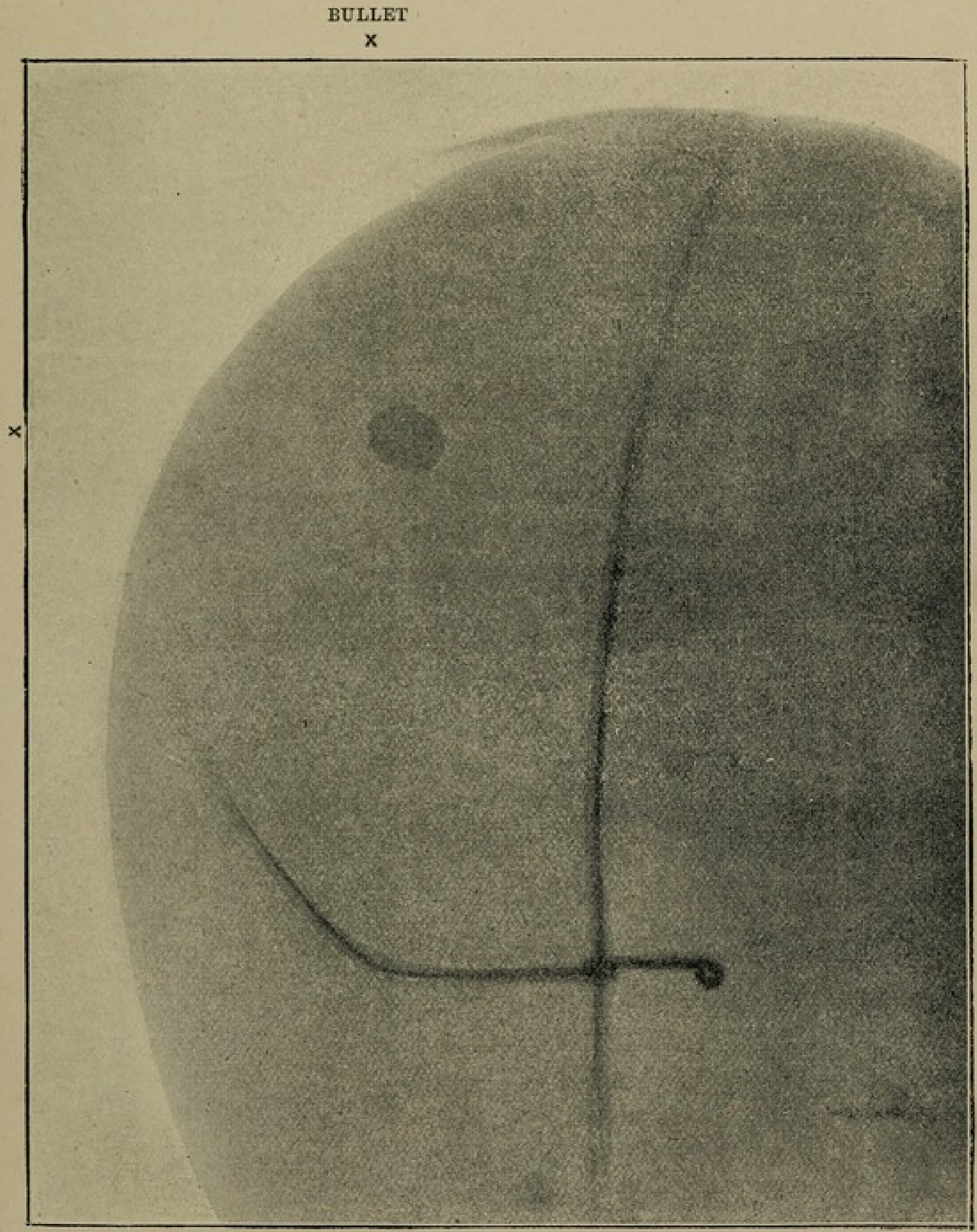


Fig. 42.—Bullet in Brain (or within Skull) of Living Subject. Lead Wire Cage used for localizing.

Professor Waymouth Reid's case.

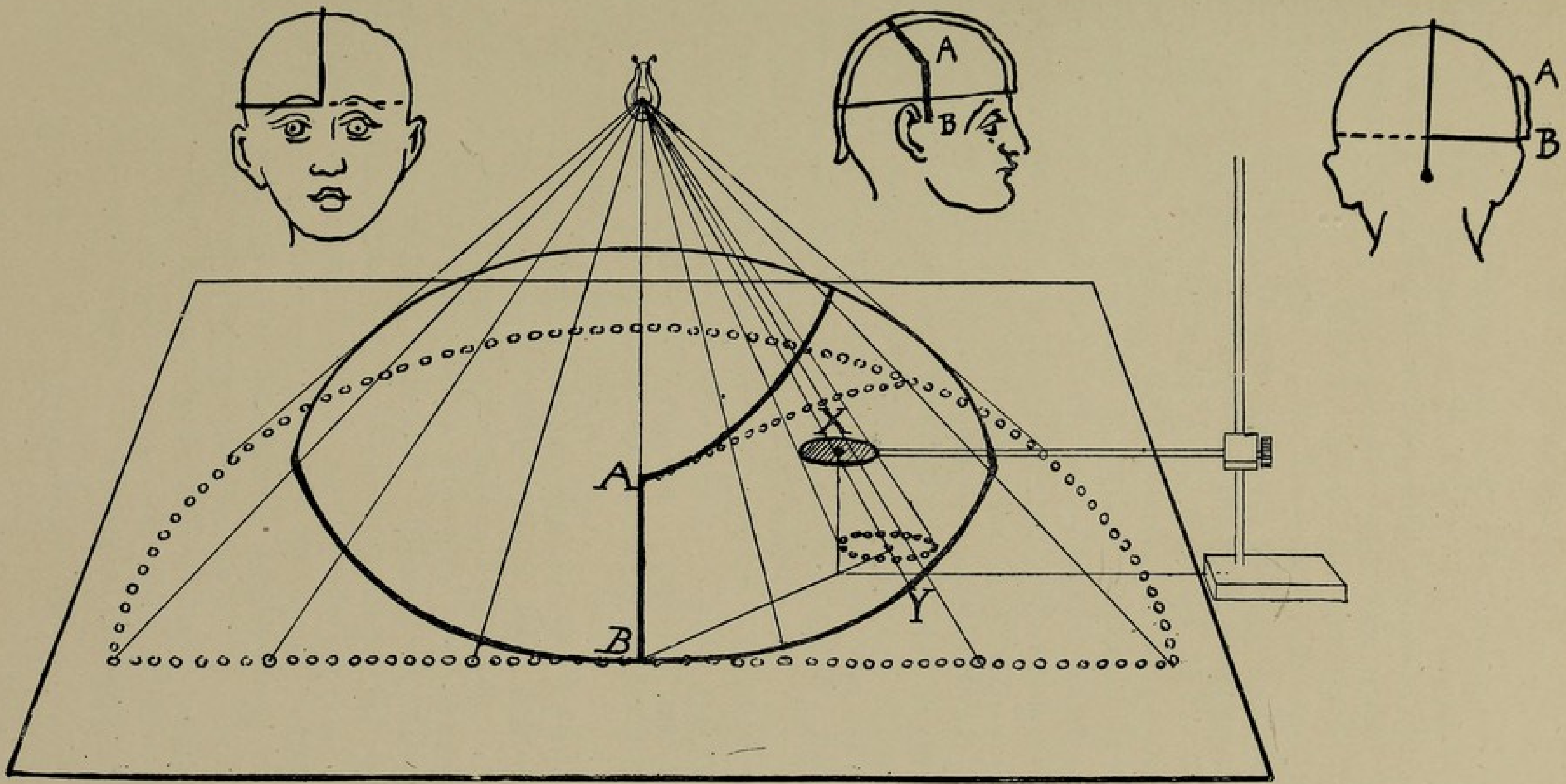


Fig. 43.—Diagram explaining Dr. Reid's Case (see preceding figure).

was taken, accidentally shot himself by a bullet from a revolver on May 21, 1891. He came under the care of Dr. Blaikie Smith, of Aberdeen, who published an interesting account of his case.* When found after the accident, blood and brain matter were oozing from a wound in his forehead, a little above and to the outer side of the right supra-orbital foramen. A director passed into the aperture of the frontal bone, and through the substance of the brain, reached somewhere near the upper extremity of the fissure of Rolando. With regard to the track of the bullet, Dr. Blaikie Smith remarked: 'It seems clear, from the position of the opening in the skull, that the missile penetrated the brain about the lower part of the first frontal convolution. Continuing its course obliquely upwards through the convolution, it apparently next entered the motor area of the brain, producing, as direct results, paralysis of the arm and leg on the opposite side.'

Strange to say, the patient recovered entirely from this serious wound. Five years after the accident, at his own request, a Röntgen ray photograph, reproduced in Fig. 42, was taken by Dr. Reid, to whom the writer is indebted both for the illustrations and for the notes of his method of localization.

An external landmark was secured by means of a head-cage of leaden wire fitted to the right side of the head, which was placed upon the sensitive plate. The cage was constructed and fitted in accordance with the measurements given by Poirier ('Traité d'Anatomie Humaine,' 1895, t. iii., p. 431).

A tracing of the Röntgen photograph was fixed to a flat surface, and over it was nailed that portion of the wire cage rising vertically from the Sylvian line, so as exactly to cover its own shadow mark (A, B in the sketch, Fig. 43). A small surgical incandescent lamp was then suspended at the height of the anode of the focus tube, as measured in the first place when taking the photograph. The lamp was then moved laterally until the shadows of the cage were cast upon the tracing of the original negative. By that means the incandescent lamp was placed in a position corresponding precisely with that of the anode in the first exposure. Paper discs of varying size were next interposed beneath the rays at X, until their shadows fitted those on the tracing Y. Measurements were then taken upon the curved wires

* *British Medical Journal* for September 17, 1892.

of the lead cage, just as they would be upon a patient's head before operating.

Clearly, the depth of the bullet might be calculated very differently by this method, according to the size of the interposed disc. Accordingly, a bullet of the same size as that with which the patient shot himself was obtained, and three discs were cut—(1) of same diameter, (2) half as large again, (3) double the size.

No. 1 indicated a location on the *left* side of the brain. The shadow on the original radiogram, however, was too sharp for such a position. Moreover, the bullet must necessarily have been more or less flattened by frontal impact. Lastly, the clinical symptoms pointed to a right-sided injury.

No. 2 showed bullet on the right side $1\frac{7}{8}$ inches up from the Sylvian line, $2\frac{3}{4}$ inches back from the vertical rising to Rolandic line (A, B), at a depth from surface of 2 inches.

No. 3 fixed the foreign body on the right side close to the surface, $1\frac{1}{2}$ inches above the Sylvian line, and $3\frac{3}{4}$ inches back from the vertical rising to the Rolandic line.

This last inference is probably the correct one. Dr. Reid concludes that the bullet, after it had traversed the brain, came to a dead stop, flattened against the inner surface of the skull.

It is interesting to note that this highly ingenious—indeed, brilliant—*x*-ray diagnosis nearly confirmed that arrived at in the first place by Dr. Blaikie Smith. In his published account of the case, that gentleman wrote: 'In all probability, the bullet has become arrested either in the leg centre or in its immediate vicinity. The exact situation is open to doubt; *possibly the future may determine its position with greater accuracy than can be done at present.*' In the light of recent events, the remarkable passage printed in italics reads like an inspired prophecy. Dr. Smith, however, has explained to the writer that what he had in mind was the possible future development of localizing signs. He has added that when he last saw the patient the left knee jerk was still exaggerated, and the left hand apt to become cold from slight causes, the latter result being perhaps due to trophic disturbances.

A somewhat similar case has been published by Dr. Fattic in an American journal.* A boy of nine was shot in the forehead—

* *New York Medical News*, August 28, 1897.

½ inch over the superciliary ridge, and 1 inch to the right of the median line—with a revolver bullet of small bore (32 calibre). The wound passed upwards, backwards, and slightly outward, but the missile could not be felt by a sterile probe passed in for a distance of 3½ inches. Antiseptic irrigation and dressings were applied, and shock overcome by free stimulation. The lad had complete paralysis of the left arm for a week, after which time he got gradually well. Seventeen months after the accident the bullet was located close to the frontal bone by two exposures—a trans-frontal one of eight minutes, and a fronto-occipital of twenty minutes. Dr. Fattic's explanation of the position of the foreign body may be gathered from the following note: 'From the history of the case it is evident that the motor area of the right side of the brain, controlling movements in the left arm, was injured, and the relief from the paralysis and the present location of the bullet, as shown by the radiograms, warranted the belief that the missile must have retraced its passage along the brain wound, assisted by the force of gravity.'

Messrs. Rémy and Contremoulin have devised an ingenious method of localization, which was laid before the Paris Academy of Medicine on March 20, 1897. Having taken two radiograms by a Crookes' tube in different positions, they were enabled by means of a geometrical figure to determine the exact position of a foreign body. Then, by a special apparatus, somewhat like the compass used by sculptors, they were able to fix with mathematical accuracy the depth of the object from the surface.

An interesting case, recorded by Max Scheir, was that of a man of twenty-seven, who had received a gunshot wound above the right superciliary ridge. From the symptoms it was imagined that the bullet had lodged in the orbit, which was explored, but without success. Five years later the rays revealed a foreign body somewhere near the Gasserian ganglion. A radiogram taken at the time would have prevented the useless exploration of the orbit. Moreover, had the bullet been removed by operation, the patient might have been spared the ensuing paralysis of the fifth (except its motor branch) and of the olfactory and optic nerves.

Many other bullets have been detected in the brain by the Röntgen rays.* Thus, Eulenberg described two such cases. In the first the foreign body was found in the right middle fossa of

* *Deutsch. Med. Wochenschrift*, August 17, 1896.

the skull, a little to one side of the median line; in the second it was shown close behind the orbital fissure. In detecting a bullet in this position, it is of practical importance to note that it may sometimes be readily seen by means of the fluoroscope where a long exposure (an hour) has failed to obtain a photographic record, as in a case described by Dr. Bruce.* In such an event it would be possible to locate with the tube in two positions (A, B) by bringing an opaque object into line with the foreign body, and then marking the entry and exit of that line on the

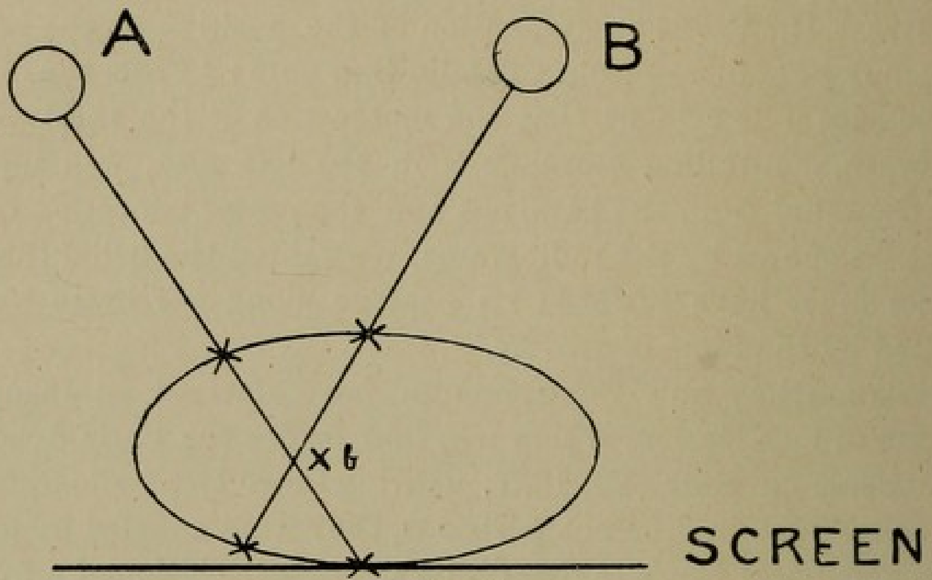


FIG. 44.

skull. The point of intersection would be the site of the bullet. A special instrument for marking is the 'punktograph.'

Foreign Body lodged in Spine

Dr. Phelps, of New York, has reported a case where a revolver bullet struck the thyroid cartilage, and, after passing through the neck, lodged in an unknown part. A radiogram showed a dark spot in the fourth cervical vertebra, and with the knowledge thus gained the surgeon was enabled to operate successfully. The ball had struck the hard lamina of the vertebra and flattened out, after which it had barely penetrated the canal. Recovery was uneventful.

* *Medical Record*, April 17, 1897.

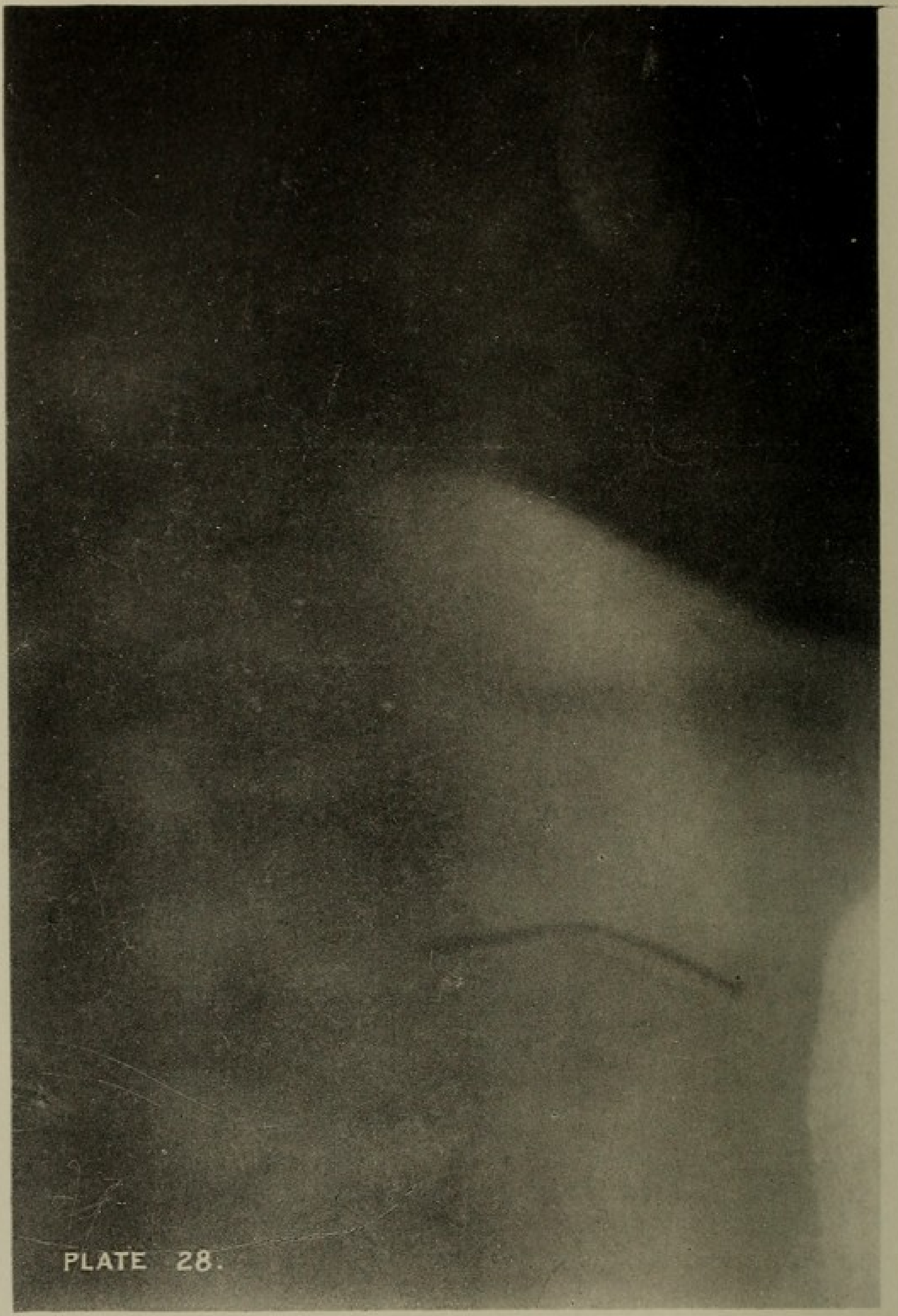


PLATE 28.

Foreign Bodies in Neck and Thorax

Such objects as coins and buttons have been detected in the larynx, bronchi, lungs, mediastina, and pleura by means of the Röntgen rays. In most of these sites, however, it is likely that the clinical signs and symptoms will afford an equally ready means of diagnosis.

Dr. Walker Downie, of Glasgow, found a pin which had slipped into the larynx from the mouth. The foreign body could not be seen by the laryngoscope, but the patient, a boy, complained of 'a pinching pain at the back of the throat, and some pain in swallowing.' The pin was discovered by the rays, and easily extracted by external operation.* Dr. Downie has kindly allowed the accompanying reproduction (page 103) of his original photograph. It was taken with an exposure of eight minutes to an Apps coil having a 10-inch spark.

The plate shows parts of upper and lower jaws, with some of the molar teeth and their fangs. To the left are several of the cervical vertebræ, and in front, under cover of the lower jaw, is the hyoid bone, below which a light perpendicular band indicates the position of the larynx and trachea, structures which are particularly translucent. Crossing this light area, at the level of the lower border of the body of the fourth vertebra, is the pin with the head anteriorly, corresponding to the outline of the thyroid cartilage, and with its point embedded in the cartilaginous disc between the fourth and fifth cervical vertebræ. The pin appears at least $\frac{1}{4}$ inch longer than the antero-posterior diameter of the larynx, and it is bent near the middle, with the convexity directed upwards.

In an antero-posterior radiogram the pin was localized by means of two pieces of silver wire fastened with sticking-plaster, the one in the middle line, and the other at right angles in a carefully-noted position. In the picture the two wires were shown fixed to the skin, and $\frac{11}{16}$ inch above the horizontal one was the image of the foreshortened pin, with the head close to the middle line, from which point the body of the pin was directed upwards and backwards. It is interesting to note that there was no indication of the vertebræ, through which the rays must have passed to give the image of the pin shown in the photograph. That result is

* *Edinburgh Medical Journal*, January, 1897.

doubtless due to the high penetrative action of the focus tube, as well as to its nearness to the spine.

The principle of localizing by means of wires is capable of extensive application. Soft lead wire is suitable, and may in many cases be twisted round a limb. If fastened on with plaster, it should be remembered that most forms of that material are opaque to the rays, owing to the contained lead.

Dr. Downie has reported another case in which a pin was localized outside the larynx in a line behind the right thyroid cartilage, and removed by forceps.*

The beginner will do well to study all the figures attentively. In this way he will train his eye to the recognition of various objects, and will also prepare himself for the more difficult task of reading the fluorescent screen. Unfortunately, there is a loss of detail in almost any kind of reproduction for book illustration. This is especially the case when the original radiogram is reduced on the block.

An indiarubber drainage-tube, when lost in the pleura, may now and then be located by the rays. However, as a rule it will yield no readable record, falling as it does within the uncertain region of faint soft tissue shadows.

There is doubtless a great field of future usefulness for the Röntgen processes in lung surgery. That fact is well illustrated in a case published by Dr. White, of Pennsylvania.† 'I have now under treatment,' he writes, 'a young lad who accidentally shot himself with a 22-calibre parlour rifle. The ball entered the wall of the right chest on the mid-axillary line in the sixth interspace. The muzzle of the rifle was pointing upward. The patient complained bitterly of pain under the upper border of the right scapula. The history of the case and all the clinical phenomena would have led to exploration in that region, but the radiograph shows the bullet in the lower lobe of the lung, on a level with the tenth rib, and near the middle line of the body. The picture also shows in a convincing manner a pulmonary area (corresponding to the lower lobe) of increased opacity, and evidently the seat of blood-effusion and inflammation. The patient has all the clinical symptoms of a traumatic pneumonia.

'There can be little doubt that the difficult decision between

* *British Medical Journal*, October 22, 1898, p. 1243.

† *The American Journal of Medical Science*, January, 1898, p. 4.

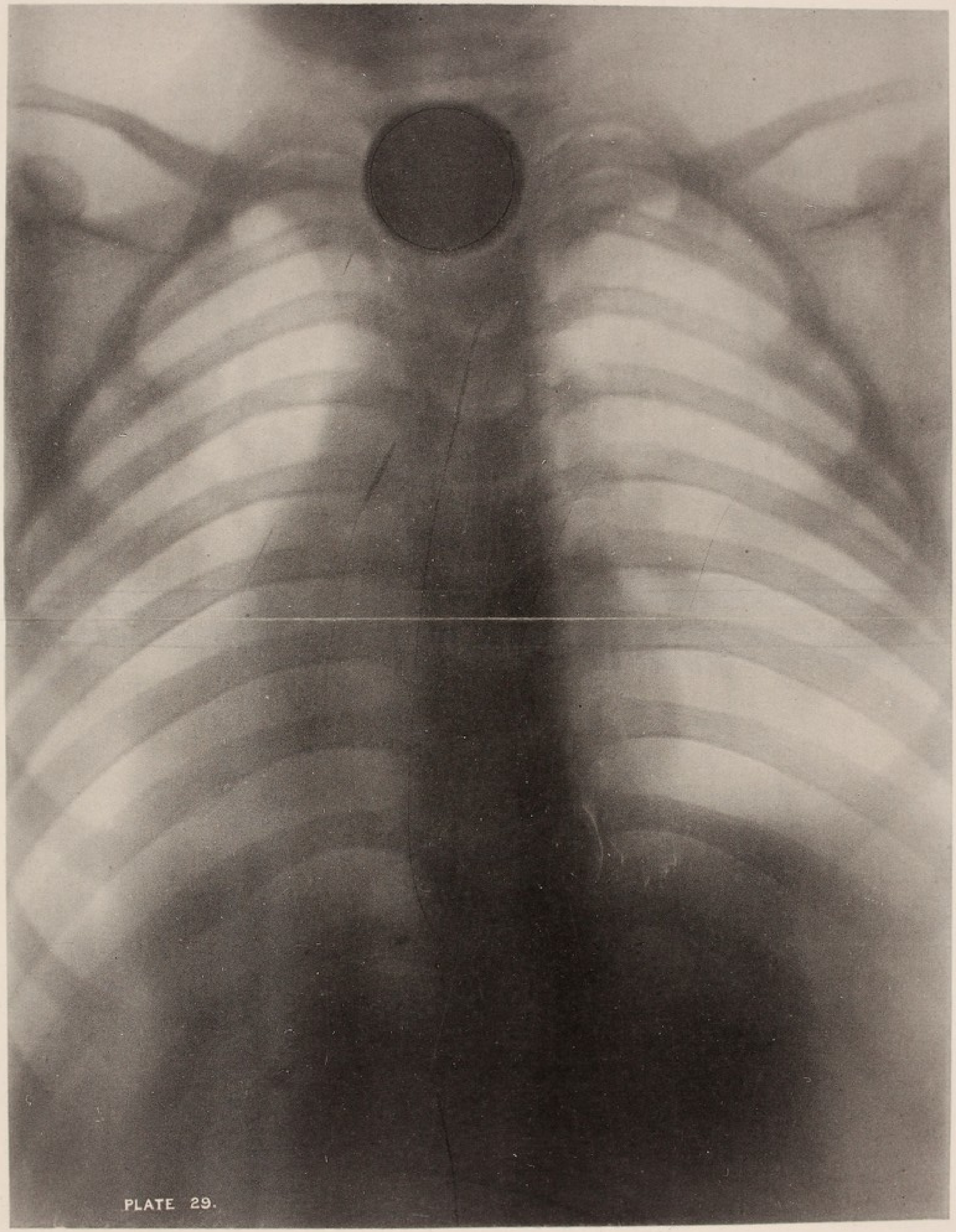


PLATE 29.

operative interference and expectancy in penetrating gunshot wounds of the thorax without wound of exit will be greatly facilitated in the future by the accurate localization of the bullet.'

In the œsophagus it is fairly easy to locate false teeth and other objects opaque to the rays. Thus, a London medical journal* commented on a case where the results of such an attempt, although negative, were nevertheless of an instructive nature. The facts were briefly as follows: A young lady swallowed by accident a set of false teeth. She called in a medical man, who, failing to remove the impacted plate from the gullet, pushed it, or thought he pushed it, down into the stomach. Some time later she went to a hospital, complaining of pain in the abdomen, and that region was radiographed, but without result. Shortly afterwards she brought up a quantity of blood, and was taken to another hospital, where she died while an attempt was being made to radiograph the abdomen, to which part pain was referred to the last.

Post-mortem it was found that the plate had lodged in the œsophagus below the bifurcation of the trachea, whence it had ulcerated into the aorta. This case suggests the advisability of examining the thorax at once by means of the rays whenever a person has been unfortunate enough to swallow a dental plate.

Dr. Barry Blacker has reported the following case: 'A. B——, æt. 48, male. Swallowed set of false teeth consisting of plate and eight teeth, seen in lateral view between the levels of the cricoid and thyroid cartilages, immediately in front of the bodies of the vertebræ, and in the antero-posterior view from behind as a semicircular object, with the convexity to the right side of the vertebræ, about 2 inches in length."†

If a foreign body be found impacted in the upper part of the gullet, the surgeon may decide forthwith to perform an œsophagotomy. Indeed, it is chiefly on account of the difficulty of localizing such objects that this operation has been hitherto of rare occurrence. As in the foregoing instance, where a foreign body is impacted in the gullet, the occurrence of gastric pain is apt to be misleading. Dr. Macintyre has described a case where a boy swallowed a halfpenny some six months previously. The fluorescent screen showed the coin to be lodged opposite the

* *Medical Press and Circular*, January 13, 1897.
† St. Thomas's Hospital Reports, 1897.

third dorsal vertebra. In that instance the pain was constantly referred to the stomach. Indeed, where pain in that region cannot be explained by some obvious cause, the surgeon will do well to make the *x*-ray examination of the chest a routine practice.

An excellent example of a coin impacted in the œsophagus was brought forward at the Clinical Society of London on June 22, 1897, by Mr. Bowlby. The patient, a boy three and a half years of age, was under the care of Mr. Howard Marsh. He had been under observation for five weeks, during which time he showed no symptoms beyond occasional sickness. A radiogram taken by Messrs. Allen and Hanbury (page 104) at once revealed the presence of the coin, a halfpenny piece, lodged in the gullet at the level of the second dorsal vertebra. Removal was ultimately effected by means of a catch carried within a gum elastic catheter.

Dr. Mayo, of Rochester, U.S.A.,* has reported a case where an open buckle was shown by the radiograph to be impacted in the gullet of an infant. The buckle lay behind the upper part of the sternum, with its teeth projecting upwards and to the right. A left œsophagotomy enabled the surgeon to remove the foreign body by means of a bent probe. The chief point of interest was that the position of the teeth would have effectually prevented the pulling upwards of the buckle. The danger of attempted extraction by curved forceps would obviously have been great.

Professor White, of Pennsylvania, had a child, two years and five months old, brought to him with an obscure history of dysphagia and vomiting. The Röntgen rays showed a cruciform toy known as a 'jackstone,' impacted in the œsophagus on a level with the space between the second and third dorsal spines, a little above the bifurcation of the trachea. The object was in the shape of a Maltese cross, with an additional bar at right angles through its centre. As it could not be extracted by the mouth, gastrotomy was performed, and the 'jackstone' drawn down into the stomach and removed.

Mr. George Heaton, of Birmingham, has recorded† two interesting cases of coins that had been impacted in the gullet for a considerable time, but gave little evidence of their presence. In one case the foreign body had been swallowed three months,

* *North-Western Lancet*, March, 1897.

† *British Medical Journal*, June 4, 1898, p. 1449.

and in the other forty days previous to detection by the rays. One patient took solids and fluids freely, the other fluids only.

Among numerous other instances, the following may be selected. Dr. Bliss* found an iron staple an inch long, with two sharp points, so fixed in the gullet that the use of a probang would have still further impacted the foreign body. Removal could not be effected by curved forceps until the exact position of the staple and the direction of its points had been localized by means of the Röntgen rays.

In this class of cases the importance of the Röntgen rays can hardly be overestimated. As every surgeon knows, the difficulty of locating is often extreme. Undetected foreign bodies in the gullet have been treated for pulmonary phthisis, croup, catarrh, asthma, and so on. Wallace of Edinburgh has recorded a case where a plate bearing six artificial teeth could be located only after repeated negative attempts with the œsophageal olivary bougie and 'coin-catcher.' A low œsophagotomy proved a failure, and gastrotomy was finally required.

White has suggested the combined use of instruments, as the curved forceps, with the fluorescent screen. A similar suggestion has been made by Mr. T. L. Gillanders, M.B.† After failure to find a bullet in a hand, where it had been shown by the rays, he removed it by observing its relative position to the bullet forceps upon the fluorescent screen. The first negative result was due to the fact that the bullet had become flattened against the bone, and was bound down tightly by the powerful flexor tendon. Mr. C. G. Burton, of the North Eastern Hospital for Children, London, has recorded another interesting case of a coin thus removed (*British Medical Journal*, April 1, 1899).

Foreign Bodies in Abdomen

So far as the abdomen is concerned, coins and other foreign bodies have been located in the case of children. The importance of exact information of this kind will be at once recognised by those who are familiar with the needs of abdominal surgery. The results of ray work, when applied to the abdomen in adults, have for the most part been either uncertain or negative. However, a good definition of intestines and other abdominal

* *International Medical Magazine*, March, 1897.
† *British Medical Journal*, May 14, 1898, p. 1252.

organs can be procured in the case of small lower animals, and also of children. In the face of such facts it may be confidently anticipated that before very long it will be possible to obtain satisfactory ray pictures of the abdominal viscera in the adult human subject. From time to time different experimenters have succeeded in obtaining an obscure record of intestines. The present writer has such a result in the shape of a photograph taken in the summer of 1897, which shows a faint, but discernible, tracing of colon, of loops of small intestine, and of the sigmoid flexure of the rectum. The patient from whom the radiograph was taken had signs of chronic intestinal obstruction. On the chance of localizing the lesion, he was given bismuth in 10-grain doses thrice daily for over a week before the abdomen was examined by the rays.

The advantages of localization of foreign bodies in the intestines of adults need hardly be pointed out. Numerous possibilities will readily occur to the mind of the medical reader, such as the detection of a forceps or other instrument inadvertently sewn up in the abdominal cavity. The passage of a Murphy's button through the bowel has been repeatedly demonstrated. The knowledge of the progress of a foreign body through the intestinal canal not only guides the surgeon in his prognosis, but must also afford great relief to the anxiety of the patient and his friends.

Foreign bodies can be detected in the pelvis, either in the rectum or the bladder. Calculi in this and in other parts of the abdominal cavity will be discussed in another part of the book (see p. 117).

Foreign bodies can be readily detected in the stomachs of children. The same thing has also been now and then accomplished with adults. Thus, Dr. Scott of Kansas has published the following interesting case, accompanied with a Röntgen photograph :

'Radiograph of abdomen of ostrich-man, Mr. G. W. Whallen, taken by Dr. E. Von Quast. The dark mass on the left side of the picture contained 116 different pieces of metal and a handful of glass. Patient operated upon, June 8, 1897, at German Hospital. Occupation, showman ; 26 years old. Median gastrotomy. The following foreign bodies removed: 3 ounces glass, two pocket-knives (one a Varlow 4½ inches long, the other a four-blade), five knife-blades, one barb-wire staple, three screws, one horse-shoe nail, sixteen tacks, forty-one wire nails, forty-one twelve-penny nails. On account of the weight of the above articles the stomach was lower down than normal. The outline of the

FIG. 45.—STOMACH OF "OSTRICH MAN" DISTENDED WITH A MASS OF METALLIC ARTICLES AND GLASS, WHICH CAUSED HIS DEATH (*American X-ray Journal*, July, 1898).

articles does not show, as they were all rolled up in a round mass. Patient emaciated from want of food, as he could not eat anything for about a week before operation. Foreign bodies had been in stomach for two or three weeks. After operation the stomach was closed by interrupted and Lembert sutures. Death in forty-eight hours from enteritis and exhaustion. There had been hæmorrhage from the bowels. The post-mortem showed absolute union of wound in stomach; no leakage; wound healed in part.'*

In the same article Dr. Scott shows the radiogram of a swallowed watch in the lower end of the œsophagus of the

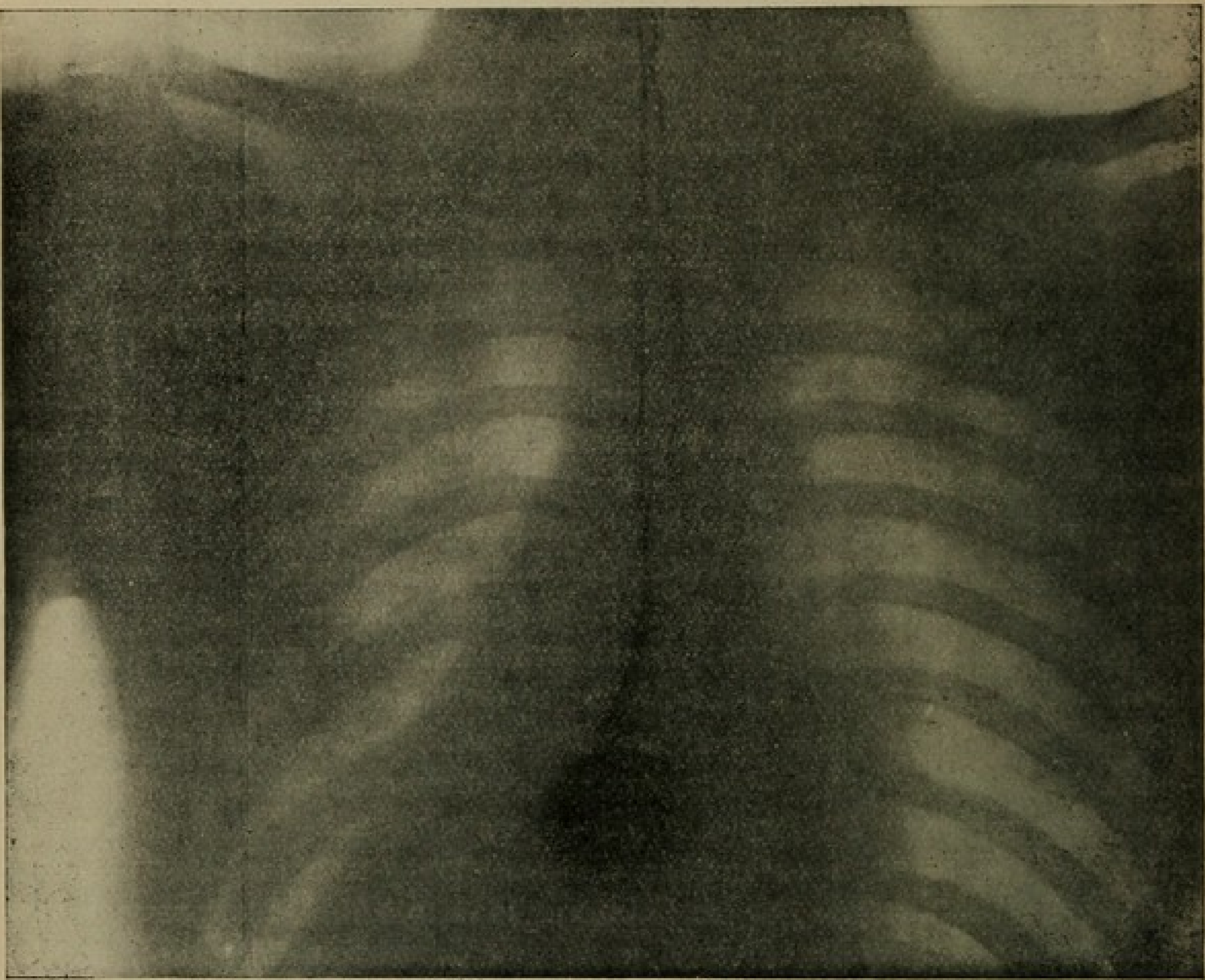


FIG. 46.—WATCH AND CHAIN IN ŒSOPHAGUS, SWALLOWED BY "OSTRICH MAN" (*American X-Ray Journal*, July, 1898).

ostrich-man. Immediately after the photograph was taken the patient removed the watch by means of the attached chain. Both watch and chain stand out in dark shadow upon the less dense record of the heart and spine. In the lower part of the course the chain bends slightly towards the left, thus following the direction of the œsophagus. The subject of this experiment was in the habit of swallowing wadded cartridges, tacks, money,

* *American X-Ray Journal*, July, 1898.

screws, and other solid articles, at public performances. He stated that as a rule he passed metallic bodies in twenty-four hours. A failure in the latter respect appears to have led to an accumulation and fatal result.

Dr. White has suggested* that in suitable cases the presence of a foreign body in the stomach could be demonstrated by moderately distending that organ with a harmless opaque fluid, like lime-water, and observing whether or not the body disappeared from view.

Linderman suggests the outlining of a dilated stomach by means of a soft stomach-tube armed with a flexible metal style. A relative landmark on the abdomen is obtained by fixing a small coin to the umbilicus.

Foreign Bodies in the Eye

The Röntgen ray exploration of the eyeball, buried, so to speak, in a dense bony socket, was in the early days of Röntgen work attended with insurmountable difficulty. Now, however, it may be readily performed by the use of a tube of good penetration and definition, and in some cases yields results of great value.

So early in the history of the method as March, 1896, Professor Van Duyse communicated some interesting experiments to the Medical Society of Gand. He introduced a shot into the eye of a rabbit, and pushed it up behind the iris towards the centre of the lens. He then, with the aid of a local anæsthetic, produced an exophthalmos, and slipped under the protruding eyeball a small sensitive plate. The result, an extremely sharp shadow, is shown in Fig. 47.

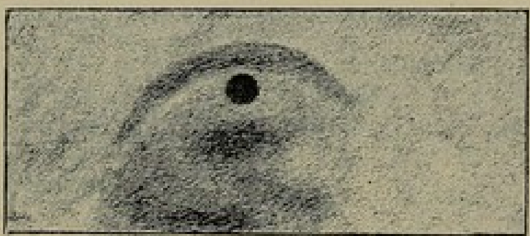


FIG. 47.—SHOT IN EYEBALL OF RABBIT.

An important point is that the foreign body could not be detected by the ophthalmoscope.

This second picture (Fig. 48) shows a pellet and a fragment of lead introduced into the equator of a human eye after removal from the body. His main conclusion was as follows: 'To obtain a shadow of metallic bodies lying in the anterior chamber, it

* *Deut. Med. Woch.*, April, 1897.

will suffice to place, in the inner angle of the lids, a small sensitive plate or film of which one of the corners has been rounded, and to turn on the x-rays from the temporal side.'

For the use of both the above illustrations the writer is indebted to the courtesy of Dr. Van Duyse.

Many cases have been reported of the detection by the rays of foreign bodies in the living human eye.

Dr. Leukowitsch,* one of the early workers in this direction, obtained good results in sheep's eyes with two tubes, but found it better to use one tube and take two views.

For the living human eye he used small semicircular sensitized plates, as that shape allowed the largest possible area to be inserted at the inner angle of the eye opposite the lachrymal bone. By rolling the eye inwards or outwards, a large part of the globe could be brought within range of the rays. Rotation, however, rendered a fixing-point necessary. This he obtained by a glass indicator, bent twice at right angles, with a short straight terminal placed so as to point exactly to the antero-posterior axis of the centre of the cornea. In this way he obtained localizing radiograms of a foreign body (a sequin) placed on the conjunctiva of his own eyeball.

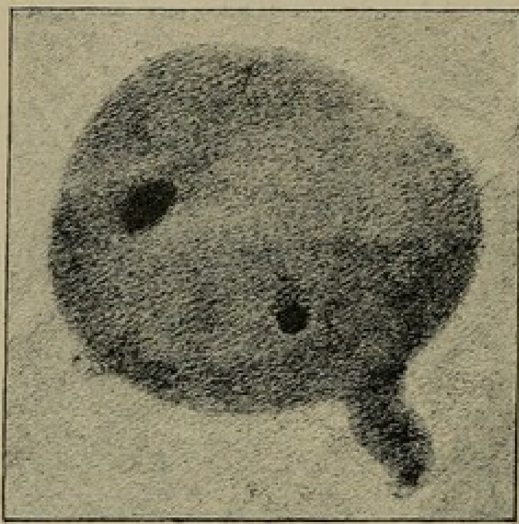


FIG. 48.—PELLET AND FRAGMENT OF LEAD IN HUMAN EYE.
Van Duyse.

In February, 1897, two cases of steel fragments in the vitreous humour were brought before the Ophthalmological Section of the College of Physicians, Philadelphia, by Drs. Oram Ring and Hansell. The latter gentleman mentioned another instance communicated to him verbally by Dr. de Schweinitz, who found a foreign body by the rays, and afterwards extracted it by the Hirschberg magnet. Dr. Hansell, in a communication to *The Journal*, Philadelphia, observed : 'Thus it will be seen that the bony walls of the orbit and the coats of the eye are permeable to the rays. By comparison of the shadow of the metal with that

* *Lancet*, August 15, 1896.

of the margin of the malar process of the superior maxillary bone, and the knowledge of the relation of the Crookes' tube to the sensitive plate, the location of the foreign body can be closely estimated.'

Dr. Stern, of the Philadelphia Polyclinic, however, claims by an original method to have succeeded six times in demonstrating, by both fluoroscope and radiogram, foreign bodies in the eye, undiscoverable by other means. In each instance he reported subsequent removal by ophthalmologists. Before he detected

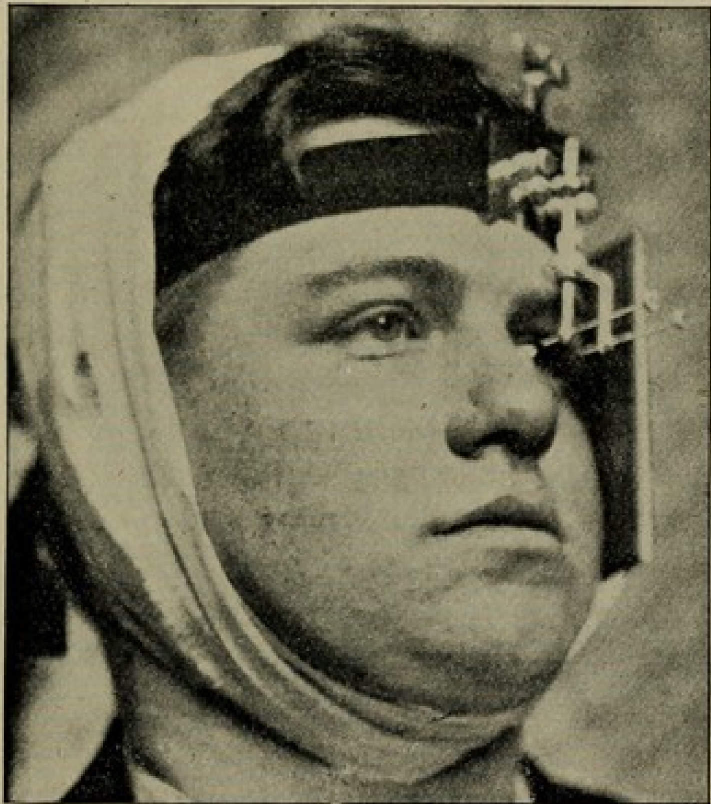


FIG. 49.—SWEET'S LOCALIZING APPARATUS.
From *The Practitioner*.

the fragment in the case of Dr. de Schweinitz's patient, the eye had actually been cut down upon once, and the magnet applied three times with negative results.

Good records of small shot and fragments of wire introduced into orbits were obtained by Dahlefeld and Pohrt.* Their plan was to place the sensitive plate against the temple of the affected side, and to place the focus tube at a distance of 10 to 15 millimetres distant from the opposite temple. Then came the stage of exact localization, which in certain cases has

* *Deut. Med. Woch.*, No. 18, 1897.

rendered the x-rays invaluable to the ophthalmic surgeon. In America, Dr. Sweet* and Dr. Kibbe† appear to have led the way; and Dr. Sweet took Röntgen photographs in one or more of Dr. Hansell's cases where extraction followed. Dr. Leonard's method was published in April, 1898,‡ two months later than that of Mr. Davidson in England.§

An excellent account by Mr. Treacher Collins, of the Röntgen rays in relation to ophthalmology, was published in the *Practitioner* for August, 1898. He describes Dr. Sweet's method thus:

'Dr. Sweet fixes to the patient's head an "indicating apparatus,"

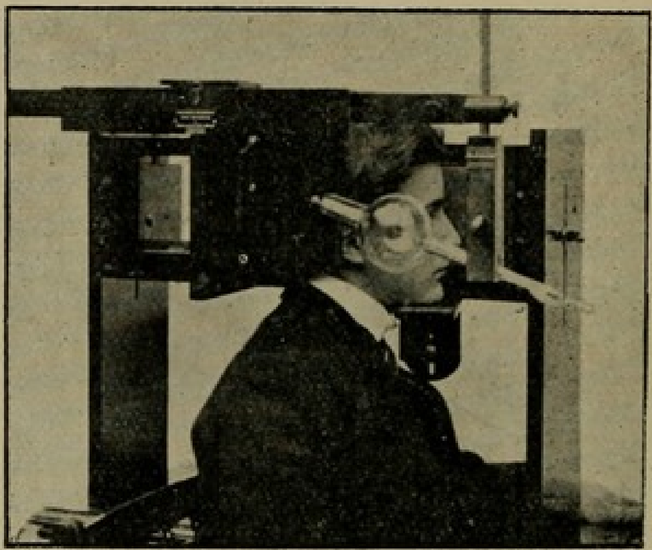


FIG. 50.—DAVIDSON'S EYE APPARATUS.

carrying two steel rods each, with a rounded ball at the end. These balls are placed at a known distance from the eyeball, one pointing to the centre of the cornea, the other to the external canthus, both parallel to the visual line and perpendicular to the plate.

'From the relation of the images of these balls of the indicator to that of the foreign body in the skiagraph he is able to work out, on a horizontal and vertical diagrammatic section of the eyeball, the approximate position of the foreign body.

* *Trans. Amer. Ophth. Soc.*, vol. viii., p. 88, 1897.
† *Archiv. of Ophth.*, vol. xxvi., p. 517, 1897.
‡ *Philadelphia Medical Journal*, February 5, 1898.
§ *British Medical Journal*, April 28, 1898.

'In a patient of Dr. W. Thomson, of Philadelphia, who had received an injury to the eye eight months previously, Dr. Sweet predicted that the piece of steel would be found below the horizontal line of the eyeball, to the temporal side of the vertical one, and 20 millimetres from the cornea. The foreign body was subsequently removed by operation from the position indicated.'

Mr. Davidson applies the photographic plate, fixed in an angular rest, to the temple on the affected side of the patient, who sits upright. A loop of lead wire is fixed by sticking-plaster to the edge of the lower lid, opposite a known point of the eye; the point of this wire, projecting upwards, forms the landmark from which the position of the foreign body is calculated. The patient is directed to gaze steadily at a distant object in an axis parallel with the plate—that is, straight in front—and two exposures are made on the same plate with the tube in different positions on the sliding bar. Localization is made from the resulting photographic records in the manner already described, and has now been successfully applied by many ophthalmic surgeons.

Mr. T. Collins, at a meeting of the Ophthalmological Society on January 27, 1898, described a series of cases in which the above method had been used. In none of them could the presence of a foreign body have been determined from the clinical appearances. In two of the cases the chip of steel was subsequently withdrawn by the introduction of an electro-magnet in the direction in which it had been ascertained to lie. The size of one of these bits of steel was practically the same as had been estimated by Mr. Davidson previous to its removal. In another case, the eye being quiet, and two and a half months having elapsed since the injury, operative procedure was not thought justifiable. In a fourth case the eyeball was removed, and dissection showed the foreign body to lie in the position and be of the exact size predicted.

In taking these objects, often very minute, the tube must emit the rays from a small point on the anti-kathode, and the exposure must be short—say a minute to a minute and a half. The method may be illustrated from the following reports of actual cases where extraction was successful:

1. 'A chip of metal situated 3 millimetres external to a piece of lead wire previously fixed to the lower lid, 7 millimetres upwards from it, and 4 millimetres backwards. On working this

out, it led to the conclusion that the foreign body was in the lens, directly behind the discoloured spot in the iris.'

2. 'Diagnosed the presence of a spicule of metal 5 millimetres in length, and located its lower end as situated 5 millimetres inwards, and 4 millimetres upwards, from a lead-wire pointer placed on the lower lid.'

3. 'He was able to diagnose the presence of an exceedingly small chip of metal (less than 1 millimetre in diameter) in the eye. He further located it 5 millimetres above, and 1 millimetre to the nasal side of, a pointer placed opposite a known point on the lower lid, and at a depth of 5 millimetres from the surface of the cornea. These measurements, worked out on the schematic eye, showed the foreign body to be situated in the lens, opposite about the centre of the outer half of the cornea.'*

The advantages of the method in ophthalmic surgery have been excellently summed up by Dr. Collins as follows :

1. They enable us in doubtful cases to determine the presence or absence of a metallic foreign body in the eye. With a good apparatus properly used, a piece of metal less than a millimetre in diameter can be detected in a skiagraph.

2. The exact position in the eye of a foreign body can be located by the method, which allows of the procedure which will most facilitate its removal to be deliberately planned, so that a minimum disturbance of the tissues of the eye is brought about.

3. The same method allows of the exact size of an unseen foreign body being ascertained, and of the size of the incision necessary for its removal being determined.

4. This method enables us to say whether or not a foreign body which has entered the eye has passed through it into the orbital tissues or remained in the eye, a point sometimes left in considerable doubt as the result of clinical examination. For example, it is by no means uncommon for a foreign body entering the front part of the eye to pass through the vitreous, strike the retina, and rebound into the anterior and lower part of the vitreous. In such a case, if the lens is not wounded, the foreign body may be invisible ophthalmoscopically, and the mark left where it struck the retina be taken for the aperture of exit of the foreign body.

5. The unsuspected presence or the absence of more than one foreign body may be demonstrated. In one case of Mr. Wray's

* *British Medical Journal,* August 20, 1898.

several foreign bodies were shown scattered about in the orbital tissues, the eyeball having escaped injury.

In March, 1897, Benedikt* showed a radiogram of a man who had been injured in the right temporal bone several years previously. Since then his vision had gradually declined, together with the occurrence of retinal detachment. The onset of pain led to a radiographic exploration, which revealed a sharp body penetrating the orbit from the neighbourhood of the zygoma.

The humours of the eye appear to be somewhat resistant to the rays, and the crystalline lens markedly so, while the retina is insensitive to their vibrations.

Calculi in Various Positions

The detection of stones in internal organs, closely connected with the subject of foreign bodies, is likely to become an important branch of radiography. Under present methods, however, results are still more or less uncertain in the case of renal and biliary concretions, and not altogether certain in those of the urinary bladder. For all that, stone has been shown by the radiogram to exist in the gall pouch, in the urinary bladder, and in the kidney of the adult living human subject.

So far as the opacities of the various calculi are concerned, both Neisser and Petersen have demonstrated that while cholesterine concretions are almost transparent, those of phosphates and urates are opaque to the rays. From these premises they concluded that it would be impossible to detect gall-stones by the rays, yet stone in the bladder and the kidney might be thus demonstrated. As already stated, this theoretical conclusion has been more or less upset in practice. Thus, a plate shown to the writer exhibited a faint but unmistakable shadow of a gall-stone. The image was too faint to print, but, as often happens with objects translucent to the rays, could be distinctly recognised on the negative. Such evidence, however, is of value, and, so far as one can judge, is all that is likely to be forthcoming for a time in the case of biliary calculus.

Messrs. Laurie and Leon, in a paper in the *Lancet*, January 16, 1897, published results of experiments showing that calculi of oxalate or of phosphate of lime were more opaque than bone,

* *Medical Press and Circular*, April 7, 1897, p. 359.

uric acid of almost the same opacity, and gall-stones very slightly more opaque than flesh. They thus substantially confirmed previous results arrived at by Mr. Henry Morris. Experiments upon gall-stones have been reported by Messrs. Neisser, Goodspeed, and Cattell,* and many others.

In France Messrs. Chapuis and Chauvel at an early date studied kidney calculus in relation to the rays. They concluded that stones composed of uric acid, urates, and phosphates were little less opaque than bone. Those composed of many layers and of unequal opacity proved by analysis to consist of uric acid nuclei covered with layers containing phosphates. They found the kidney substance less penetrable than muscular tissue, so that the kidney appeared as a light patch on the negative (dark in the print).

In a radiogram of a removed kidney a stone shows as a dark body. Many excellent examples of this sort have been published from time to time.†

To Dr. Macintyre, of Glasgow, belongs the distinction of having obtained the first focus-tube record of a renal calculus *in situ*.‡ It appears that he had failed to demonstrate any concretion in half a dozen cases where stone in the kidney was suspected. Undeterred by these negative results, however, he tried the Röntgen rays upon another patient who had been previously operated upon for the malady in question. Thereupon, with a 6-inch spark and twelve minutes' exposure, he was rewarded by a clear record on a Paget XXXXX sensitive plate. 'In this instance,' to use his own words, 'at the correct situation, a picture of an obliquely-placed elongated deposit was obtained.' From his reading of the result, Dr. Macintyre inferred the presence in the kidney of a stone, but not a well-formed one. The correctness of his inference was subsequently proved by Mr. Adams, of Glasgow, who, on operating, found at the bottom of an old cicatrix an ill-defined mass, which he removed with a spoon.

Messrs. Leon and Laurie, in the paper above referred to, obtained a 'faint but distinct image' of a stone introduced into the urinary bladder of a cadaver. They made an exposure of

* *Medical News*, February 15, 1896.
† See plate in Morton's '*X*-Ray,' New York, 1896.
‡ *Lancet* for July 11 1896

thirteen minutes with a 6-inch spark, the body lying on its back. It is noteworthy that in their experiment the spine itself was very faintly indicated.

The same experimenters obtained a record of a stone in the living subject, a boy eight years of age, after an exposure with a 6-inch spark of seven minutes to a XXXXX Paget plate. The stone was removed a few days later with a lithotrite by Mr. Silcock. A collotype of this calculus, which appeared to be a little over an inch in diameter, was published in the *Lancet.* Subsequently another stone was demonstrated in the bladder of a boy of fifteen.

Dr. James Swain, of Bristol, has made some important observations on the subject. He exposed on a single plate various kinds of calculi of nearly uniform thickness to the rays for periods of one, two, four, eight, and sixteen minutes. He found the general law laid down by Röntgen, namely, that the denser the object the deeper the shadow, did not apply exactly to these experiments. Arranged in the order of the highest specific gravity, the greatest permeability to the rays, and the greatest density of the shadow, the results are :

	Specific Gravity.	*Permeability.*	*Density of Shadow.*
1.	Oxalate of lime.	Biliary.	Oxalate of lime.
2.	Uric acid.	Uric acid.	Phosphatic.
3.	Phosphatic.	Phosphatic.	Uric acid.
4.	Biliary.	Oxalate of lime.	Biliary.

Dr. Swain exposed each of the above kinds of calculi, together with a piece of human rib and a portion of kidney. With each increase of exposure the shadows became fainter, until at length, after an exposure of sixteen minutes, only the oxalic acid and phosphatic calculi, with the merest trace of rib, were to be seen. The important deductions are that a short exposure may give a better result than a long one, and that an oxalate of lime calculus will be much easier to detect than one of phosphates or of uric acid. If the exposure be too long, some of the less dense calculi will disappear altogether.

The uric acid calculus in an eight minutes' exposure gave a less dense shadow than that of rib, and much less, again, than that of a piece of rib covered with kidney. The extreme difficulty of diagnosing uric acid calculi by the Röntgen method is therefore obvious.

Prolonged exposure caused a 'denser' negative. Objects that could not be printed were still visible to the eye. Hence it is always desirable to study the negative to avoid missing shadows not evident in the print. This observation was applied by Dr. Swain to a case where a patient was suspected to have a stone in the kidney. The x-ray negative showed a distinct shadow in the region of the left kidney, but no satisfactory print was obtainable. This result was taken as confirmatory, and a subsequent successful operation removed a stone half as large as a walnut. In this case it is important to note that the shadow given after an exposure of thirty-five minutes was not very deep, but with an exposure of twenty minutes the presence of the calculus was made abundantly clear. In this case the radiograms were taken with a coil capable of giving a spark of 19½ inches, worked at about half its full strength. The focus tube was placed about 12 inches from the body.*

Messrs. F. Taylor and Fripp showed a case at the Clinical Society of London.† An operation had been performed before the x-rays were tried. The kidney was found high up, and as no stone could be felt, it was left unopened. Later a stone high up under the ribs was shown by a Röntgen photograph. A piece of rib was resected a week after the first unsuccessful operation, and an atrophied kidney containing a fair-sized stone was removed.

An excellent case of successful focus-tube photography of a renal calculus has been published by Dr. F. H. Low. The patient was a slight-built youth aged twenty, and the stone, which Mr. Swinford Edwards subsequently removed by nephrolithotomy, was found to weigh nearly 2 ounces.

Dr. Low has kindly furnished the following details: The coil used was a 6-inch, working at a 5-inch spark. Tube of medium resistance and shifting cathode pattern (Watson). Plate, Cadett lightning; development by hydrokinone and metol, subsequently intensified. Distance of tube from plate, 14 to 15 inches. Duration of exposure, seven minutes (much the same result obtained with nine minutes). No precautions taken to restrain respiratory movements.

* *Bristol Medico-Chirurgical Journal*, March, 1897. † *Lancet*, April 30, 1898.

Alsberg* reported a case where the signs and symptoms of renal calculus left the diagnosis doubtful. The rays, however, showed a sharply-defined shadow, 3·5 centimetres long, 2·25 centimetres wide, between 3 and 4 inches above the crest of the ilium. The presence of a smaller group of stones was also disclosed. A large stone weighing over 2 drachms was subsequently taken from the pelvis of the kidney, while from a calyx at the lower end of that organ a collection of seven small stones was removed. The calculi were of oxalate of lime. In this instance not only was a doubtful diagnosis cleared up, but important indications were also afforded to the operator.

The present position of the Röntgen rays in regard to stone in the kidney and the bladder is distinctly encouraging, and may be illustrated by Dr. Blacker's experiences for 1897 in the *x*-Ray Department of St. Thomas's Hospital. 'Among the examinations,' he writes, 'included under the heading of medical and surgical diseases were those of suspected calculus, both renal and vesical. Of the former there were seventeen cases, in eleven of which the result of the examinations was negative, although in one case a very large calculus was subsequently removed, and in another a mass of small calculi; in the remaining six an opinion was given that a calculus was probably present, although in no case could it be definitely stated that one existed, so that it would seem that in no doubtful case is it wise to omit the precaution of an *x*-ray examination. . . . With vesical calculi the stone was clearly defined.'†

The writer has obtained a curious result in a tall stout female patient under his care, who had suffered for many years from an innocent tumour of uncertain diagnosis, apparently connected with the kidney. There were signs of pressure on the gall-bladder, inferior vena cava, and intestines. After many attempts, a diffuse shadow of the tumour showed it to be unconnected with the gall-bladder. At length, with the plate in front of the loin, and an exposure of six minutes with a 12-inch coil, the tube bein 20 inches from the plate, a photograph showing fine detail was obtained. In the absence of the confirmatory evidence afforded by operation, and in view of the great difficulty of interpretation

* *Münchener Med. Wochenschrift*, December 20, 1898.
† 'St. Thomas's Hospital Reports,' vol. xxvi., p. 488.

of the radiogram, the author has determined to postpone publication for the present. The tumour could be felt from the front of the loin.

Mr. Hurry Fenwick applies a specially-constructed fluoroscope to detect the presence of small, deeply-placed stones in the kidney. As a preliminary step, the kidney is brought out on the loin, and the room must be darkened for the screen examination.*

The original of plate 32 was kindly furnished the writer by Mr. Davidson. It shows very clearly a uric acid calculus in the urinary bladder of a living male, twenty-eight years of age. The size of the stone was estimated at 3 to 4 c.m., and its actual diameter when removed by Professor Ogston turned out to be 3·2 cm. The apparatus used was a 10-inch spark coil of Apps. During exposure the patient lay on his belly, and a remarkable print of the scrotum appears on the plate. This phenomenon is attributed by the operator to the moisture of the parts having penetrated the two folds of sateen cloth which covered the plate and moistened the gelatine film so that the cloth slightly adhered to and impressed the film. To obviate similar occurrences, which he had noted more than once, he has since used waterproof paraffined paper for covering the plates. It is open to some question if this interesting phenomenon is quite so easily explained, for warmth, pressure, and electrical action might be one or all involved.

In the foregoing case the patient, as already stated, was on his belly, so that the stone, which lay loose in the bladder, was brought near the plate. The rays were then passed obliquely through the lower outlet of the pelvis, so as to fall obliquely on the recording surface, the tube being placed below the buttocks. In children, and also in suitable cases in adults, a good result can be obtained by placing the focus tube close to the sacrum, with the patient on his face, and taking the photograph through the pelvis.

It seems tolerably certain, then, in the light of what has been already done in this important branch of surgery, that the demonstration of all internal calculi of any size in the adult will sooner or later be within the power of the Röntgen ray operator. At present it is difficult or impossible to obtain any

* *British Medical Journal*, October 16, 1897.


PLATE 32. REDUCED ONE THIRD.

satisfactory results in the case of stout persons, and the operator who undertakes such cases must be prepared for disappointment.

II. BONES

(a) General Remarks

The following experiment was devised by the author with a view of ascertaining to what particular element of bone the Röntgen ray shadow of bone was due. Three small bones were taken from just above the hoof of a sheep; the first was left in its natural condition, the second decalcified by soaking for

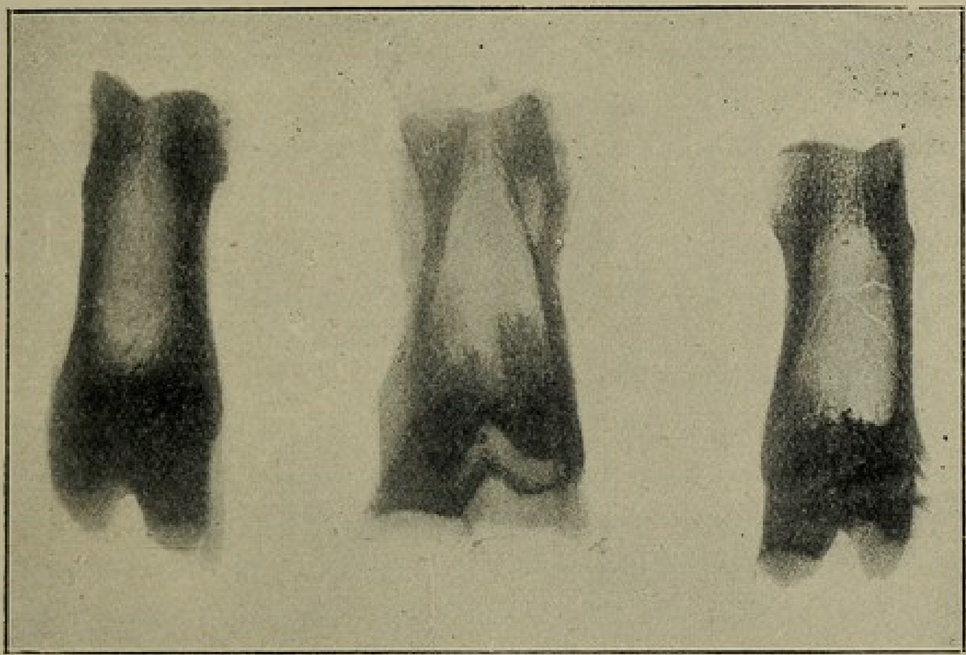


Fig. 51.—Three Small Bones from Foot of Sheep: on Left, Normal; in Centre, Decalcified; on Right, Calcined (and Cracked by the Heat).

several days in dilute hydrochloric acid, and the third calcined in a furnace. The three bones thus prepared were placed side by side on a sensitive plate, and subjected to the rays, with the result reproduced in Fig. 75. The normal bone on the left affords a standard for relative comparison; the centre or decalcified one casts a much fainter shadow; and the calcined one on the right yields a photographic record as dark as the normal bone, but sharper and clearer in detail. It should be noted that the process of decalcification was not completely carried out, so that some of the shadow in the centre bone, especially in its lower portion, is doubtless due to lime salts that have not been entirely removed by the acid. This simple experiment seems to show that the main part of the shadow thrown by bone is due to its contained lime salts.

The opacity of bone to the Röntgen rays is much greater than that of the neighbouring soft tissues—a fact doubtless due to the earthy matters which form three-fourths of osseous structure. This quality enables us, by means of the 'new photography,' to obtain a sharply-defined shadow of most of the bones of the human body. Where the latter lie in a single layer, and the soft parts around are comparatively thin, as in the hand, a record can be quickly obtained upon either the screen or the sensitive plate. But in the pelvis, where the parts are thick and the bones more or less overlapping, the resulting photograph is obscured. In the case of the head, each half of the skull is more or less recorded on the plate, so that a blurred picture of double shadows results. For all that, the surface next the plate is always the more sharply recorded, so that indications of the utmost value are often obtainable from Röntgen ray examinations both of skull and of pelvis.

Bone being relatively opaque to the rays, it follows that any break, whether in continuity or in outline, and any abnormal position in relation to joints, will be readily detected by means of the Röntgen methods. As a matter of fact, not only are fractures and dislocations indicated in this way, but also many other pathological states, such as exostosis, caries, altered density, and the formation of callus. The surgeon, indeed, when called upon to deal with injuries and diseases of bone, will find himself furnished with an entirely new weapon of accurate investigation. Instead of long and painful manipulations, often ending in nothing better than a suspended judgment, he will in many instances be able after an appeal to the rays to give a definite diagnosis and prognosis. Such results, it should be noted, may be obtained without causing the patient a moment's additional pain, and without taking off splints (if non-metallic), bandages, or dressings that may have been applied.

In order to read his results aright, the surgeon should make himself familiar with the radiographic appearances of bone, both in a healthy and in an abnormal state. A workman's hand, injured many years previously in a machine accident, is portrayed in Fig. 53. The hand, it may perhaps be pointed out, is the right, and not the left, as might be at first imagined by anyone unfamiliar with the process. The reason is that the photograph is taken by transmitted and not by reflected light, so that we have on the sensitive plate the record of a shadow, and this is reversed in the process of printing. Owing to non-recognition of this fact by the surgeon, the wrong hand is said to have been actually operated upon. Healthy bone appears as a dark shadow with a more or less well-defined outline, and where it is thinner and more spongy, as in the bosses projecting sideways from the distal ends of the metacarpals, and in the small sesamoid bone below the metacarpo-phalangeal joint of the thumb, the image is fainter. The joints are indicated by clearly-marked light intervals between the bones, where the rays have penetrated the intervening articular cartilages.

A point worthy of passing notice is that the sesamoid bones of the hand often show as well-defined spots, the size of small shot, through the distal portions of one or more of the metacarpal bones. In that position they have been mistaken at times for a pathological condition. The sesamoid over the metacarpo-phalangeal joint of the thumb is usually taken in profile, and, falling clear of the thumb-bones, presents a sharp picture. Dr. Clendinnen, of Melbourne, has published a Röntgen photograph of the mummied hand of a nobleman's wife, aged twenty-five years, entombed at Memphis B.C. 1500.* No less than five sesamoid bones are shown—one over each of the metacarpo-phalangeal joints of the index and little fingers, two at the metacarpo-phalangeal joint of the thumb, and one over the ungual phalanx of the thumb. As to the last-mentioned, Professor Allen states that he has never found or heard of a similar abnormality in modern skeletons. A number of instances of the kind, however, have been collected and brought to the writer's notice by Mr. Frederic Fenton.

As to the abnormal hand, Fig. 53, the reader will do well to study it carefully in detail. The phalanges of the three remaining fingers are enlarged and dark, while the usual gaps between the end joints of the middle and ring digits have disappeared. The most likely reading of these recorded facts is that the fingers

* *Intercolonial Medical Journal of Australasia*, February 20, 1898, p. 106.

have been affected with chronic osteo-arthropathy, which has enlarged the bones and obscured or obliterated some of the joints. As regards pathological conditions, the following appear to be probable :

1. Old greenstick fracture (thumb metacarpal).
2. Malunited fracture (right angle, second metacarpal).
3. False joint (this may possibly be bony union ; third metacarpal).
4. Impacted fracture (bony union, fourth metacarpal shaft).
5. New articulation (fourth metacarpal base).
6. Bony anchylosis (distal end fifth metacarpal and first phalanx of fourth).
7. Fibrous and partially osseous anchylosis (base fourth and fifth metacarpals).
8. Dislocation (multiple, carpus).
9. Compensatory curving of bones (twisted index-finger).
10. Bone hypertrophy (various bones).
11. Obliterated joint (terminal joints second and third fingers).
12. Arrested development of distal epiphysis of first phalanx of middle and ring fingers.

One or two of the above explanations, especially in the absence of a careful examination of the hand itself, are perhaps somewhat open to an alternative reading.

(*b*) Fractures and Dislocations*

It is in these injuries, especially when obscure, that the Röntgen methods render invaluable and often brilliant results. For example, they are available when the surrounding parts are too swollen to admit of examination by ordinary methods, or when the manipulations of the surgeon cannot be borne by the patient.

The objection has been made by some surgeons that the rays reveal nothing that could not be equally well learnt by other methods. To this it may be answered that not a few bone injuries occur in which it is impossible for any man, however skilful, to make an exact diagnosis—at one time, it may be, owing to the swelling and tenderness of parts, and at another to the

* This section has been kindly revised by Mr. Lynn Thomas, F.R.C.S., of Cardiff.

obscurity of the signs. Under such adverse circumstances precise evidence may be obtainable forthwith from the Röntgen screen or photograph. Moreover, the gain of this particular form of investigation does not end with recovery. In cases of accident likely to come before a jury, the proof afforded by a photographic record of a bone condition may one day win a civil action, or vindicate the scientific reputation of the medical attendant, two points that will be referred to again under the heading of jurisprudence. Further, if the progress of a fracture be unsatisfactory, the surgeon can hardly be doing his duty either to himself or to his patient if he neglect the possible assistance to be gained from a Röntgen photograph. Some medical men scout the idea of calling in the services of a professional photographer to help them in arriving at a diagnosis. If that line of reasoning were sound, it would equally prevent physicians from weighing a patient because the scaling chair is the work of a professional balance-maker. In a similar way it would preclude them from sending throat secretions to a biological laboratory to be tested for the presence of the diphtheria bacillus, or from using the microscope, the stethoscope, the phonendoscope, and the rest of the hundred and one aids to accurate investigation sold by the instrument-makers.

The surgeon should bear in mind that iodoform, bismuth, and some other metallic dressings are opaque to the rays, as well as lead lotion and the various kinds of adhesive plaster that have a lead basis; but we have it on the testimony of the medical department of the Soudan Expedition that, although such effects injure photographic results, they do not seriously impair the evidence afforded to the surgeon.

Splints made of felt, pasteboard or wood are translucent, while those made of metals, except aluminium, are of course opaque. Plaster of Paris is dense, but a photographic record can be obtained through such a splint by using a focus tube of high penetration; in which case the resulting photograph is apt to be mottled and patchy, owing to the varying thickness of the plaster. A good substitute for plaster is the handy 'water-glass' or silicate of sodium splint, which is translucent to the rays, and may be used conveniently where it is intended to take a Röntgen photograph during the progress of any particular case.

Nowhere is the necessity for comparative photographs more evident than in the case of obscure fractures. A slight peculiarity of the individual bone may be exaggerated into a pathological guise by the peculiar relative position of the tube, by the rays falling obliquely on the plate, or by an awkward attitude of the patient. In one case of alleged old-standing fracture of

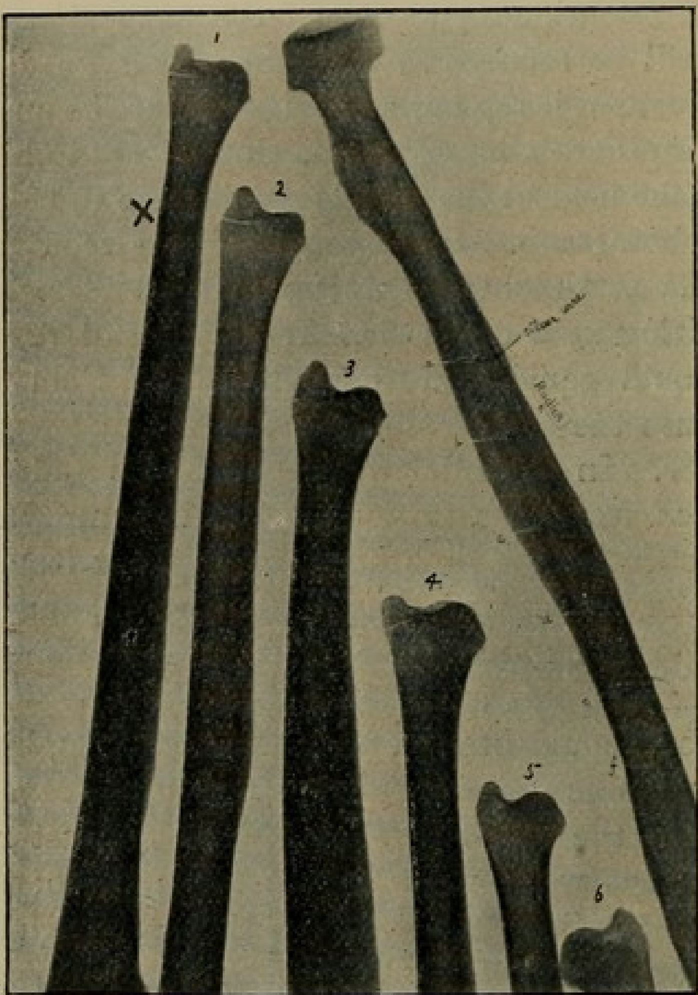


FIG. 52.—LYNN THOMAS'S DISTORTION EXPERIMENT.

(Six specimens of ulnæ with the bases of their styloid processes sawn through, but not detached, with a fret-saw. On the right is a radius with six fissures, made by the same fret-saw, through its ulnar margin.)

the external condyle of the humerus, the reading of the Röntgen photograph itself, without another of the sound elbow taken under similar conditions, became a matter of pure conjecture.

A fracture may not be shown on the plate because the x-rays have not hit the gap in the bone in their straight passage from the anti-kathode to the sensitive plate. Then the break itself may be oblique, and thus interpose overlapping edges of bone

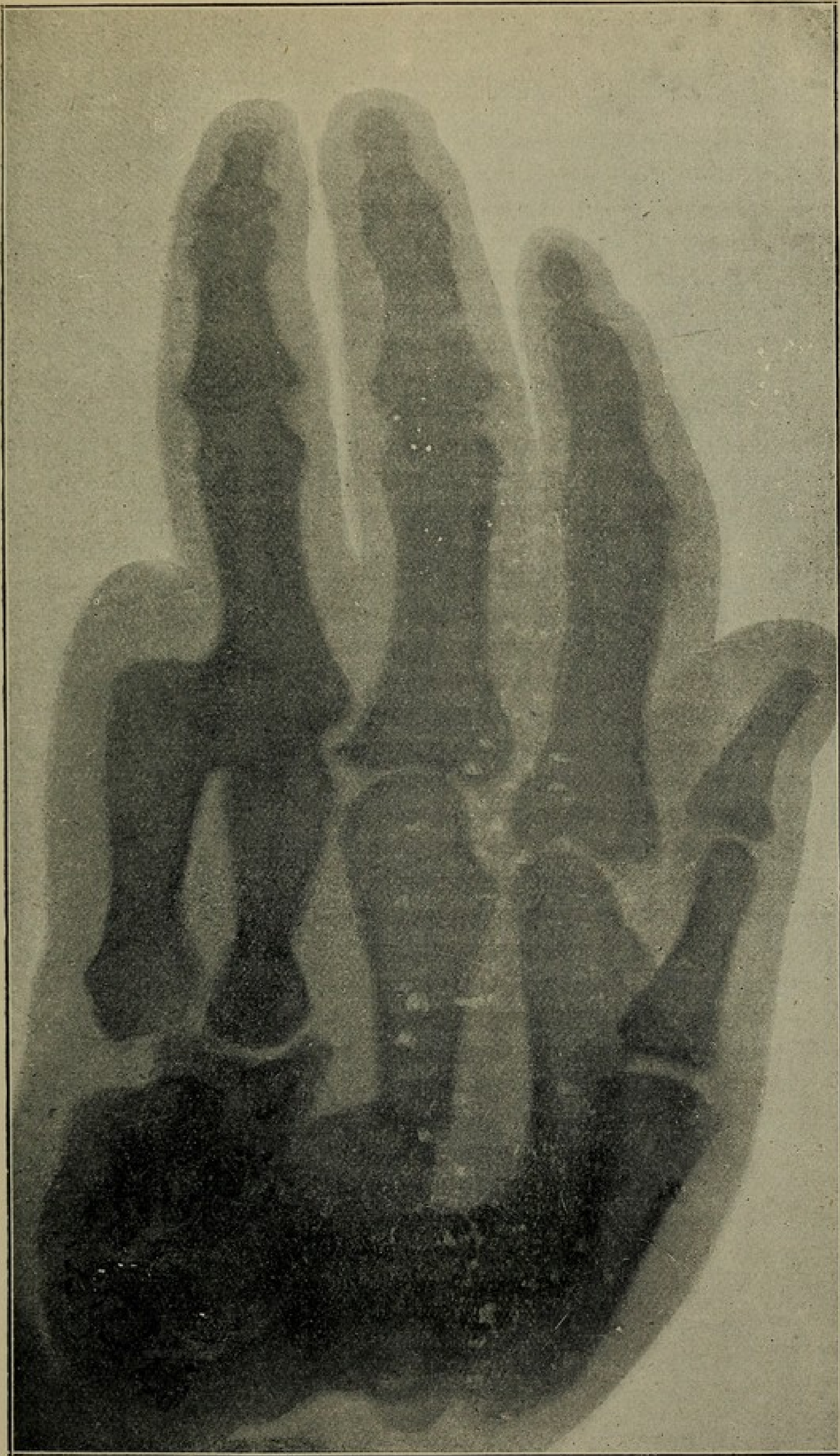


Fig. 53.—Injured Right Hand of Workman.
By Mr. Greenhill.

between the source of the rays and the photographic surface. Mr. Lynn Thomas described an instructive experiment at a meeting of the Röntgen Society, May 1, 1899. He made parallel saw-cuts through the styloid processes of several ulnæ, and several more cuts into a radius. The anti-kathode was fixed by means of a plumb-line directly over the second ulna, counting from the top downwards (see Fig. 52). The long axis of the tube ran parallel to the radius shown in the illustration. The latter bone was also incised with a saw, and loops of wire twisted from the bottom of each saw-cut round the sound part of the shaft. The result is striking. The two upper cuts in the ulnæ show as unmistakable gaps. The next is less complete; while in the lowest one no change is visible in the bony substance. At the same time progressive distortion is shown in the shape of the ends of the ulnæ. The radial incisions become more and more V-shaped from above downwards, and the wire loops more and more oval.

The anti-kathode of the focus tube on the Röntgen lamp was placed over the point X—*i.e.*, perpendicular to the base of the styloid process of No. 2 ulna.

It will be observed that the fissure is more or less obscured by the shadow of the edges of the crack as we advance towards No. 6. If we add, in fancy, the shadow cast by the soft tissues upon this photograph, I feel quite sure that no unbiassed radiographer would accept the evidence as indicating a fracture. The different ulnæ have different density to the x-rays, owing to the different ages and sexes from which they were obtained.

In the radius we have a good example of the distortion a straight crack or fissure is liable to undergo by the position of the anti-kathode. The density of the adjacent edges of the compact bone of the radius—which, by the way, is nearly triangular in shape at the line of the fret-saws—is enough to allow a photograph of the two surfaces of the fissure—*i.e.*, the one next the plate and the one next the Röntgen lamp—to appear distinctly. The result is a V-shaped light line with limbs of varying lengths. The angle of the V, as well as the limb of the V which is caused by the shadow of the crack furthest away from the plate, can be increased or diminished according to the operator's wish, or converted into a straight line.

This experiment clearly shows the confusion and distortion due to varying relative positions of object of tube and of plate. It strengthens Mr. Lynn Thomas's plea for a standard point in the centre of the wrist in examining injuries of that region. At the same time it must be borne in mind that the break is not always in the nature of a vertical separation, but often runs obliquely. The only trustworthy way of examining for fracture is by the use in the first place of the screen at various angles. This fact can be verified by five minutes' careful examination of an old Colles' fracture. By moving the arms up and down and from side to side the injury and the shape of the bones may be made to assume a variety of appearances.

It seems likely that the Röntgen rays will help towards a truer conception of what really takes place in some particular injuries, such as Colles' fracture of the lower end of the radius (see Figs. 56, 57, 58).

Of late a good deal has been heard of the practice of wiring recent fractures, such as those of the olecranon, lower end of fibula, patella, and of other bony parts where union is commonly delayed or vicious. Under the conditions of modern surgery the plan appears to offer in many cases a good prospect of securing rapid and bony union. It need hardly be added that the procedure consists in cutting down under antiseptic or aseptic precautions upon the broken ends, which are then drilled obliquely and brought together by stout silver wire. In this particular class of cases the surgeon will learn from the rays—(1) whether wiring is advisable, (2) whether proper apposition has been secured, (3) whether bony union has followed.

The plan of 'nailing' recent fractures of the condyles of the humerus, or of a loose fragment of bone, as advocated by some surgeons, would in many instances be hardly feasible without a clear knowledge of the condition of the broken bone, gained from a screen examination or a radiogram. In the method of treating false joints or malunited fractures by 'Lane's screws,' a Röntgen photograph is of the utmost value in assisting the surgeon to determine before operation the exact length of the screw required in each particular case. By uniting fractures of the leg-bones (such as Pott's) by screws that are too long, serious damage can be inflicted on nerves or bloodvessels unless the surgeon avails himself of the aid of the x-rays. The accompanying figure (54) shows that the screw used was of the right length

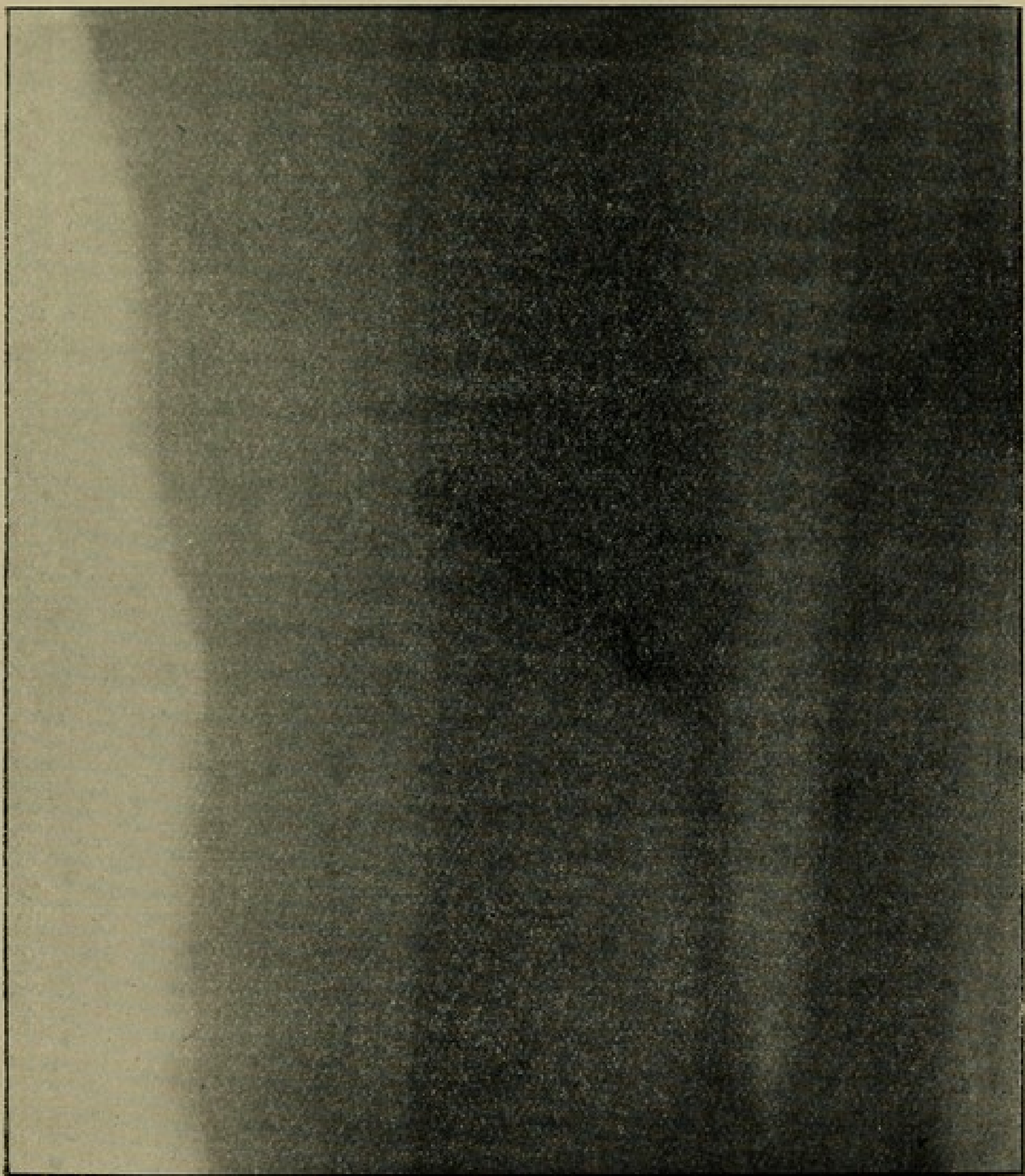


Fig. 54.—Lane's Screw in Tibia. The uneven outline is due to the bandages.

Mr. Lynn Thomas.

and that the mechanical adaptation of the tibial fragments was satisfactory. Some of the remarks made about 'screwing' apply also to 'wiring' and 'nailing.' Again, the 'screwing' on of a loose fragment offers a promising field for treatment. An excellent case in which sound union of a fractured olecranon was secured in this way was published by Mr. Thomas Moore, F.R.C.S.*

Where a fracture is attended by such complications as impaction, comminution, multiplicity, interposed tissues, extension into a joint, or dislocation, Röntgen methods afford most useful information. The practical value of the method, however, extends beyond diagnosis, for by further investigation it can be ascertained whether the bones have been reduced to proper position, and whether sound bony union has followed. The progress of a fracture can be followed readily enough when the splints and dressings are translucent to the rays. If it be desired to make periodical examinations through a fixed apparatus, the splints, as already stated, must be made of some penetrable material. The separation of epiphyses, or the so-called 'fracture through epiphyses,' a subject of great importance in surgery, will be dealt with in a separate section (see p. 152).

Where a fracture has ended in fibrous union, false joint, or other imperfect result, the exact state of affairs can, with one or two exceptions, be readily found out by the radiogram. A similar remark applies to a stiff joint after dislocation or other injury. In all these cases important indications may be gained as to the appropriate form of treatment, whether by resection, osteotomy, wiring, refracture, or the breaking down of adhesions.

The exceptions above referred to are chiefly those of fracture or dislocation, or both together, about the shoulder or the hip. In each case an antero-posterior view may be obtained, but a lateral view is rarely of any use, owing to the multiple shadows of superimposed bones. Thus, the absence of the bone from its socket can as a rule be readily demonstrated, but no lateral record is available to show whither it has gone. Under these circumstances, we fall back upon our exact localizing processes, and by a double photograph determine the exact position of the displaced bone.

The diagnostic application of the x-rays, it may be observed, is likely to do away with much of the time-honoured business of

* *Archives of the Röntgen Ray*, July, 1897.

the bone-setters. As Mr. Howard Marsh and others have pointed out, the greatest successes of those irregular practitioners have been scored in nine cases out of ten by the forcible rupturing of arthritic bands. It is now open to everyone to put to an absolute test by means of the Röntgen rays the bone-setter's stock assertions that 'the joint is out of place' or 'the bone not properly set.' In this unexpected way, it is interesting to note, science has cut away the ground from under the feet of the charlatan. Professor Röntgen's discovery has thus dealt the bone-setter a deadly blow that ages of scientific protest have failed to accomplish.

A curious condition of affairs is shown in Fig. 55. The original was taken by Mr. Gerard Peck, of Scarborough, and kindly placed at the writer's disposal. The patient was a woman sixty-two years of age, who injured her arm by a fall. Pain was felt at the time, but, curiously enough, the fracture was not detected for some months. The patient was dressed by her daughter, and is reported not to have noticed the deformity until she one day saw it reflected in a mirror.

The photograph was taken with a Tesla set capable of giving a 2-inch spark, and an exposure of two minutes. It reveals a fracture of the lower end of the forearm, united at an extreme angle, with a V-shaped forward bend.

An instance of the value of the diagnosis of adhesions is afforded by the case of a patient who suffered from a locked wrist, and the radiogram showed there was no disease of bones. This result pointed by a process of exclusion to the presence of interarticular bands, and indicated a successful line of treatment.

To sum up: in dealing with bone injuries successful radiography, compared with previous methods, offers the following advantages: It substitutes speed, accuracy, and finality, for delay and doubt; it affords exact evidence that may confirm or modify the diagnosis of the surgeon; it may furnish both grounds for prognosis and hints for treatment; it may save the patient the pain of useless, and perhaps, dangerous, manipulations, as well as the shock of anæsthetics; it provides a permanent record of the precise nature of an injury; it may prove a safeguard for the patient and for his medical attendant, both in the present and the future; and, lastly, it can hardly fail to be of value for teaching purposes.

Fig. 55.—Fracture of Humerus united with a Forward V-shaped Bend.
By Mr. Gerard Peck, Scarborough. Natural size.

(In taking the original of the above block, the apparatus broke down after two minutes' exposure. The picture, however, proves how a readable record can sometimes be procured under adverse circumstances, as it was taken in the days of long exposures.)

Special Fractures

Fractures of the scapula that may be detected by ordinary manipulation need not be considered here. Sometimes, however, an injury of the kind is exceedingly obscure, in which case a Röntgen ray examination might disclose its real nature. For

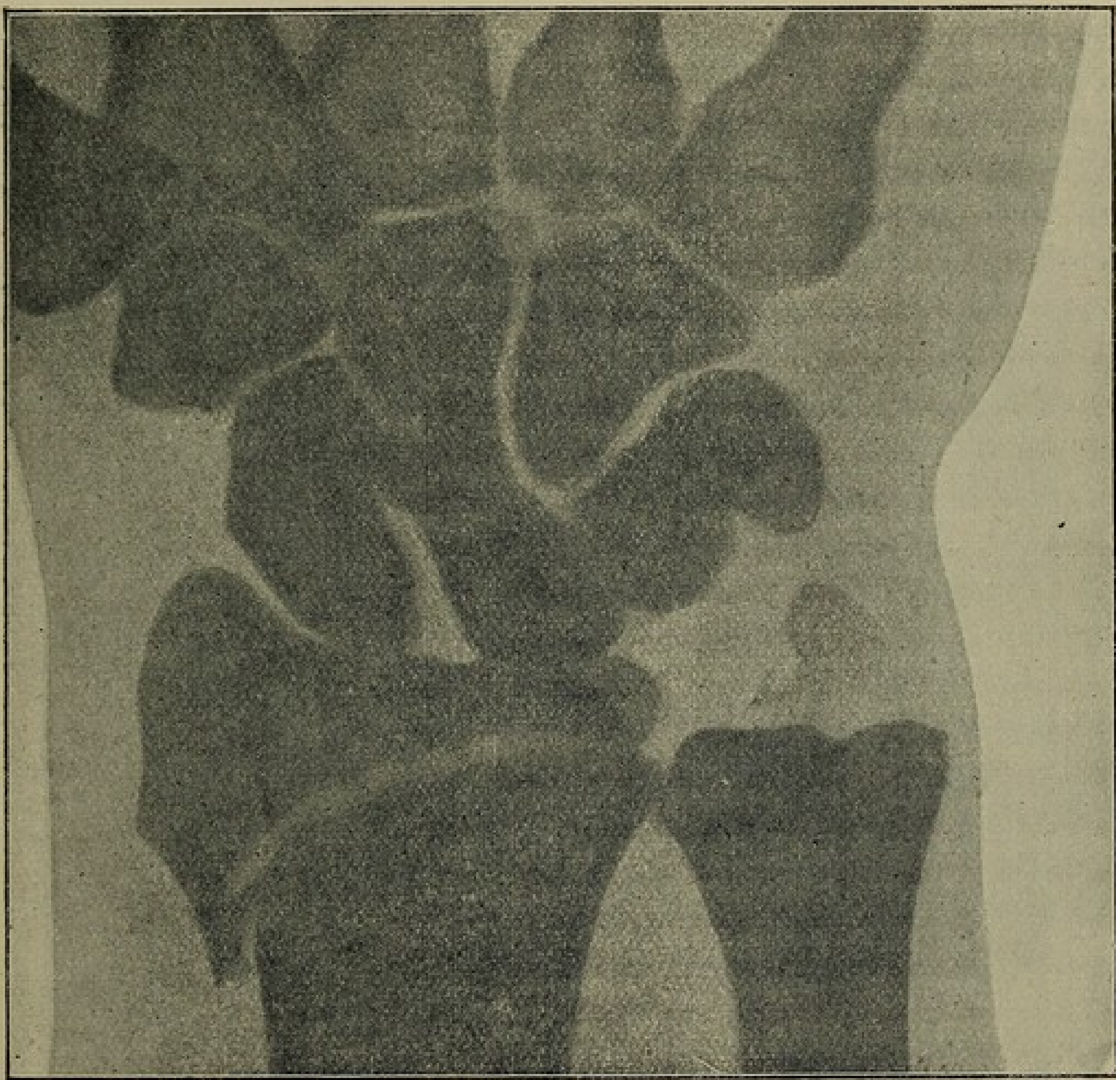


FIG. 56.—DOUBLE COLLES' FRACTURE SHOWING ORDINARY FRACTURE OF RADIUS WITH OUTWARD DISPLACEMENT, AND FRACTURE OF STYLOID PROCESS OF ULNA. Mr. Lynn Thomas. Natural size ; see also Fig. 57.

instance, it would be difficult or impossible in any other way to diagnose the rare fracture of the glenoid cavity from dislocation of the head of the humerus or fracture of its anatomical neck.

Fractures of the collar-bone can be readily shown by the rays but as a rule there is little information to be gained in that way that could not be acquired by simpler methods of examination.

An exception may perhaps be made in the case of the break without displacement that sometimes occurs between the attachments of the conoid and the trapezoid ligaments. Such a case was reported by Dr. Richardson:* 'A football-player of nineteen injured his left shoulder. Six hours after the accident tenderness was found at the outer end of the clavicle, but neither crepitus nor deformity was to be made out. The Röntgen rays showed a

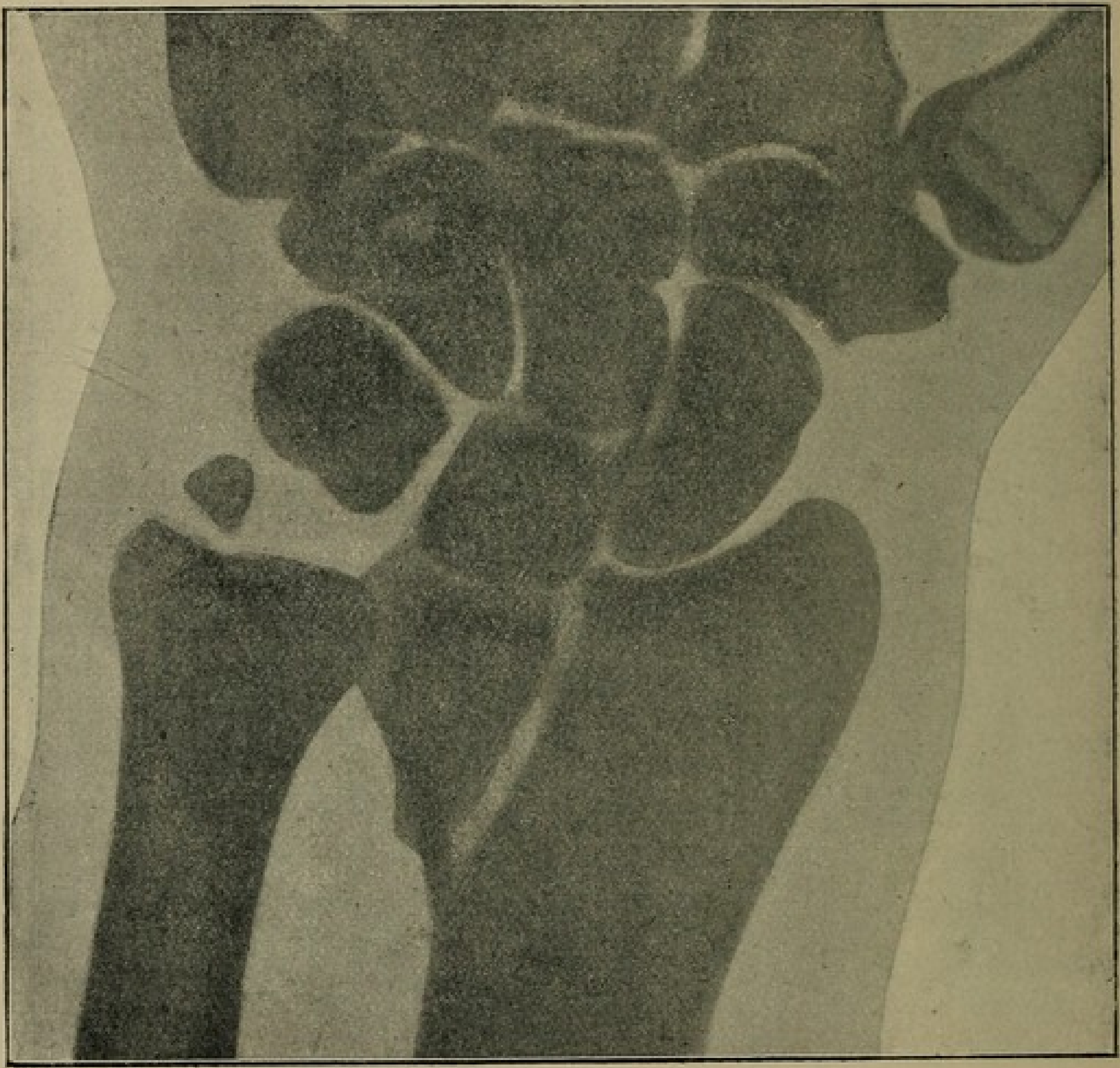


FIG. 57.—DOUBLE COLLES' FRACTURE SHOWING LONGITUDINAL FRACTURE OF RADIUS WITH SLIGHT IMPACTION, AND FRACTURE OF STYLOID PROCESS OF ULNA.

solution of continuity at the point of tenderness, where a week later callus appeared.'

Fracture of the Humerus.—This bone is readily photographed throughout its length by the Röntgen methods, which are of special

* *Boston Medical News*, December 26, 1896.

value in determining the nature of obscure injuries at its upper and lower ends. The exact diagnosis of fractures about the head, as every surgeon knows, is often attended with great, if not insuperable, difficulty, especially when there is much swelling. Incomplete separation of the head of the humerus at its junction with the shaft has been reported in cases that had been regarded as sprains before the Röntgen examination, and it seems not unlikely that such injuries may prove less rare than has been hitherto suspected. So, too, fissures due to direct violence have

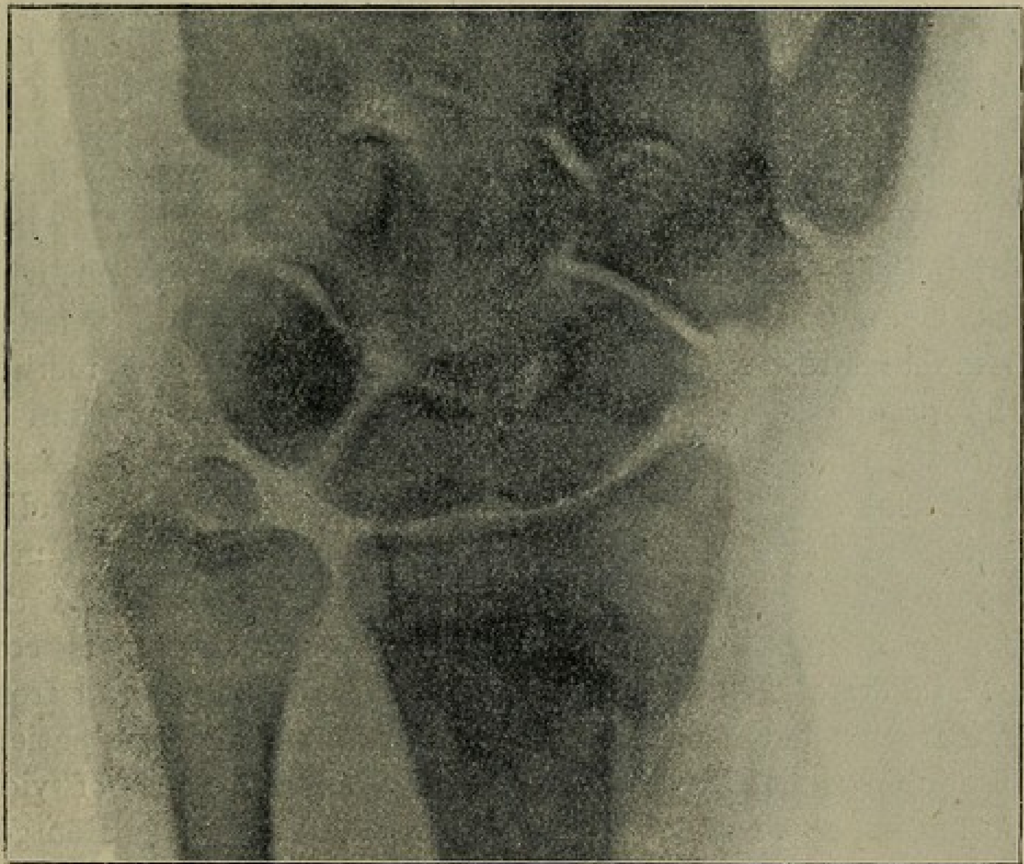


Fig. 58.—Colles' Fracture, with Rupture of Radio-ulnar Ligament.

often been observed in cases which, were it not for the Röntgen rays, would have been classified as bruising of the soft tissues. In a case under Mr. Lynn Thomas, a comminuted fracture of the surgical neck, it would formerly have been impossible to make out the precise nature of injury.

Fractures about the elbow are often attended with such rapid swelling that, unless seen at once, it is in many instances impossible to ascertain the extent of the injury for several days. Indeed, it is hardly too much to say that under such circumstances a Röntgen photograph of the swollen elbow is absolutely the only means of exact diagnosis at the command of the surgeon, who may in this way save much valuable time and anxiety. For instance, the damage may be of such a kind as to demand prompt excision. In any event, the *x*-rays will indicate whether the line of fracture at the lower end of the humerus is (*a*) transverse, (*b*) T-shaped, (*c*) through condyles, (*d*) through epiphyses, and whether it is complicated by (*e*) dislocation or (*f*) fracture of the olecranon. In this way the surgeon can inform the patient forthwith as to the probable duration and result of treatment. Moreover, from the knowledge gained as to whether the fracture is extra- or intra-capsular, he will know exactly when to begin and when to avoid early passive movements. Thus, if the break be transverse, above the capsule, such exercise can be delayed for a month or more, 'as there is then no danger of a stiff joint, but a risk of the passive movements at the seat of fracture leading to a false joint' (Walsham). Other authorities would, however, with Lucas Championière,* advocate immediate massage, together with mobilization. Indeed, the advantages of the new method to the practical surgeon are nowhere more apparent than in obscure injuries to the elbow-joint.

Fractures about the middle of the forearm are readily accessible to the rays, the information derived from which may be applied upon general principles. However, so far as the pathology of fracture of the lower end of the radius is concerned, the method has already demonstrated a number of fresh facts. Mr. Thomas† published the instructive case of a patient with double Colles' fracture. From a clinical point of view the lesion appeared to be identical on both sides, but the Röntgen photographs showed a wide difference in the bone injuries. In each the styloid process of the ulna was fractured at its base, an event usually described by surgical authorities as somewhat rare. One wrist (Fig. 56) showed the ordinary fracture of the lower end of the radius, with outward displacement; the other (Fig. 57) slight impaction of the radius about three-quarters of an inch from its lower end, to be detected by noticing the irregularity on the ulnar side of the bone. By the side of and near that projection is a 'complete longitudinal single fracture of the lower end of the radius, showing a detached portion of a triangular shape in its

* 'Traitement des Fractures par le Massage et la Mobilisation,' 1895.
† *British Medical Journal*, January 2, 1897.

normal position attached to the radio-ulnar ligament.' In a later communication to the same journal, the author expressed an opinion that 'the true pathology of one of the commonest of fractures (*i.e.*, Colles') requires rewriting in the leading surgical text-books in the English language.' In 1899, thanks to the *x*-rays, one can state that fracture of the ulnar styloid process usually accompanies injuries to the radius in Colles' fracture.

Mr. Thomas has placed a third record (Fig. 58) at the disposal

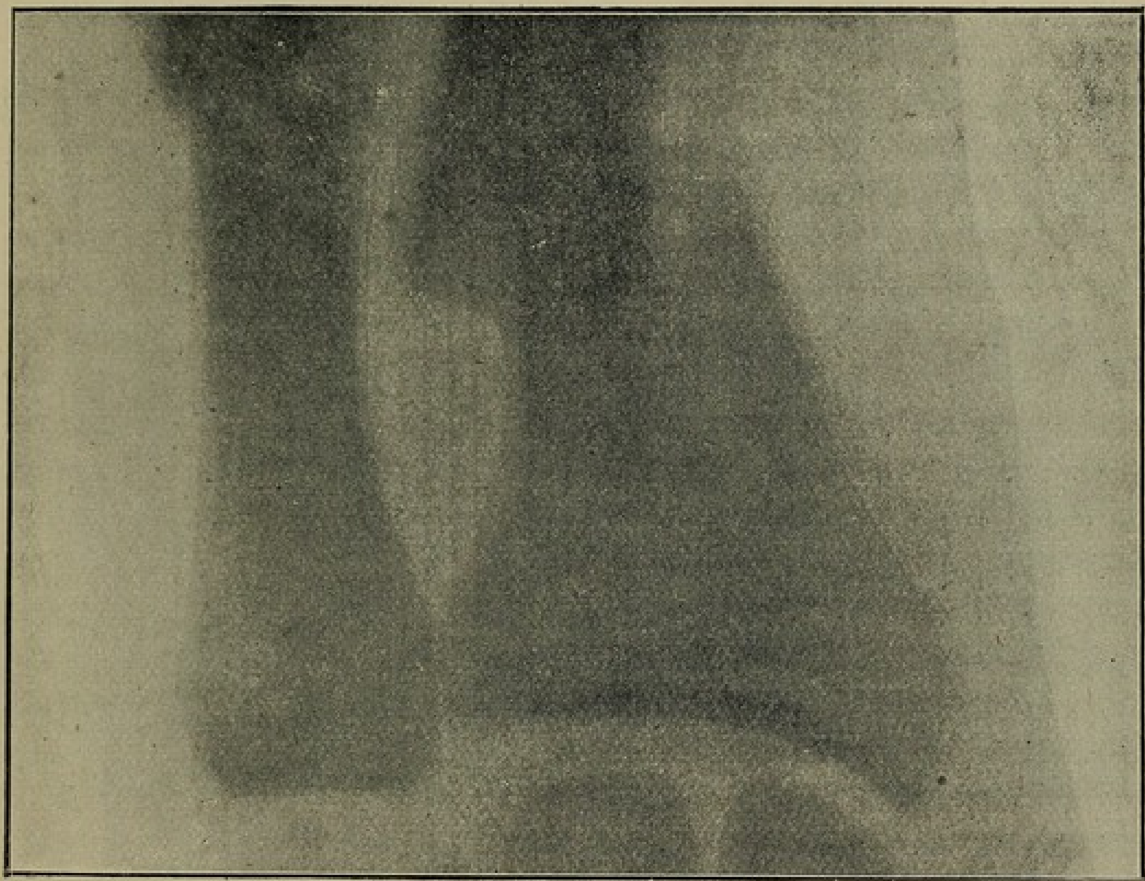


Fig. 59.—Double Fracture of Forearm, showing Displacement; Grain of Wooden Splint plainly shown.

of the writer. In his opinion, this illustrates the rupture of the radio-ulnar ligament described by Mr. Clement Lucas in Guy's Hospital Reports for 1884.

The illustrations shown in Figs. 59 and 60 furnish a good example both of fractured forearm and also of the service that the Röntgen rays can at times afford in surgical practice. They were taken from a restless and muscular young man, eighteen years of age, under the care of Mr. Jonathan Hutchinson, junior, at the London Hospital. The patient presented himself with a broken arm, which had been put up in splints a few days before at another institution, and which he imagined was not going on well. A Röntgen photograph, not here reproduced, proved double fracture, with both bones in perfect alignment. When he returned a week later, the rays revealed considerable displacement (Fig. 59).* The broken bones were thereupon readjusted,

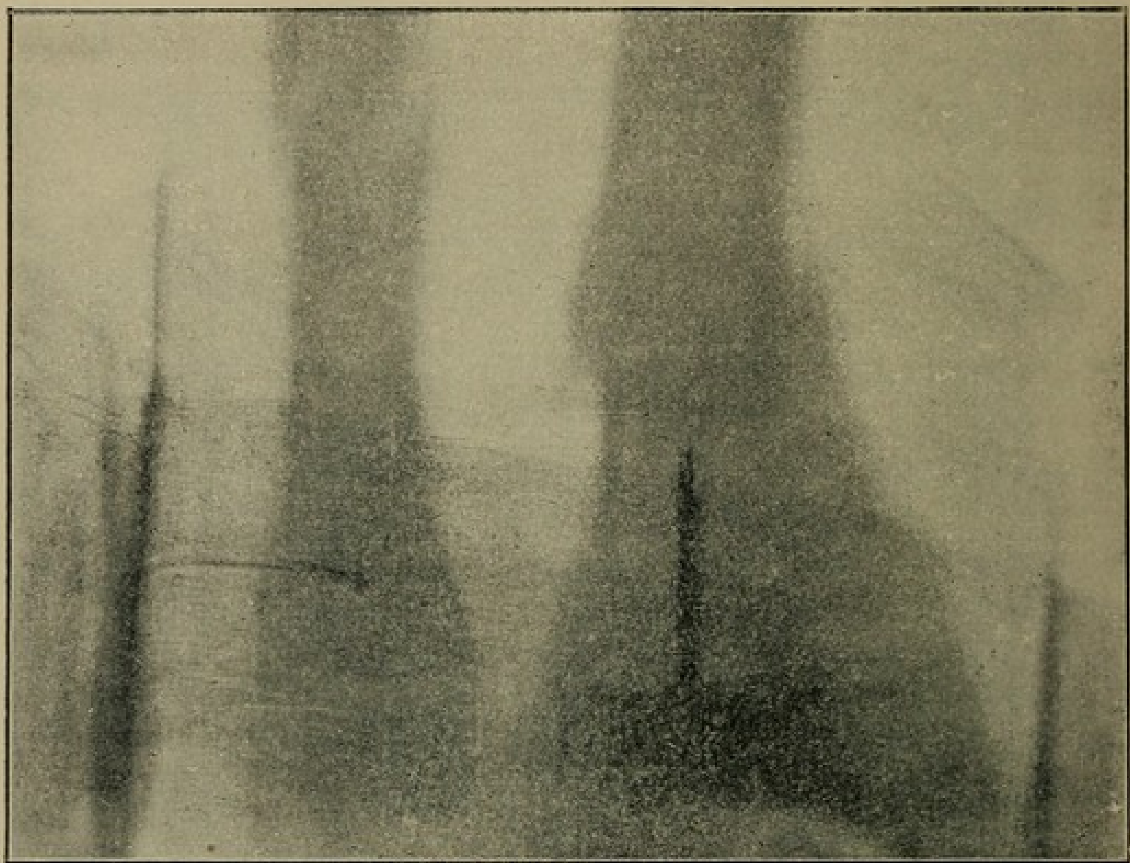


FIG. 60.—DOUBLE FRACTURE OF FOREARM, SHOWING DISPLACEMENT. The dark shadow athwart the lower fragments is due to adhesive plaster. Mr. Greenhill.

but at the end of another week the fragments were again found to be overriding (Fig. 60). The limb was reset, and ten days later the x-ray record showed union in good position, almost, but not quite, equal to that demonstrated in the first photograph.

In the after-treatment of a restless patient, then, the Röntgen methods may prove of constant value. Even if the results of such an examination be negative, no harm will have been done,

* The photographs were taken through splints and clothing. In the first the grain of the wooden splint can be traced.

as it can be conducted without taking off a single splint, dressing, or garment. By availing himself of its aid, the surgeon may possibly avoid consequences dangerous alike to the welfare of his patient and to his own reputation.

Destot* has described fractures of the scaphoid, os magnum, and styloid process of the ulna, associated or not with fractures of the radius. Of the latter, he has identified with the fluoroscope three chief types: (1) The epiphysis is entirely detached, and, strictly speaking, there is no interarticular fracture. (2) The fragment is wedge-shaped at the expense of the posterior aspect of the radius, the front of which retains its position. This type shows many varieties, as when the fragments are multiple or displaced from without inwards, when the fissure extends higher or lower, involving the posterior lip only, or the epiphysis only. Special attention was drawn to this particular kind of fracture in the pre-Röntgen-rays day by Dr. Rhea Barton in 1838,† and Hamilton, in his treatise on Fractures and Dislocations, designates it 'Barton's fracture' in contradistinction to a Colles' fracture. It is interesting to observe that many pathological conditions of bone lesions, which were hitherto known only to a few experts, have been again prominently brought before the notice of the profession from observations made by means of the *x*-rays. It is always advisable to radiograph obscure bone injuries, and not to trust the fluoroscope alone, because the former method will record what the eye cannot see in the latter: the one is like counting the stars of the Pleiades with the naked eye, and afterwards comparing notes with a photograph of the same region. (3) The anterior and posterior lips are broken off, and the shaft penetrates them, separating the one from the other, the bones being all more or less comminuted and more or less displaced on the outer side.

Destot points out several possible fallacies connected with the examination of the wrist. The shadows of the bones do not exactly correspond with the appearance on a skeleton; one may confuse a dislocation of the first row of carpal bones with a fracture of the os magnum. The scaphoid, instead of being boat-shaped, may present a globular form, crossed by a shadow, and due to a subluxation. Fracture is present only when a clear space separates the two fragments.

* 'Radioscopie Clinique,' Régnier, p. 54.
† *Philadelphia Medical Examiner*, 1838.

Fractures of the hand can be readily demonstrated by means of the Röntgen rays. A break of the fourth metacarpal, not an uncommon injury, is sometimes difficult to diagnose by ordinary methods. An *x*-ray examination would at once reveal an injury of that kind, and has often disclosed simple longitudinal fissures in bones said to have been bruised. In the case of the Poor Law Medical Officer, who is paid on a higher scale for attending fractures, the possibility of proving the existence of such obscure injuries presents a distinct economical advantage. To a less extent a similar remark applies to all who are engaged in surgical practice, whether special or general.

The illustration portrayed in Fig. 61 shows the results of a cogwheel accident fourteen years previously. The metacarpal bone of the forefinger has been apparently broken into two main pieces, which lie at a cross-angle of about thirty degrees. The irregular shape of the lower fragment probably results from chronic periostitis and osteitis following the injury. Between the two fragments there appears to be a kind of false joint. The middle joint of the forefinger is partly obliterated by what seems like bony union. The sesamoid bone opposite the distal end of the thumb metacarpal has apparently become united to the latter by a more or less ossified ligament. The original photograph, kindly lent to the writer by Dr. J. R. Philpots, of Parkstone, shows some good records of muscles and other soft structures. Thus, in the outer side of the little finger metacarpal may be traced the abductor and flexor brevis muscles. On the outer side of the middle joints of the second and third fingers are what appear to be the lateral expansions of the common extensor of the digits. Along the back of the bones of the metacarpal and phalanges of the thumb the extensor tendons can be clearly traced. The tendon of the extensor secundi internodii, indeed, can be followed up to its insertion at the base of the terminal phalanx. Unfortunately, most of these results are lost in reproduction.

In fractures about the pelvis the Röntgen rays, so far as one can judge, are not likely to help the surgeon much. The hip, again, is deeply placed, and so far satisfactory results are not always attainable. However, much is often to be learnt in the case of children and young adults, in one case a fracture of the neck of the femur was shown in a muscular adult, six feet in

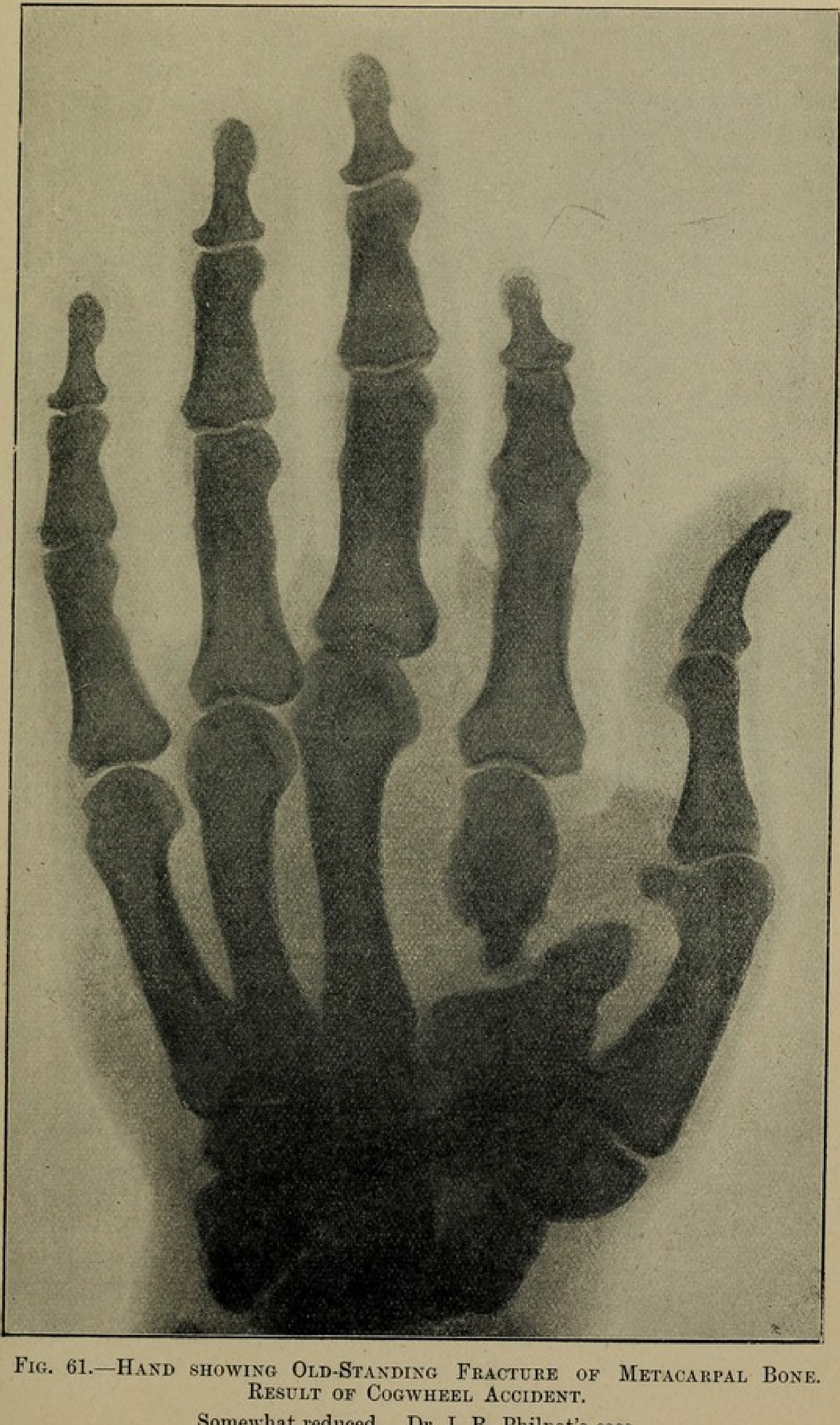


Fig. 61.—Hand showing Old-Standing Fracture of Metacarpal Bone. Result of Cogwheel Accident.

Somewhat reduced. Dr. J. R. Philpot's case.

height. It will be wise to try and secure a record of impacted intracapsular fracture of the hip, because of its frequent after-shortening, which may be attributed by patients to unskilful treatment. Under such circumstances a differential photograph, showing an alteration in form or relation of the injured side, might be of the utmost value to the medical attendant.

Coxa Vara.—Mr. Lynn Thomas has communicated the case of a young man aged about eighteen who injured his hip in playing football. From an examination of his signs and symptoms, some months after the original injury, he would have concluded that absorption was taking place of the head of the bone, most likely after impaction into it of the neck. An examination by the *x*-rays, however, showed the bending of the neck of the femur to be one of coxa vara. It is waste of time to try and radiograph the hip in adults if one does not possess a 'hard tube.'

In extracapsular fracture of the hip the rays may show conclusively whether the neck of the bone is impacted or not in the great trochanter, especially when a comparison is made with a photograph of the sound side. The knowledge thus gained, whether negative or positive, could not fail to be helpful to treatment, inasmuch as extension is contra-indicated in the impacted variety. Moreover, it would guide the prognosis as to permanent shortening and stiffness of the joint. Generally speaking, a fracture can be readily enough demonstrated by the Röntgen rays in all parts below the hip.

In fractures of the shaft of the femur the value of the radiograph will lie chiefly in its evidence as to the proper setting and subsequent union of the broken ends.

In fractures of the lower end of the thigh-bone *x*-rays are likely to be more useful. Injuries about the knee are apt to cause rapid swelling in and around the joint, so that a thorough examination by ordinary methods is out of the question. Then it is that a confident appeal may be made to the Röntgen method. Without taking off a splint or dressing, we may expect to ascertain one or more of the following conditions: (*a*) line of fracture, whether oblique, transverse, comminuted, T-shaped; (*b*) implication or otherwise of joint; (*c*) separation of epiphysis.

Fracture of Patella, or Kneecap.—Unless the patient be seen at once after this accident, the parts often become so swollen that it is impossible to diagnose the injury. For the investigation of such a case the Röntgen rays are specially adapted. They will reveal not only complete fractures, but also incomplete, —that is to say, where the starred or fissured fragments are kept in position by the aponeurosis. As regards after-treatment, the surgeon will be able by means of a radiograph to determine whether his methods have brought the patellar fragments into good position. Here, too, the results of wiring can be closely followed.

Some years before the introduction of the Röntgen methods the following case came under the notice of the present writer: A patient injured her knee. The medical man who was called in diagnosed dislocation of the semilunar cartilage. A few months later, the joint being stiff, another surgeon administered chloroform and flexed the limb in order to break down adhesions. After this procedure the knee-cap was found broken. The contention of the second surgeon was that the first examination failed to detect an incomplete fracture, which his subsequent manipulation had rendered complete. Wherever the truth lay in that particular instance, it is clear that the medical man first in attendance would have been in a very different position had it been possible to secure the evidence of a Röntgen photograph. Recently at a society two photographs were exhibited of a patella, the day before and the day after its fracture. The facts of the case did not transpire generally, but it may be stated that the first picture, showing the unbroken bone, was the result of an exposure taken for purposes of diagnosis in a stiff knee. Inter-articular adhesions were clearly demonstrated (by exclusion) to be the cause. Forcible flexion led to the subsequent fracture of the knee-pan. The resemblances and the contrast between these two cases are not a little suggestive and striking.

In fractures of the leg, when either the tibia or the fibula is alone broken, the diagnosis, as every practical surgeon knows, is often extremely difficult. Indeed, if there be much swelling, it is in many instances impossible to determine whether the injury is a fracture or merely a sprain. Any such doubt, however, could be speedily cleared away by the rays. The most conservative of surgeons will hardly deny that the ability to settle such a point must constitute a solid advance in practice.

When both bones of the leg are broken, the diagnosis is usually so clear as to need no confirmation. Nevertheless, the method

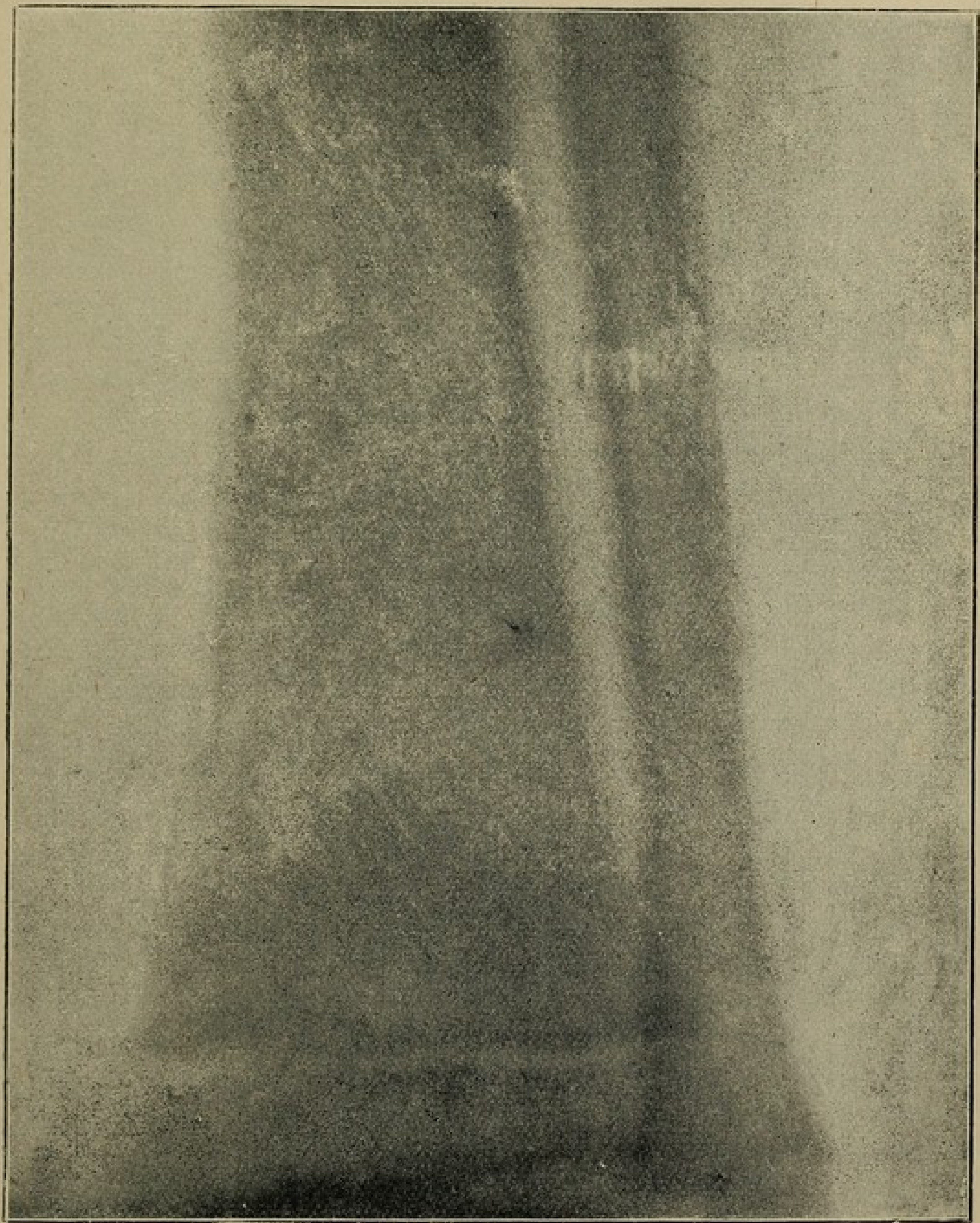


Fig. 62.—Rare Spiral Fracture of Tibia.
Dr. Taft's case.

may be of use in determining whether the degree of obliquity of the fracture or the amount of displacement of the fragments would call for immediate screwing of the bones.

A rare spiral fracture of the tibia was discovered under the rays by Dr. Taft,* and by the kindness of that gentleman is reproduced in Fig. 62. It is instructive to learn that the sensitive plate yielded a clear and unmistakable record of the fracture, which, nevertheless, could not be seen by the aid of Edison's fluoroscope. Dr. Taft accounted for this failure by the difficulty of getting the screen sufficiently near the bone on account of the splints and pads, as well as the swelling of adjacent parts. A second record, taken from the side, showed that the fracture ran up the tibia in a spiral fashion for a further distance about equal to that shown in the figure.

Another unusual fracture of tibia was reported by Mr. Hatch, of Johannesburg.† There were 1½ inches of shortening, together with stiffness and deformity. The Röntgen method showed that the main fracture was transverse below the head of the tibia, with impaction of the lower fragment. The head of the fibula was thrust up, and carried with it the broken-off external tuberosity of the tibia.

By no available means of investigation other than the Röntgen rays could the exact nature of the two foregoing fractures have been ascertained in the living subject. There can be little doubt that, as cases accumulate, many hitherto unsuspected forms and combinations of fractures will be recorded.

The double fracture of the leg shown in Fig. 63 is from a picture kindly placed at the disposal of the writer by Dr. F. H. Low, of West Kensington. The patient was a medical student of about twenty-two or twenty-three years of age. His leg was put up in splints in the ordinary way, and he was kept in bed for nine weeks. A ray photograph of his injured leg, taken three months after the accident, revealed the state of affairs to be seen in the picture. The lower fragments appear to have been thrust upwards between the upper, a condition which the medical attendant supposed to be due to the fact that the patient hd used the limb before the bones were firmly consolidated. In the light of numerous other observations, however, it would appear

* *Boston Medical and Surgical Reporter*, February 25, 1897.
† *St. Mary's Hospital Gazette* for March 1897.

that such irregular union is the rule rather than the exception. A further point of general interest is that, in spite of the apparent extent of the deformity, careful measurement showed only $\frac{1}{8}$ inch of shortening in the whole limb. No noticeable alteration was caused in the gait, probably because there was some compensatory depression of the pelvis on the injured side.

As to fractures of the lower end of the bones of the leg, it seems likely that the pathology of Pott's fracture, like that of Colles' of the radius, will have to be rewritten in view of the fresh facts gleaned from its study by the Röntgen rays. An excellent illustration of such a fracture, with dislocation, is shown in Fig. 64.

Special attention has been given to this point by Destot of Lyons, who has detected by the rays no less than seventeen instances of fracture of the astragalus and metatarsals.*

As a result of his radioscopic investigations of fractures of the astragalus, Destot has recognised two chief varieties—(1) *Fracture with displacement:* (*a*) When the displacement is forwards, the fragment projects under the skin, either in the middle line or on one side. (*b*) When it is backwards, the body of the bone bulges out more or less beneath the Achilles tendon. There is also an intermediate type in which the tibio-peroneal ligament accompanies the posterior fragment, and the foot is slightly dislocated forwards. (2) *Fracture without displacement:* (*a*) Complicated; three varieties—calcanean, malleolar, and scaphoid. (*b*) Simple, either through the neck, the anterior or the posterior extremity.

The Röntgen photograph of dislocation of astragalus, with rotation on its transverse axis, is a good specimen of a not frequent injury, and one difficult to realize its exact condition without the *x*-ray method of investigation (Fig. 65).

Fractures of the Foot.—Tarsal and metatarsal fractures are often obscure, and are no doubt at times treated as sprains. An interesting case of this kind brought under the notice of the writer was that of a young lady whose foot was injured by a fall from a bicycle. Some six weeks later, as the foot was still painful, it was radiographed, with the result that an unsuspected metacarpal fracture was at once revealed.

* 'Radioscopie et Radiographie Cliniques,' Dr. Régnier. Baillière, Paris, 1899, p. 53.

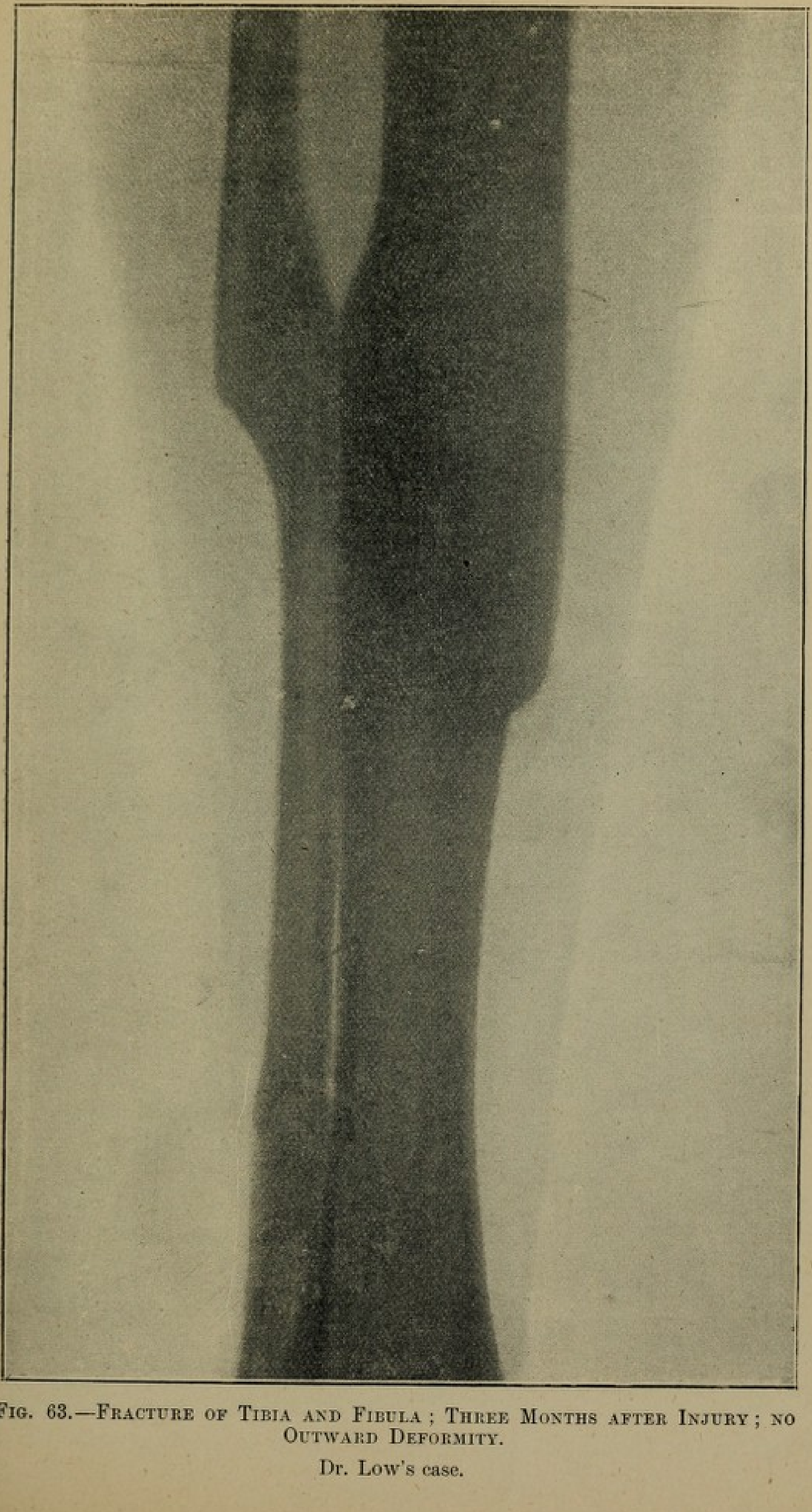


FIG. 63.—FRACTURE OF TIBIA AND FIBULA; THREE MONTHS AFTER INJURY; NO OUTWARD DEFORMITY.

Dr. Low's case.

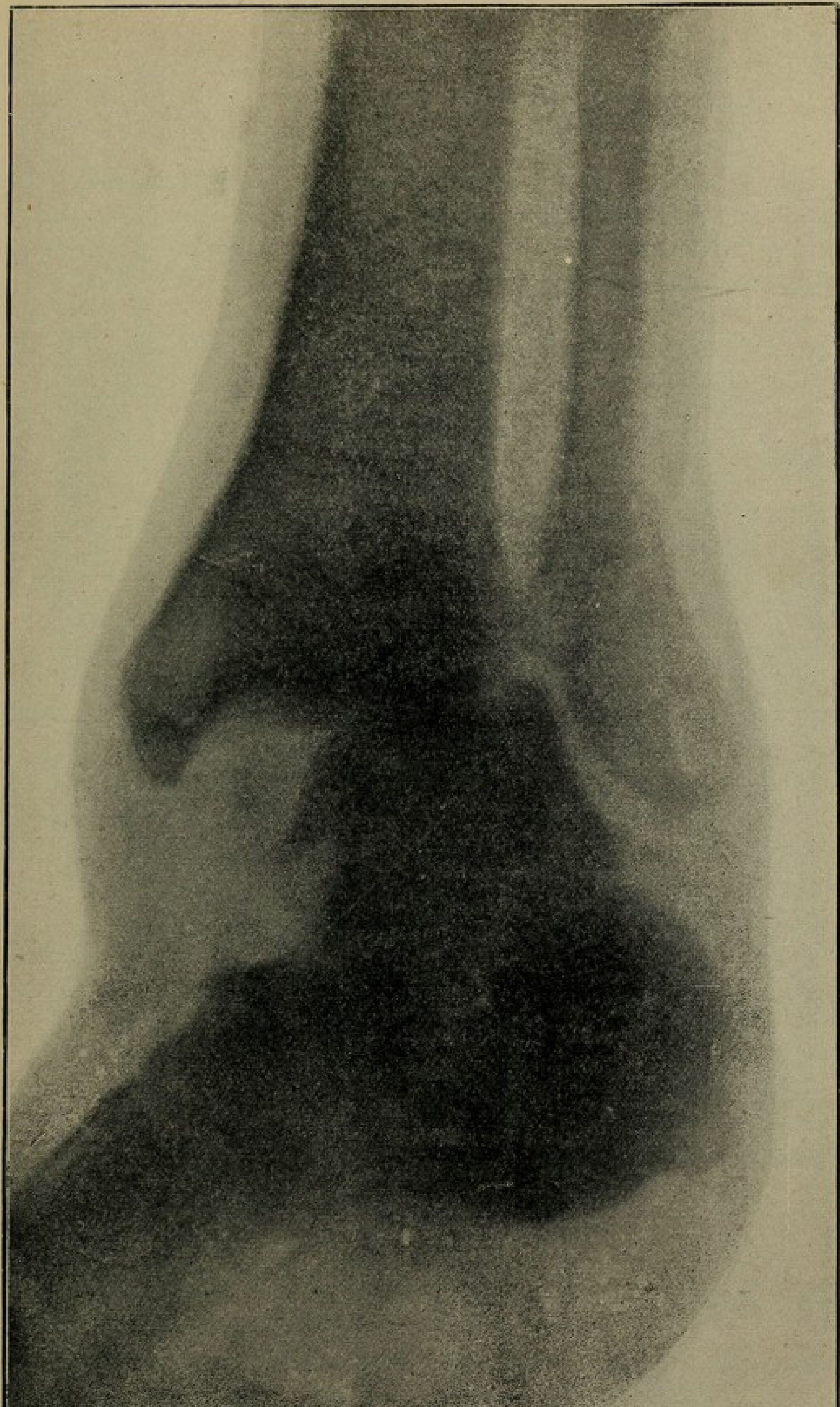


Fig. 64.—Fracture of Lower End of Fibula, with Dislocation of Ankle-joint.

Mackenzie Davidson, M.B.

Fractures about the Head

Fractured skull may be readily shown by the *x*-rays when situated upon the face or the cranium—that is to say, anywhere except at the base of the skull. In the lower jaw fractures can be readily demonstrated by using the method described for taking

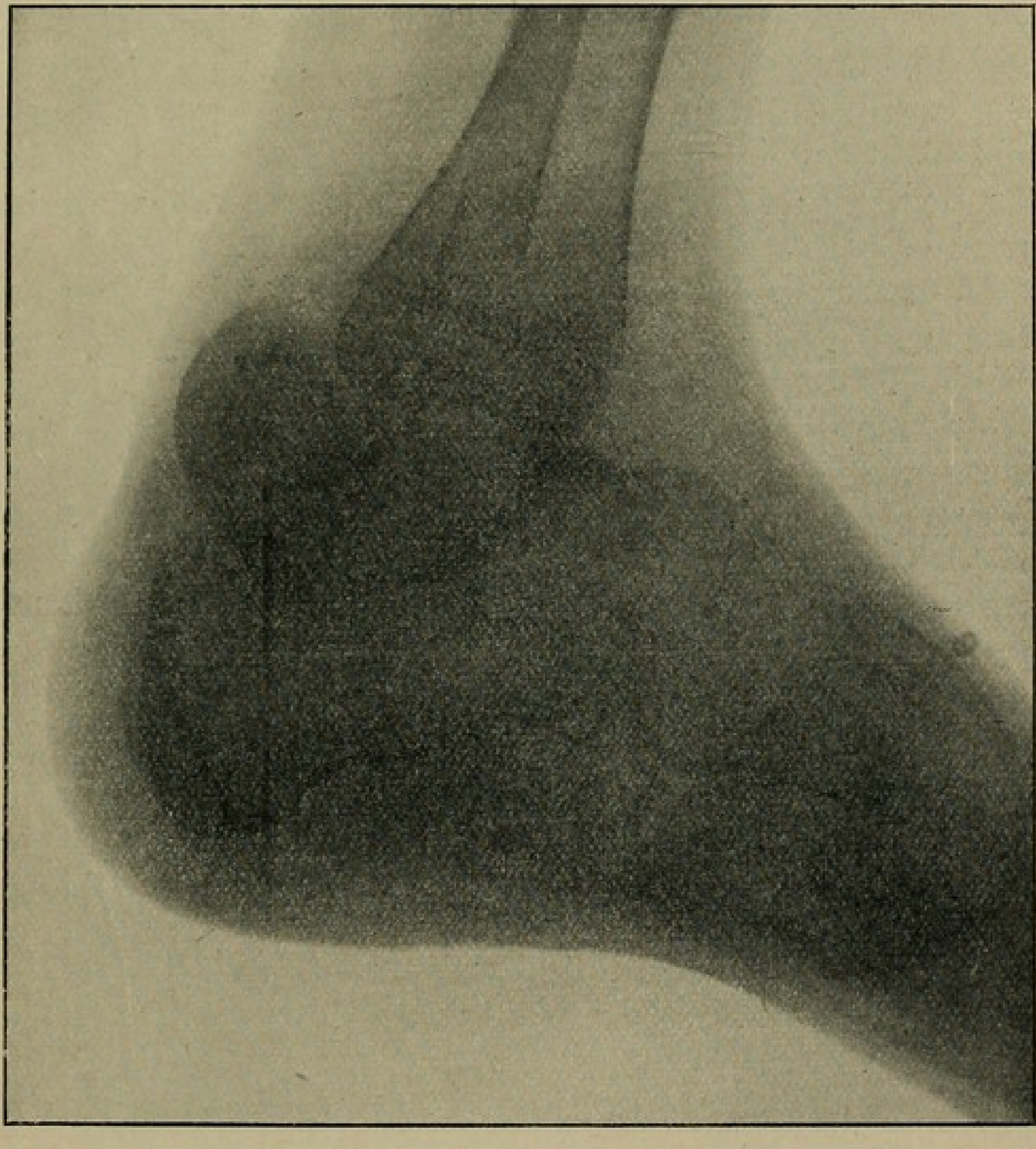


Fig. 65.—Backward Dislocation and Fracture of Body of Astragalus. Lynn Thomas.

teeth (p. 69). In all doubtful or obscure cases the surgeon will do well to appeal to this method.

Fractures of the vertebræ, from the nature of the case, usually present little difficulty in the way of diagnosis. There are, however, instances on record of unsuspected partial fractures of the vertebræ which have been converted into complete ones by some movement, voluntary or involuntary, on the part of the patient. Thus, a patient has been known suddenly to break off the odontoid process of the axis by nodding his head. Another, again, suffering from obscure cervical injury, has been suspected of malingering, and roughly shaken up, with fatal results. In doubtful injuries of the neck and spine, therefore, it would be advisable, wherever possible, to obtain an *x* ray record. In the neck this is comparatively easy, and no doubt in the process of time equally good results will be obtained lower down the spinal column. Lastly, if fractures of the spine be exactly located by the rays, the feasibility of such surgical methods as 'wiring' might be considered by the surgeon.

An excellent illustrative case of dislocation and probable fracture of cervical vertebræ has been published by Mr. R. J. Pye-Smith, of Sheffield.* The diagnosis was confirmed by Röntgen photographs. It rested on the nature of the accident, the region where pain was experienced, the position of the neck and the nature of the limitation of its movements, and the evidence afforded by the application of Röntgen's rays.

The following extracts will explain the chief points of this probably unique case:

P. H., a mechanic, aged twenty-six, admitted to hospital February, 1897, complaining of pains in shoulders and upper thorax. On June 20, 1896, he fell from a raised path on to the road 6 feet below, alighting on the right side of the head. He was unconscious for half an hour, and was kept in bed for two days. His neck was stiff and he could not raise his head properly, but in ten days he returned to his work, which involved bending his head over a machine. Six months later pain began in the chest down to the nipples, in both shoulders, and on the inner aspect of both arms.

The head was inclined forwards and slightly to the left, and could not be fully extended either by voluntary or assisted efforts. Nodding movements almost normal. Lateral rotation of head slightly limited to right, more so to left, and accompanied by a soft, grating sensation, as if tendinous fibres were slipping over bony prominences. Lateral flexion of neck markedly diminished, especially to the right. No marked lateral deformity on either side. The spinous processes of the vertebræ above the fourth could not be felt, and seemed to be displaced forwards, the fourth being very prominent. No definite projection, however, of the body of the fourth could be felt in the pharynx. The chest and abdomen moved well in respiration, and neither loss of muscular power nor of sensation was anywhere detected. The pain complained of lay chiefly in the distribution of the descending superficial branches of the cervical plexus of nerves. The Röntgen photograph taken from the side showed the body of the third cervical vertebra to be a considerable fraction of an inch in advance of that of the fourth, whilst the postero-lateral view taken from the left side showed considerable separation of the transverse processes of those two vertebræ.

---

* *The Sheffield Quarterly Medical Journal*, October, 1897, p. 30.

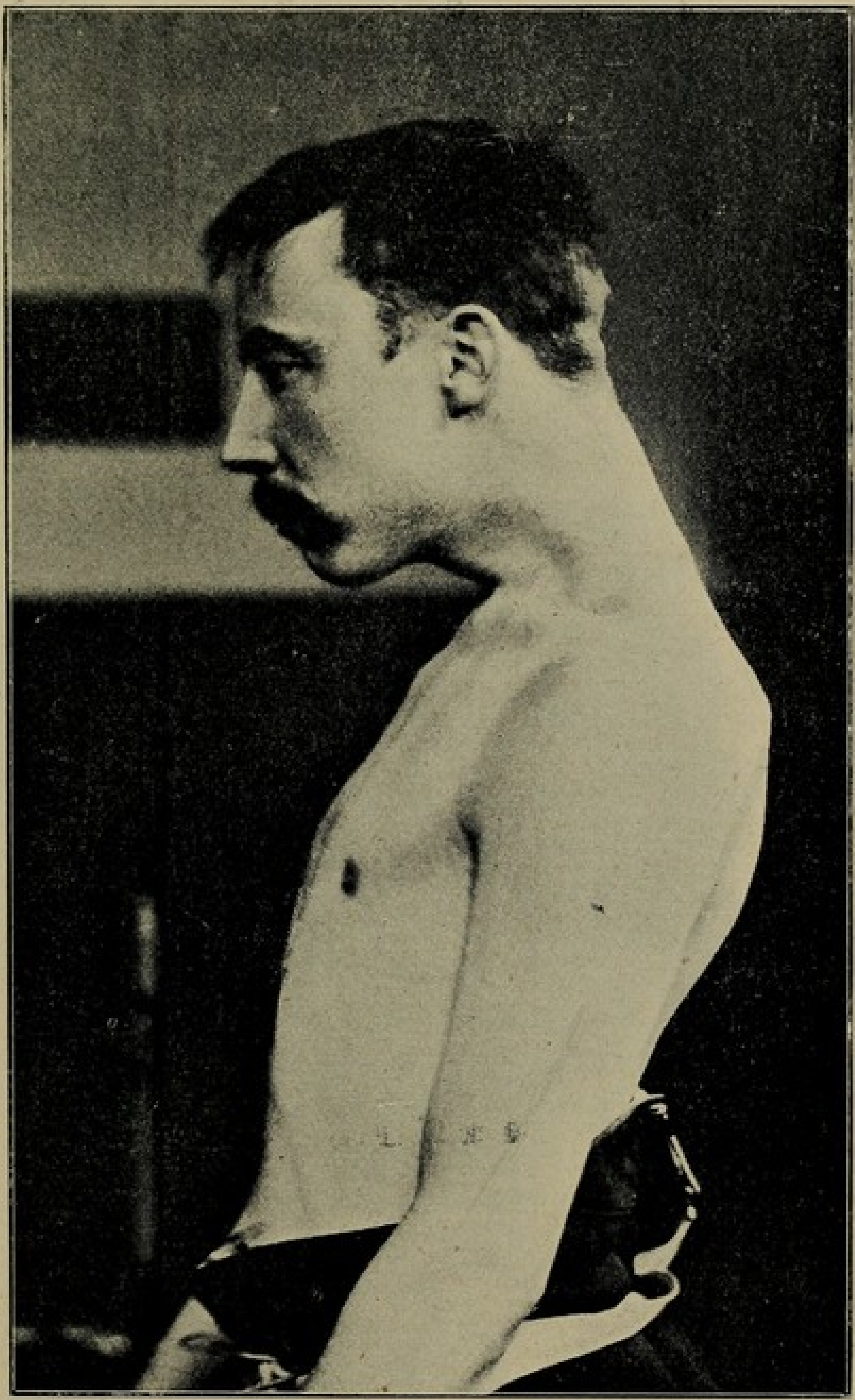


FIG. 66.—FRACTURE-DISLOCATION OF CERVICAL SPINE.
From the *Sheffield Medical Journal*.

REMARKS.—'The rarity of the long survival of a case of fracture-dislocation of the spine in the cervical region is well known, and depends, of course, on the lesion of the cord which so generally accompanies that injury. The rarity of such an injury to bone and ligament without involvement of the cord is perhaps equally great.'

Fractures of the ribs, which are now and then difficult to detect, may be diagnosed by the radiograph. In some instances —as, for example, in lunatic asylums—the proof of such injuries may have a medico-legal interest. Indeed, it may be mentioned in passing that the rays are likely to be of special service to the surgeon when called upon to diagnose injuries of lunatics, mutes, infants, and other folk who are from any reason unable to furnish sound personal evidence of their subjective symptoms. Where death has taken place, a tedious dissection may perhaps be avoided by a Röntgen photograph.

There are special difficulties in the way of securing a proper record of rib injuries. For instance, the movements of the chest wall in respiration will clearly confuse the focus-tube shadow. It has been suggested that the ribs may be fixed by a dressing translucent to the rays, such as silicate of soda. When the fracture is at or within the neck, the movements are sufficiently restrained simply by lying on the back. The present writer, with Mr. Burton, secured an excellent picture in that position of seven broken ribs at the North-Eastern Hospital, London. The patient was a child who had been run over by a vehicle; the fracture had united when the exposure was made, weeks after the accident. The photograph was darker on the affected side, owing to the absorption by the skin of a certain amount of lead from the plaster which had been applied to fix that half of the chest, and also to traumatic pleurisy.

It is also difficult in adults to obtain any record of the ribs over the region of the liver. The writer failed to do so in a medico-legal case where fracture of the lower ribs was alleged to have taken place in the nipple line as a result of direct violence (fall on kerbstone). The patient in that case was an elderly asthmatic man of great girth. In another instance the writer has secured a clear record of ribs over the liver in a middle-aged man of average size, by causing the patient to fix the part to be taken by leaning firmly against the sensitive plate. In young adults and children the ribs can often be beautifully shown through the liver by taking them lying face downwards.

There seems to be no particular reason why lateral fractures should not be photographed if the chest be fixed in some way, and the rays directed transversely through the thorax from the sound side.

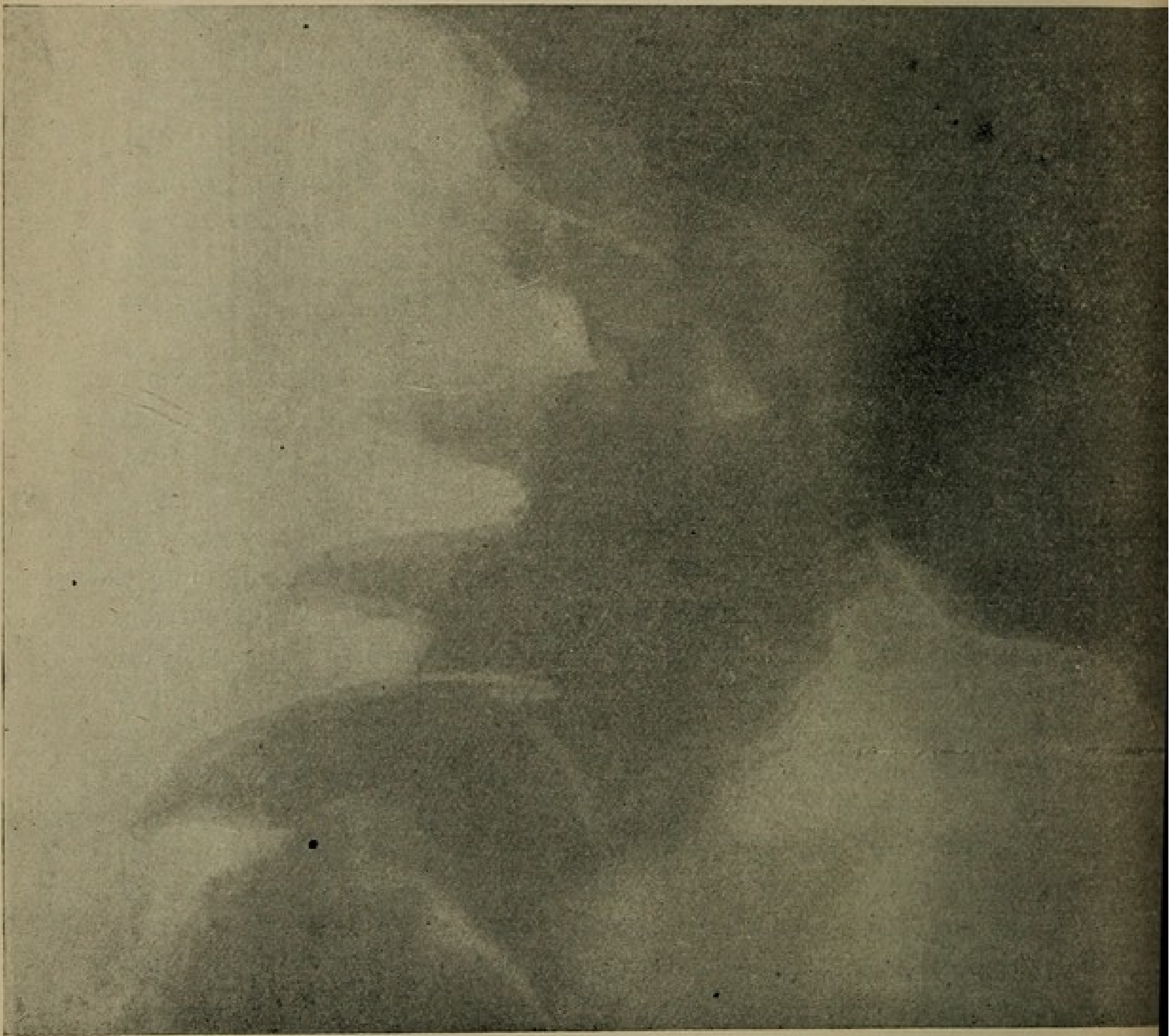


FIG. 67.—FRACTURE-DISLOCATION OF CERVICAL SPINE. From side. Mr. Pye-Smith's case.

Concluding

This section may be finished by quoting some important practical conclusions arrived at by two surgeons, one in Germany and the other in America. For some months both made a routine

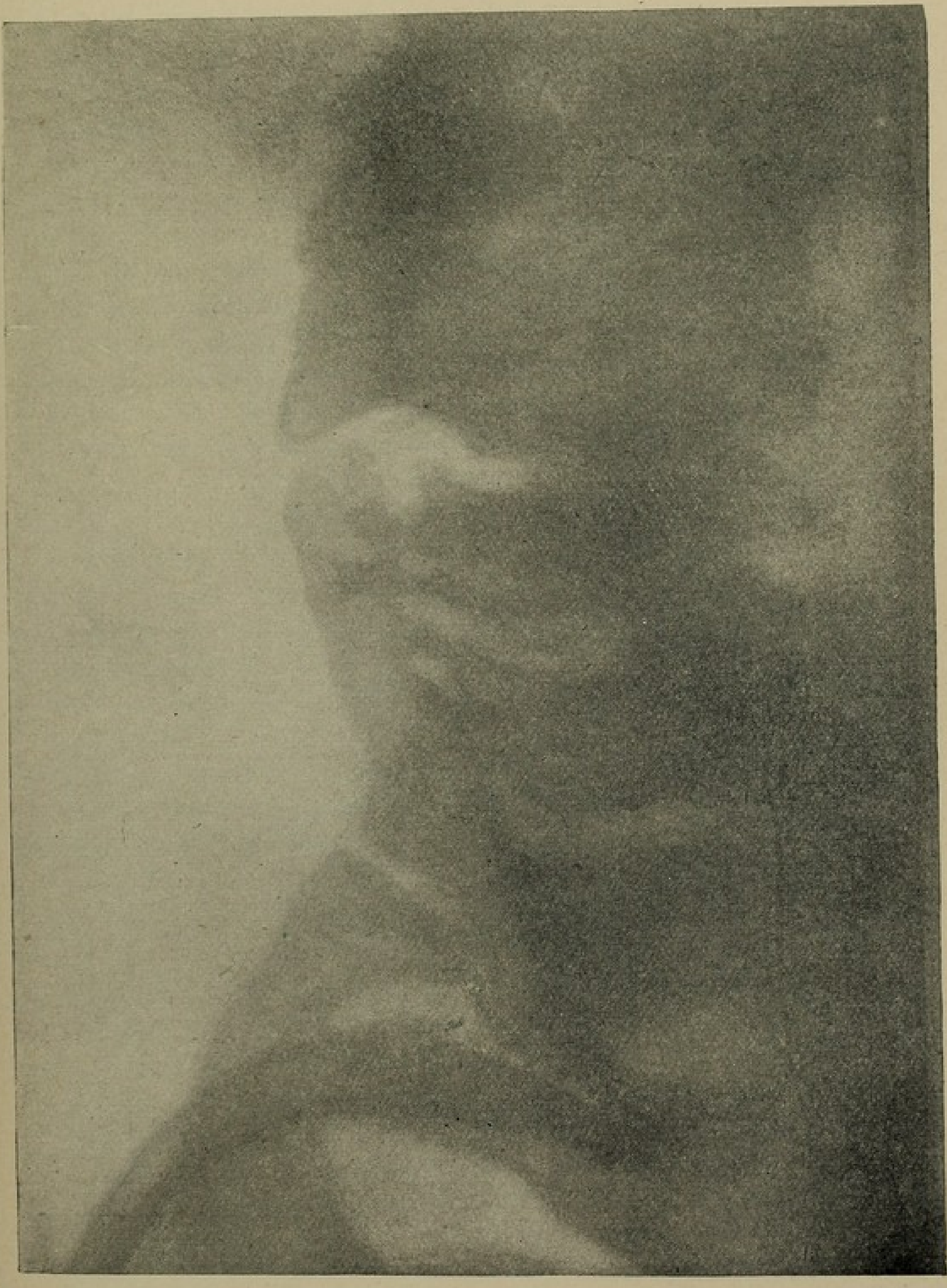


FIG. 68.—FRACTURE-DISLOCATION OF NECK. Antero-posterior view.
Mr. Pye-Smith's case.

practice of examining with the Röntgen rays every fracture brought under their notice.

The chief point insisted upon by Dr. Richardson of Boston is that both in recent and in united stages malposition of broken ends is common, although not revealed by any previously known method of examination. He mentions a number of cases where the position was absolutely perfect so far as could be ascertained by ordinary means, but in which, nevertheless, a Röntgen ray photograph showed considerable displacement.

Oberst of Halle finds that without the aid of anæsthetics and without handling the parts he can make an exact diagnosis as to the position, the nature, and the direction of fractures. He thus avoids the danger of laceration of vessels and of other structures that attends manipulation of the fragments. Ether he now reserves for painful reductions. He also makes a practice of taking a radiogram at the end of treatment. His main conclusions are as follows :

1. The ideal or perfect union is rare.
2. In all oblique fractures there is more or less overriding of the broken ends.
3. In bones that are deeply seated considerable deformities may escape notice.
4. In cases followed by long-continued functional disturbances, the Röntgen rays invariably showed overriding of fragments to a greater or less extent, when manual examination revealed no deformity.

Dislocations

In this class of injury the surgeon will usually arrive at an absolute diagnosis by ordinary methods.

A dislocation may be examined with advantage when the parts are too swollen and painful to admit of manipulation. When complicated with fracture, the value of the new method can hardly be overestimated for the ease with which a difficult diagnosis may be reduced to a certainty. To take a concrete instance, let us suppose a dislocation of the elbow to be examined by the *x*-rays, which may demonstrate one or more of the following fractures as a complication—(1) of the coronoid, (2) of the olecranon, (3) of the neck of the radius, (4) of lower end of humerus, (5) of condyles of humerus, (6) through epiphysis of humerus. The importance of trustworthy evidence on any of these points must be clear, when one considers to what an extent such knowledge must modify diagnosis, prognosis, and treatment.

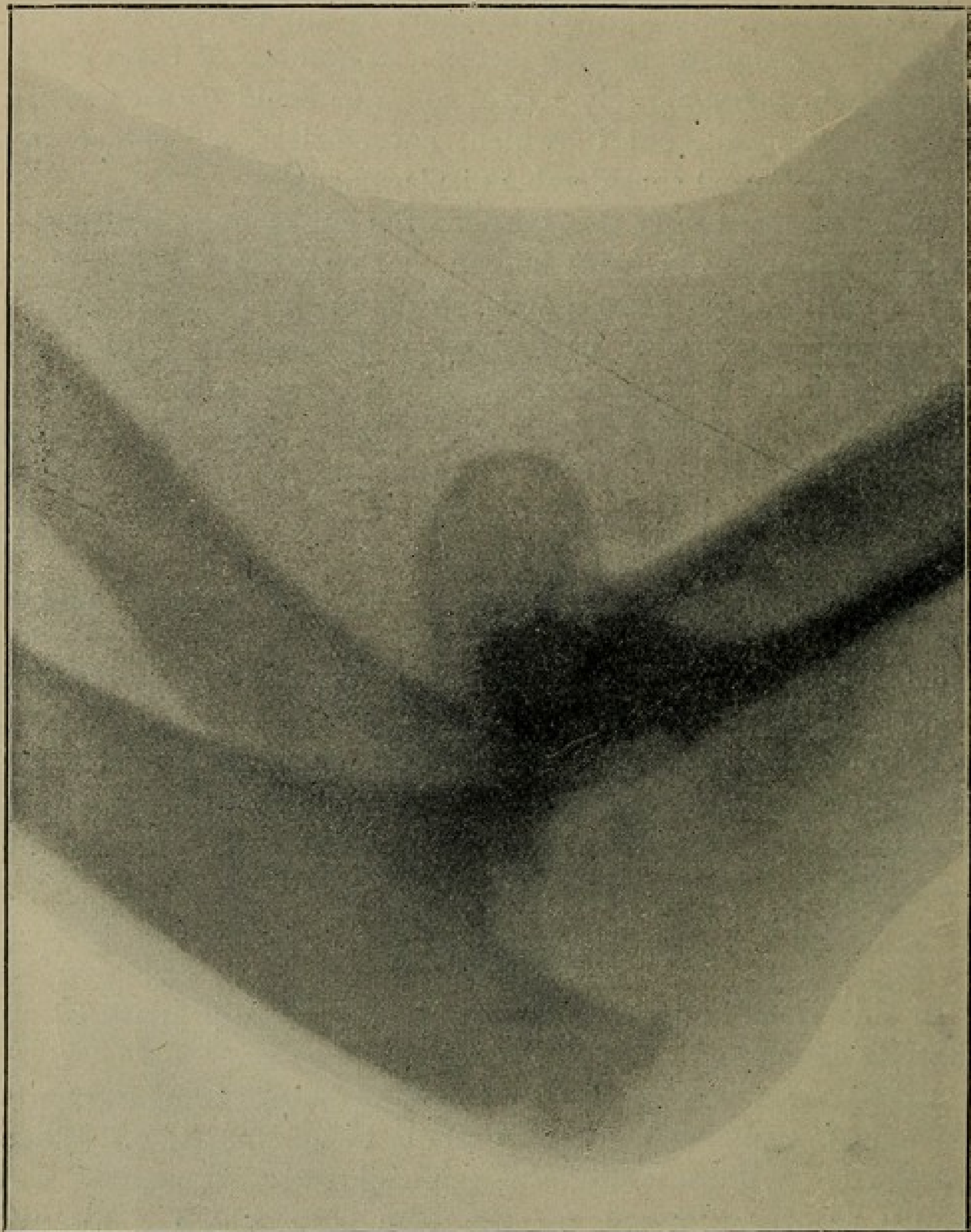


Fig. 69.—Backward Dislocation of Bones of Forearm in a Child.

The illustration of backward elbow dislocation of both bones of the forearm in a child shown in Fig. 69 is from a ray photograph taken by Davidson.

The backward dislocation of the first phalanx of the thumb

FIG. 70.—PELVIS, SHOWING RICKETY DISTORTION OF NECK OF THIGH-BONES

upon the metacarpal has always been a matter of surgical interest, chiefly because of the difficulty often experienced in replacing the bones. It is interesting to note that the rays have confirmed

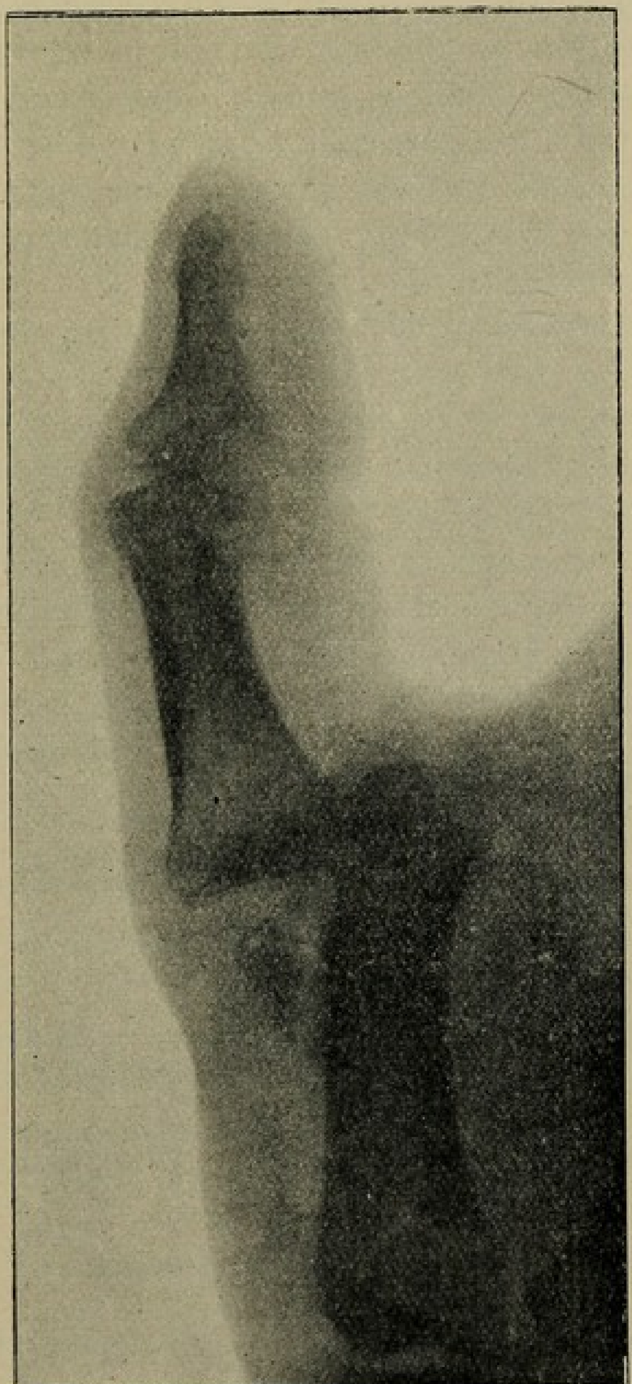


FIG. 71.—BACKWARD DISLOCATION (OLD) OF METACARPO-PHALANGEAL JOINT OF THUMB. Position of sesamoids behind and below head of metacarpal well shown.

Lynn Thomas.

the anatomical theory advanced many years ago by the late Sir George Humphrey, that the hindrance was due to the sesamoid bones being carried back with the phalanx, and held there between the separated articular surfaces by the flexor brevis pollicis.

In old-standing dislocations the new photography is likely to be of service. For instance, it will enable the surgeon to ascertain the precise condition of affairs at the seat of injury, so that his subsequent treatment shall be founded upon exact data. Thus, if the rays showed a fresh articulation to have been formed in an old-standing dislocation of the shoulder, the surgeon would not make any attempt at reduction, except under most exceptional circumstances.

Congenital dislocation of the hip can be well shown in children.

The accompanying illustration (Fig. 70) shows a suspected congenital double dislocation to be really a rickety bending of the angles of the thigh-bones.

Dislocation of the body of the astragalus backwards—an extremely rare accident—is shown in Fig. 65. The original radiogram was taken by Mr. Lynn Thomas from a lad of seventeen, who eight months previously, while riding on a moving trolley with his feet in front, struck the roof of an underground cutting.

There is fracture through the neck of the astragalus, while the body is displaced backwards with the trochlear surface in contact with the tendo-Achilles; in other words, there is an axial rotation of 90 degrees backwards through its transverse axis, 'anticlockwise.'

There is no formation of bone in the gap between the neck and the displaced body of the astragalus, for the fibular malleolus is distinctly recognisable. The tibial malleolus is seen resting upon the two segments.

In Stimson's seven cases of this particular injury 'persistent flexion of the terminal phalanx of the great toe was present' (Keen and White's 'Surgery'). A similar condition was well shown in this instance.

A comparison of the bones and tendons of this radiogram with the illustration of a like injury in Treves' 'System of Surgery' (vol. i., p. 1025) is not a little striking.

(*c*) Injuries to Epiphyses

The importance of injuries to the epiphyses is now recognised by surgeons, and existing knowledge on the subject has been brought together in an exhaustive monograph by Mr. Poland.*

The damage may occur in intra-uterine life, during birth, or in childhood; most often perhaps between the years of eleven

* 'Traumatic Separation of the Epiphyses.' By John Poland, F.R.C.S. London: Smith, Elder and Co. 1898.

and eighteen, up to the union of the last epiphysis, usually at twenty-three, although that may be delayed in some cases until thirty years or more. The Röntgen ray worker will be guided in the reading of results by the following table :*

The Times of the Union of the Epiphyses to the Diaphyses of the Long Bones.

At the 16th year	The upper epiphysis of the radius.
Between the 16th and 17th years ...	The olecranon epiphysis of the ulna.
At the 17th year	The lower epiphysis of the humerus.
At the 18th year	The internal epicondyle of the humerus.
Between the 17th and 20th years ...	The epiphyses of phalanges of toes.
Between the 18th and 20th years ...	The epiphyses of phalanges of fingers and lower epiphysis of ulna.
About the 20th year...	The metacarpal epiphyses.
Between the 18th and 22nd years ...	The upper epiphysis of the humerus.
Between the 19th and 23rd years ...	The lower epiphysis of the radius.
Between the 22nd and 25th years ...	The epiphysis of the clavicle.
At the 18th year	The lesser trochanter.
Between the 18th and 19th years ...	The great trochanter.
Between the 19th and 20th years ...	The metatarsal epiphyses.
At the 19th year	The epiphyseal head of the femur.
Between the 18th and 19th years ...	The lower epiphysis of the tibia.
Between the 19th and 21st years ...	The lower epiphysis of the fibula.
Between the 20th and 22nd years ...	The upper epiphysis of the fibula.
Between the 21st and 22nd years ...	The upper epiphysis of the tibia.
Between the 20th and 23rd years ...	The lower epiphysis of the femur.

Separation of epiphyses is much more common in the male sex, as shown by Poland in the three most frequent situations—namely :

Lower Epiphysis of Femur. – Out of 114 cases, the sex is stated in 96—83 males and 13 females ; all the latter below fourteen years of age.

Lower Epiphysis of Radius.—Out of 112, the sex is given in 89 as 79 in males, and 10 in females ; the whole of the latter being at or below fourteen years of age.

Upper Epiphysis of Humerus.—Out of 119, the sex is given in 104. Of these, 85 were males and 19 females (16 being at thirteen years and below, three above).

The practical worker will find the following tables from the same book of constant value for reference. The statistics are compiled from Poland's own cases of separations of epiphyses.†

* 'Traumatic Separation of the Epiphyses,' p. 47.
† *Op. cit.*, p. 56.

UPPER EXTREMITY.

Clavicle	5
Humerus, upper epiphysis	120
,, lower end (before puberty)	75
,, lower epiphysis at and after puberty	6
,, internal epicondyle	61
,, external epicondyle	9
Radius, upper epiphysis	7
,, lower epiphysis	112
Ulna, upper epiphysis	9
,, lower epiphysis	11
Phalanges of fingers	3
Metacarpus	8
Total	426

LOWER EXTREMITY.

Femur, epiphysis of head...	35
,, great trochanter	14
,, lesser trochanter	1
,, lower epiphysis	125
Tibia, upper epiphysis	24
,, epiphysis of tubercle	10
,, lower epiphysis	46
Fibula, upper epiphysis	3
,, lower epiphysis	5
Phalanges of toes	2
Metatarsus	2
Total	267

The importance of an exact diagnosis in this class of injuries is clear, as severe deformities often result from them. A certain number of so-called congenital deformities are no doubt caused in this way during birth. Hitherto, however, the surgeon has been hampered by the want of exact means of diagnosis and by the lack of precise pathological data. On these points Mr. Poland remarks :

'At the lower end of the humerus, for example, there are but few anatomical specimens in museums to guide the surgeon in making an exact diagnosis of the numerous and complicated

DIAGRAMS OF THE COMMON FORMS OF EPIPHYSEAL SEPARATION.

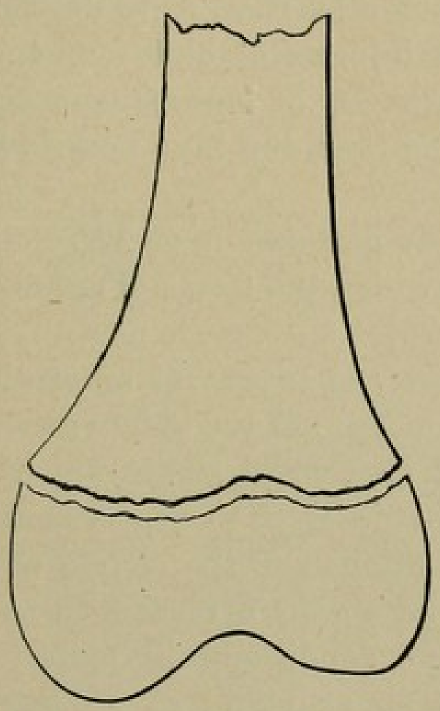


Fig. 72.—Pure and Complete Separation.

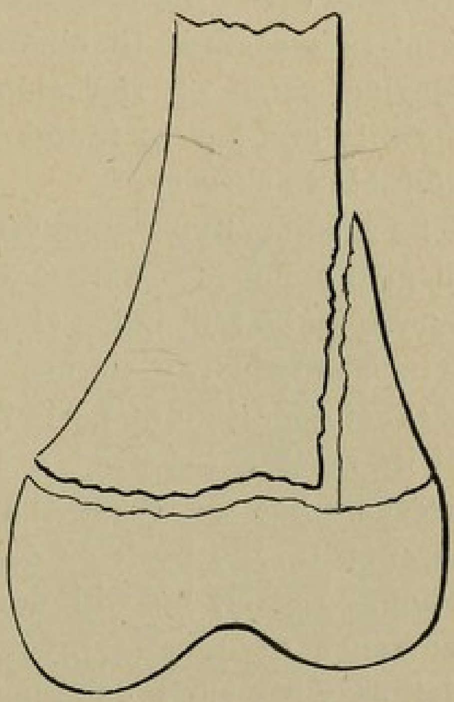


Fig. 73.—Partial Separation, with Fracture of the Diaphysis.

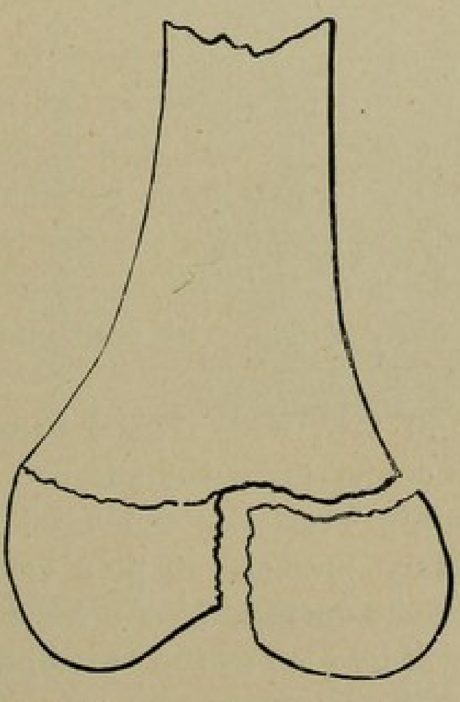


Fig. 74.—Partial Separation, with Fracture of the Epiphysis.

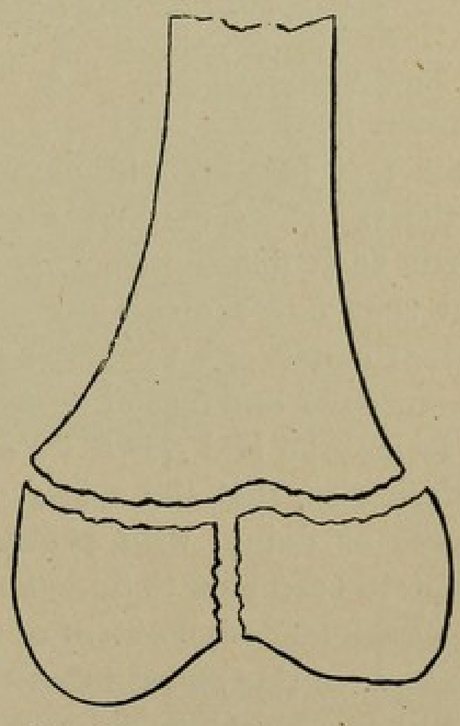


Fig. 75.—Complete Separation, with Fracture of the Epiphysis.

From Poland's 'Traumatic Separation of the Epiphyses,' 1898.

lesions which from daily experience must exist during life. If this knowledge be obtained by Röntgen's method, it will materially assist the surgeon in giving a decision as to immediate operative measures in elbow-joint injuries of children, and in removing some of the many instances of subsequent severe deformity and loss of function of the joint and limb now so little creditable to surgery.'*

The accompanying illustrations, by permission of Mr. Poland, will give some idea of the way in which the forms of epiphyseal injury may be multiplied (Figs. 72-75).

The Röntgen ray worker has now the means of ascertaining the exact condition of parts in traumatism of the epiphyses. He will in most cases want a second or control radiogram of the corresponding sound side, and will do well to make constant reference to the book so often mentioned in the course of this section. Lastly, he will be able to obtain evidence as to the occurrence of plastic inflammatory conditions in epiphysitis, together with such complications as stripping of periosteum, suppuration, necrosis, absorption of bone, and so on.

(*d*) **Congenital and other Bony Deformities**†

The underlying bone conditions of many deformities of the human body can be clearly demonstrated by means of the rays. This fact has been brought out by Mr. Barwell in a series of articles. He remarked that hitherto it had been possible to study such deformities only after death, and upon the dry bone, but that now radiography had made it feasible to ascertain the actual conditions upon the living body, during the continuance of muscular and fascial tension.

It may be laid down as a general law, with regard to such deformities, that the Röntgen rays confer upon the surgeon the power of doing, with pretty accurate precision, what he has hitherto been able to do but tentatively—namely, to plan beforehand the mode and extent of his osseous operation. An excellent example of this general statement will be seen in the accompanying illustration (Fig. 76), reproduced by permission of the *Lancet*.‡

* 'Traumatic Separation of the Epiphyses,' p. 97.
† This section has been kindly revised by Mr. H. A. Reeves, F.R.C.S.
‡ 'On Various Forms of Talipes as depicted by the *X*-Rays,' *Lancet*, 1896.

Mr. Barwell says of it: 'The reader will perceive that the *x*-rays have marked out an abnormal length and a downward bend of the neck of the astragalus as being the obstacle to the restoration of proper form to the tarsal arch.' Fig. 77, also from the *Lancet*, gives an excellent illustration of a healthy foot bent strongly downwards.

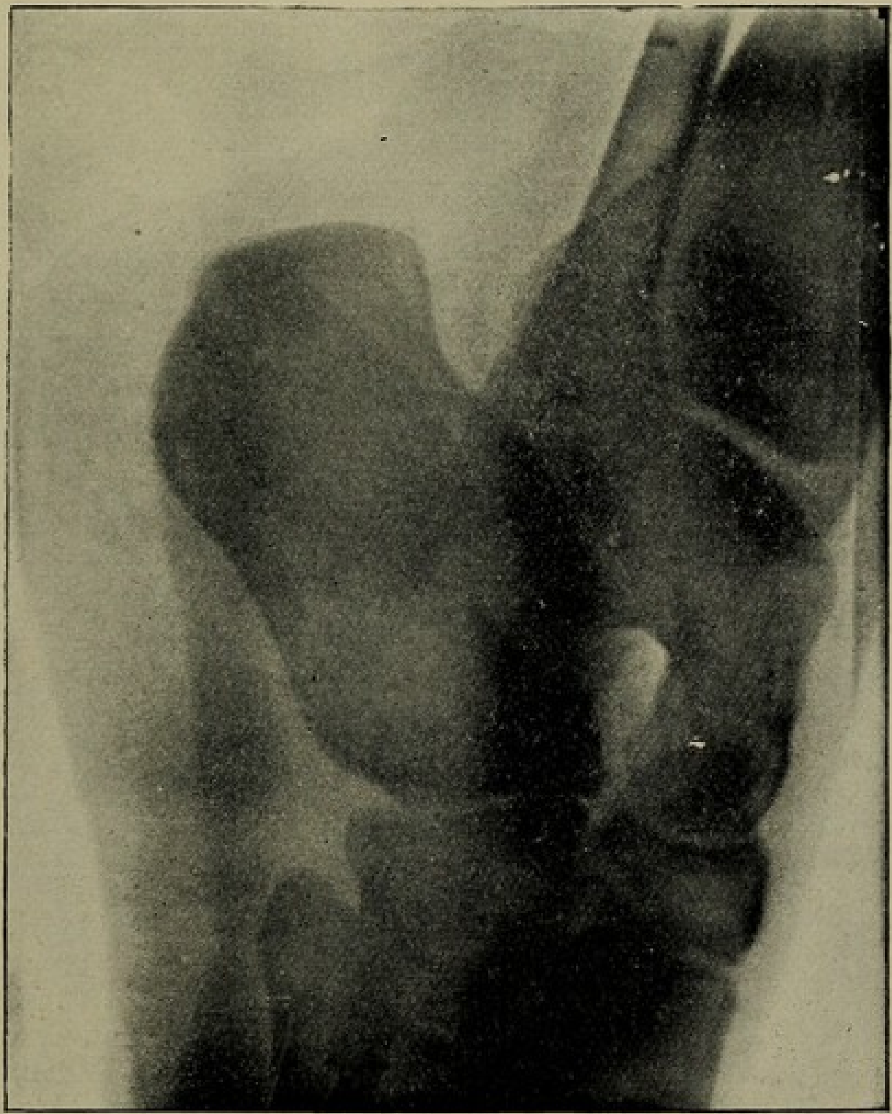


Fig. 76.—Talipes Equinus in a Young Man of Nineteen: Deformity began at three years of age.
Rowland.

In deformities of the spine the rays often afford valuable information. This is all the more likely now that operations in that region are becoming matters of everyday surgery. A good instance of the diagnostic value of the rays in cervical cases will be found mentioned under the section 'Diseases of Bone' (p. 163).

Numerous cases of polydactylism and allied congenital deformities have been published. In one or two instances the radiograph has indicated the appropriate line of operation upon supernumerary fingers and toes.

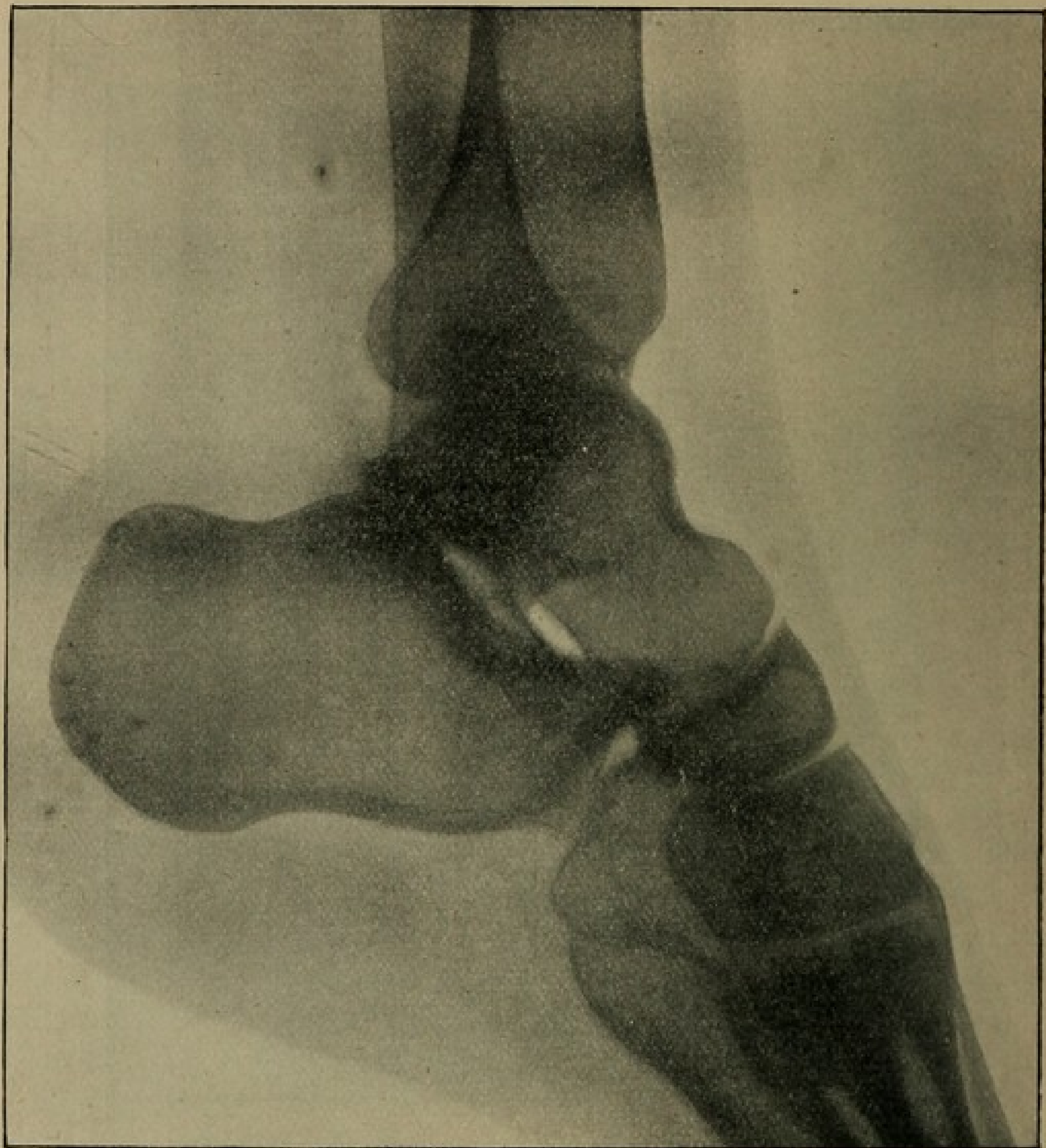
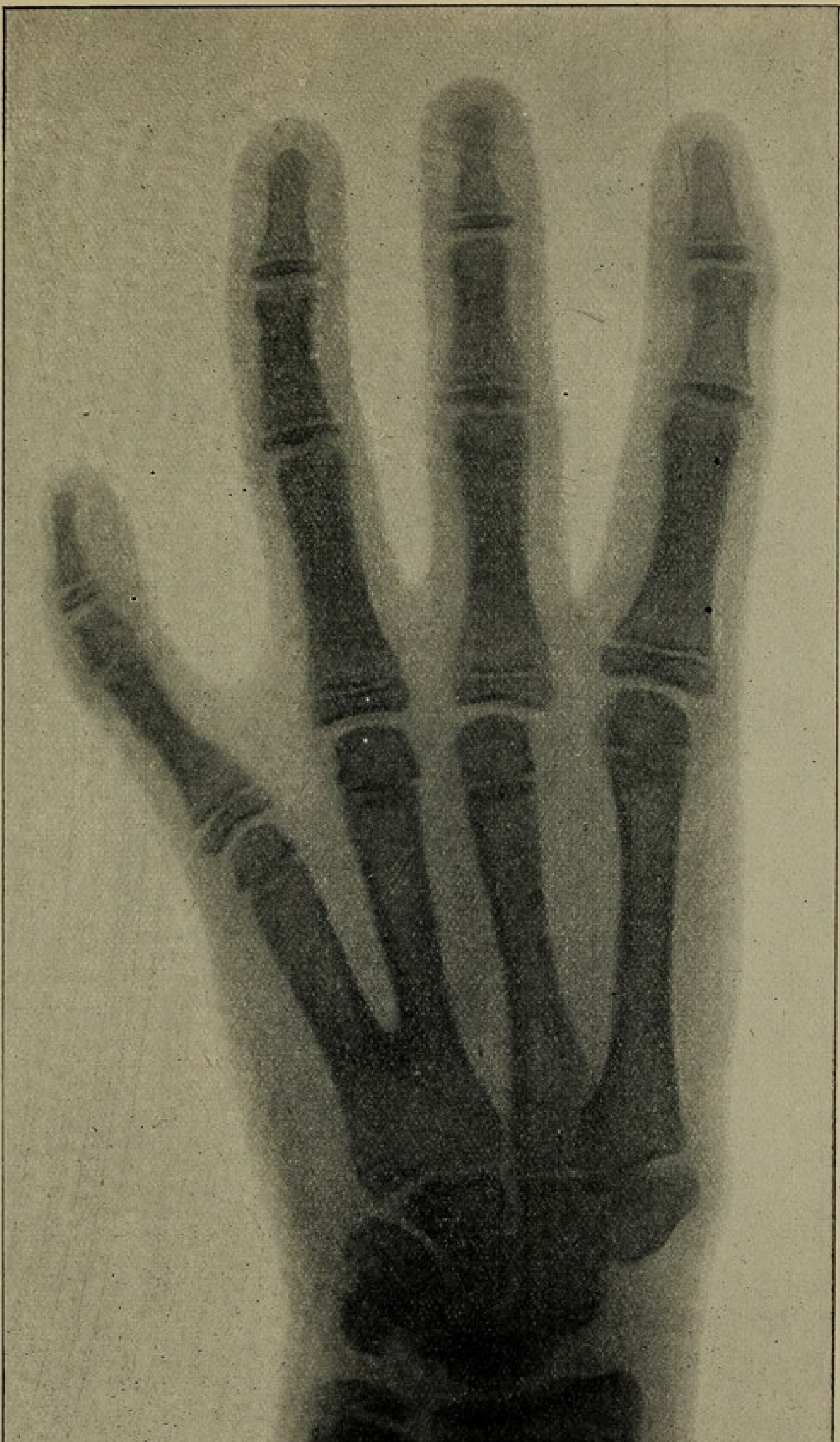


Fig. 77.—A Normal Foot bent strongly downwards.
Compare with preceding figure.

The writer appends an interesting example of polydactylism. The case was kindly placed at his disposal by Dr. Milne, the medical officer of Dr. Barnardo's Home in London (Figs. 81 and 82).

The hands and feet in these illustrations are from the same



Dr. Walsh.

FIG. 78.—MR. REEVES' CASE—THUMBLESS RIGHT HAND OF PATIENT IN FIG. 80.

subject. The hands appear to be wanting in fingers, but the radiogram shows that it is really a case of polydactylism, with supernumerary thumb. One of the missing fingers, the digit of the right hand, appears to be represented by a rudimentary phalanx forced down between the heads of the second and third metacarpal bones.

The feet, however, show suppression of toes, and suggest a two-toed type. The picture of the right foot is indistinct owing to trembling of that member during the exposure. It is interesting to note that the other foot and the hands were not affected in a similar way, but were perfectly steady—a fact which may possibly point to some nerve instability or other local peculiarity.

The two Figures 78 and 80 are from a girl of twelve under Mr. Reeves at the Royal Orthopædic Hospital. The thumbs are absent in both hands—a rare congenital deficiency. In addition, the left arm, which is rudimentary and much shorter than the other, shows a remarkable condition of bony skeleton. Humerus, radius, and ulna are blended into one long bone, with an outstanding spur at the site of the obliterated elbow-joint. The fifth left metacarpal is partly developed.

Some interesting developmental defects with radiographic pictures were shown at the West London Medico-Chirurgical Society, March 3, 1899.* They included both proximal and distal deficiencies of the limbs. Four principal explanations have been advanced: (1) Interference with arteries; (2) nerve disturbance; (3) intra-uterine amputation; (4) reversion to ancestral type.

Dr. G. T. Beatson has described a congenital deformity of both thumbs in a girl four years of age.† The radiographic picture reproduced in Fig. 79 shows an extra wedge-shaped bone between the first and terminal phalanges of the thumb. Both the end phalanges were bifid. There was a family history of extra digits and toes and broad thumbs and great-toes, and also of webbing. The father's thumbs were not bifid at the end phalanges, but the terminal phalanx of one great-toe was partly bifid, with two distinct nails. Dr. Beatson quotes the statement of Coats that 'deformities of fingers and toes are to a certain extent interchangeable, the one being transmissible from the other.' He also mentions Gegenbauer's definition of the atavistic view, namely, 'the

* *West London Med.-Chir. Journal*, April, 1899.

† *Scottish Med. and Surg. Journal*, December, 1897.

reappearance of a more primitive organization, or a reversion to a primary state.' With regard to his own case, he considers it fair to assume that, looking to the family history of hyperdactyly, the extra bone found in the thumbs of his patient was the

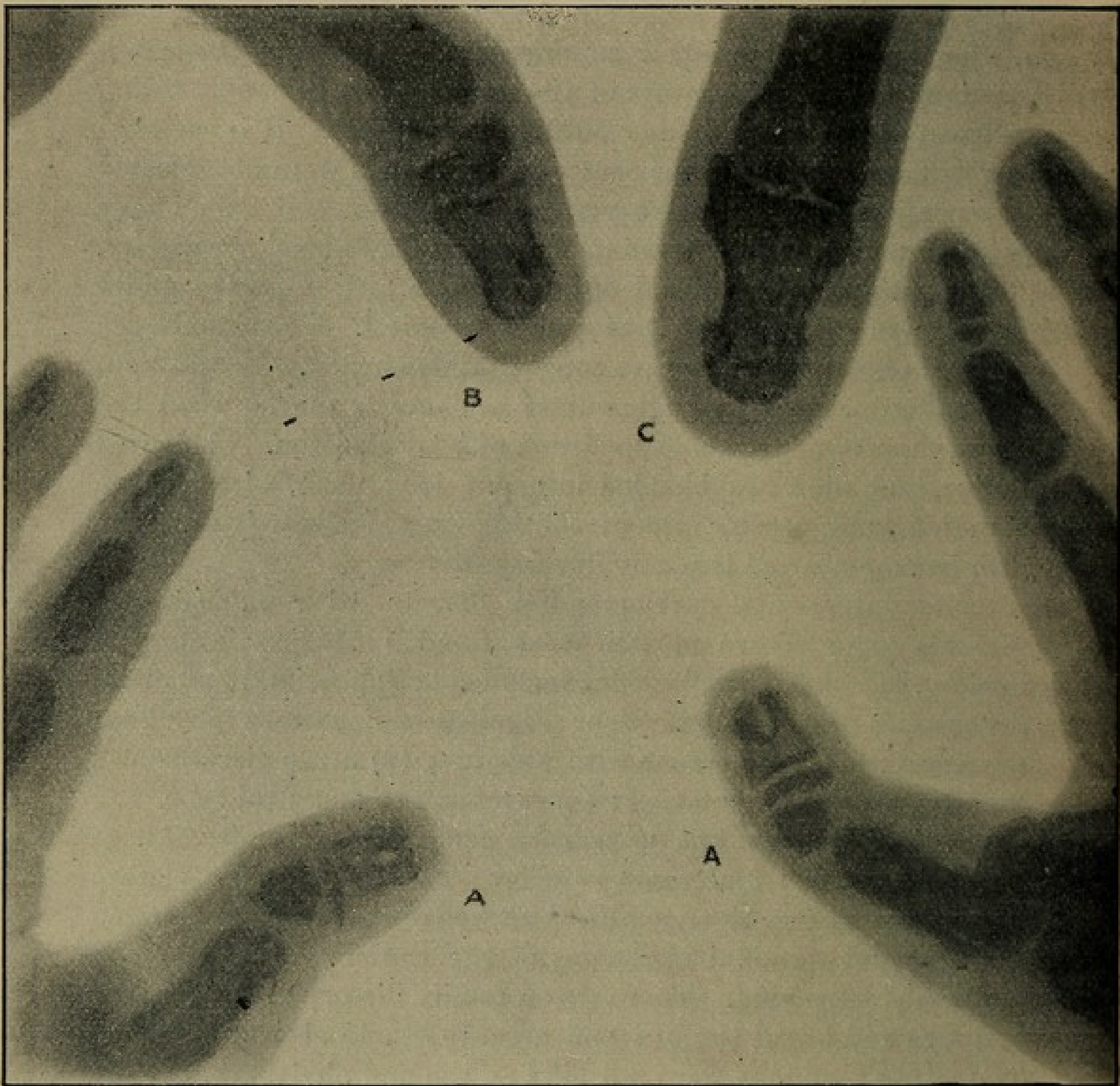


FIG. 79.—DR. BEATSON'S CASE OF BIFID TERMINAL THUMB PHALANGES.

rudiment of another finger, and that the bifurcation of the ungual phalanx indicated how the process would have been completed had it gone on to a full termination.

Congenital absence of the clavicle is a rare deformity, an instance of which was sent to the writer by Dr. George Carpenter.

Dr. Walsh.

FIG. 80.—MR. REEVES' CASE OF DEFORMED LEFT UPPER LIMB, SHOWING BONY OUTGROWTH FROM HUMERUS AND DEFICIENCY OF ELBOW-JOINT AND BONES OF FOREARM.

Right hand shown in Fig. 78.

Fig. 81.—Polydactylism: Hands of a Girl of Twelve.
Taken by Mr. Greenhill.

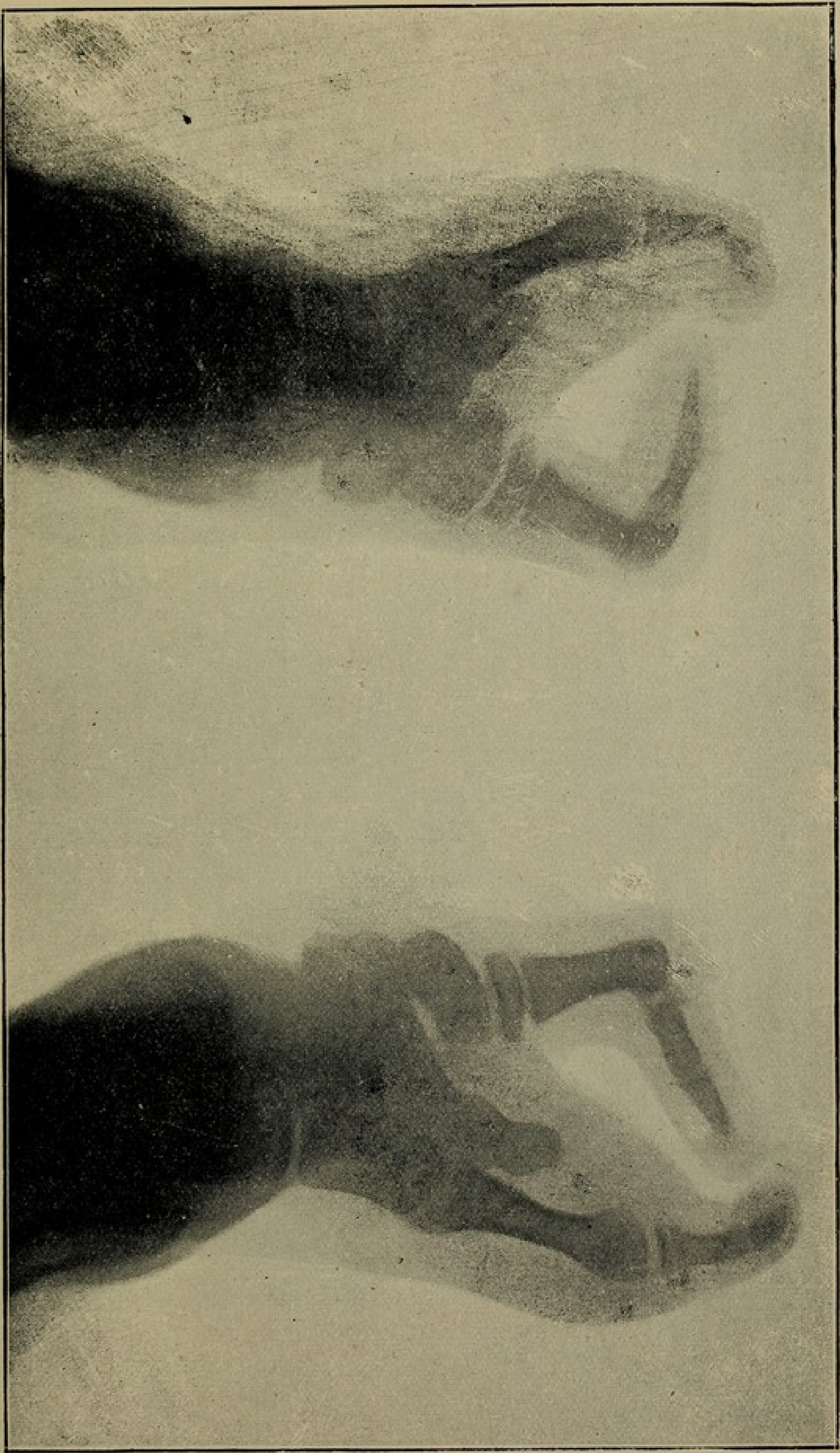
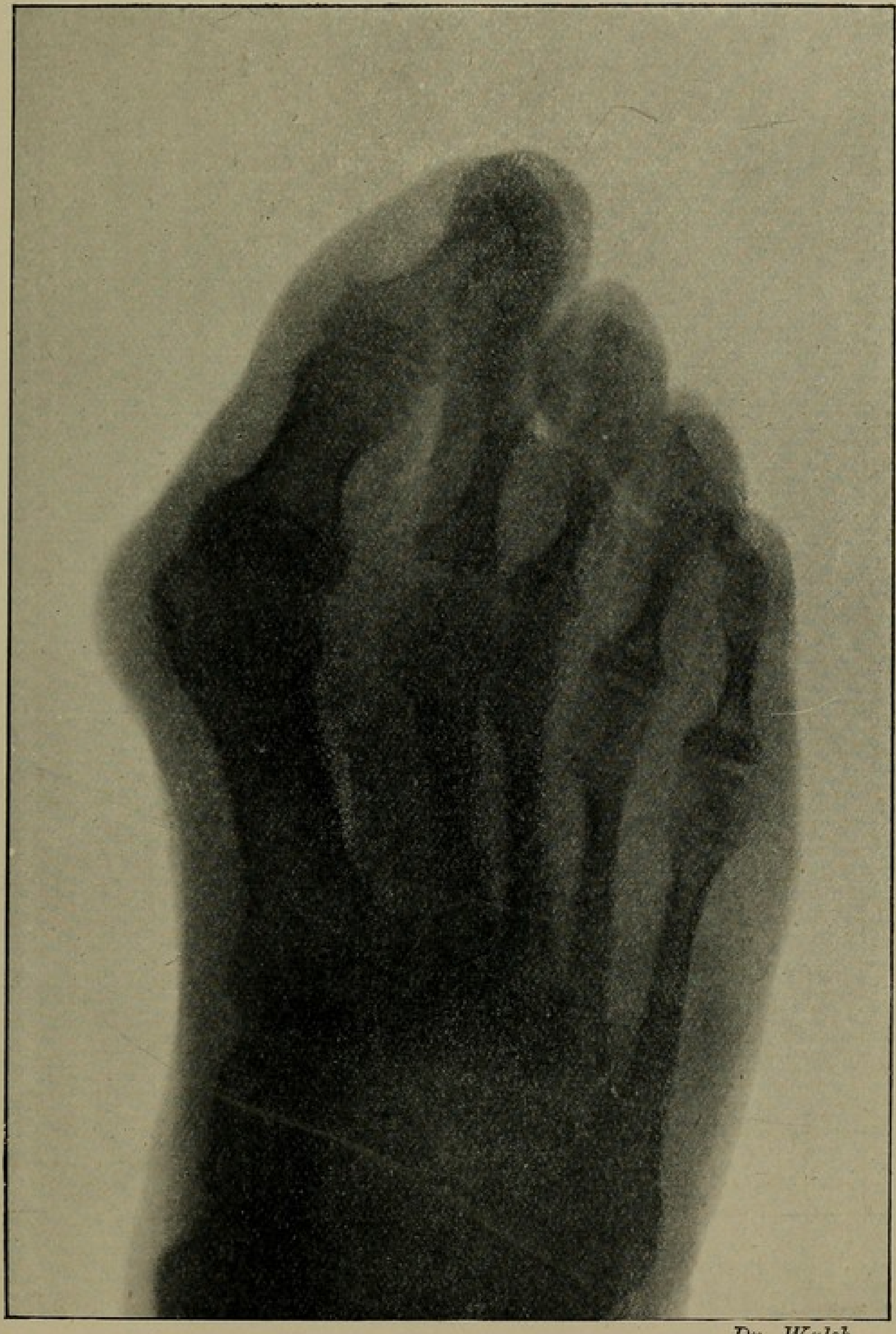


Fig. 82.—Feet of same Patient, showing Suppression of Toes and possible Reversion to Two-toed Type.

Tremor of one foot during exposure.



Dr. Walsh.

FIG. 83.—HALLUX VALGUS.
Subluxation Outwards of Proximal Phalanx of Great-toe.

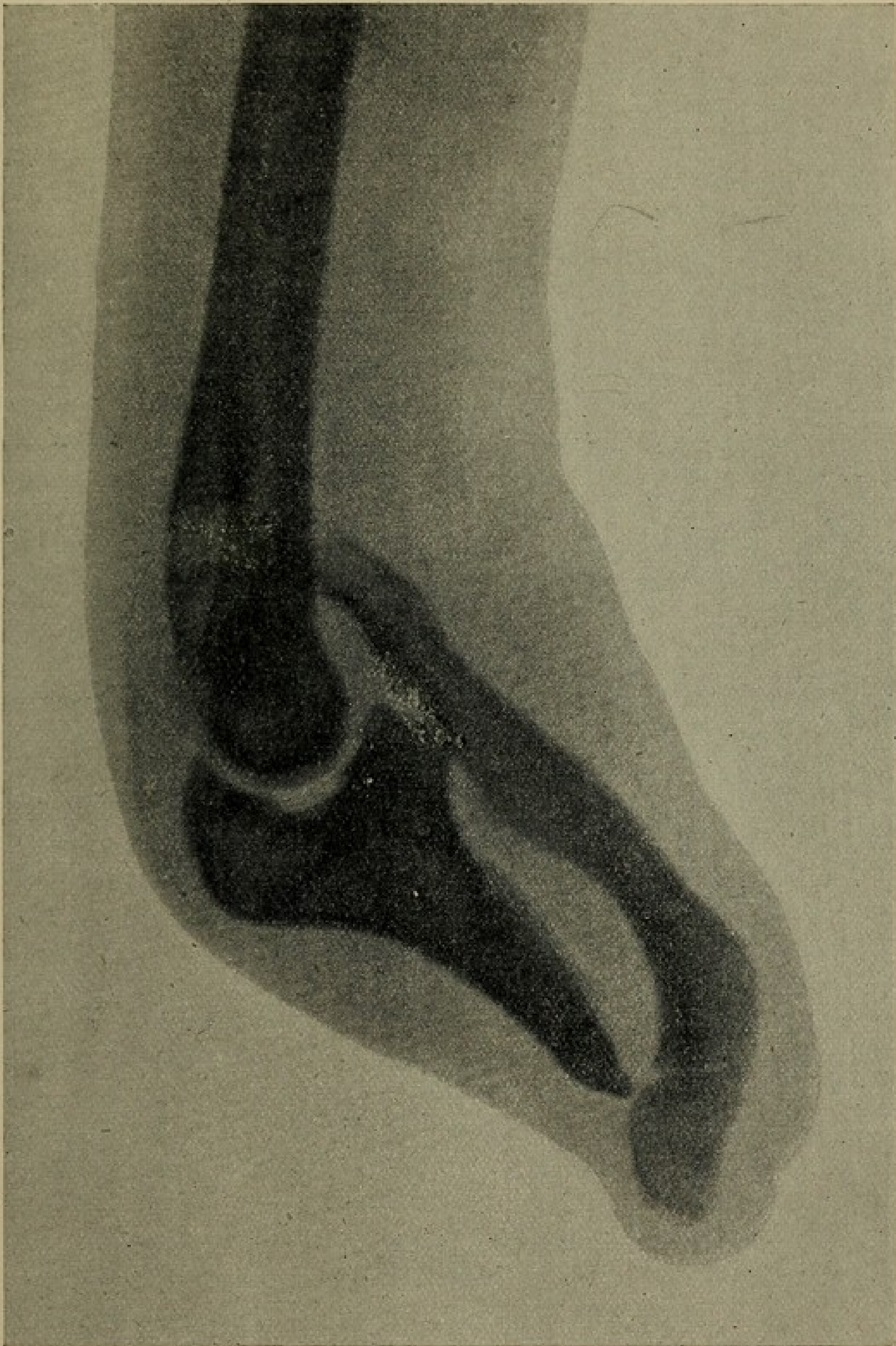


Fig. 84.—Dr. S. D. Clippingdale's Case of Deficiency of Development of Distal Portion of Upper Extremity.

The following is the description of a radiogram taken of the case:*

'The Röntgen photograph of this case was taken with the patient lying on her back, and the focus tube at a distance of 12 inches from the sensitive plate; exposure two and a half minutes. Several abnormalities appear in the photographic record. The first point that strikes one is the apparent absence of clavicles; but on closer inspection the shadow of two fragments can be seen lying in the position of the sternal ends of the collar-bones, that on the left side being longer. These shadows are so faint that it is unlikely they can be reproduced on a process block; their faintness is due to the fact that they are near the focus tube.† No trace of the outer side of the clavicle can be seen on the right side, but on the left there is a faint shadow on the photograph, which, from its size and position, suggests a cartilaginous rudimentary clavicle, with a more or less ossified inner end. The transverse process of the last cervical vertebra is so enlarged as to approach to a cervical rib.'

This patient, a girl of eight, also showed a depression in the upper part of the sternum. She could bring her shoulders together so as to meet in front of the chest. Her family presented the following abnormalities: Father had both clavicles in two pieces, the inner ends of the sternal fragments overriding. A brother, aged fourteen, showed a prominent arch forwards of left clavicle, and division of right clavicle, with inner fragment overriding; his last cervical transverse processes were prominent, especially on the right. Another brother, of nineteen, showed a prominent kink in both clavicles, but no division; his sternum showed a depression the size of half an orange. A sister, aged twelve years, had a divided right clavicle, with overlapping sternal fragment and an enlarged right transverse process of the last cervical vertebra. Another brother, of sixteen, had normal clavicles, but enlarged lower transverse cervical processes. Another sister, of five, was normal. Lastly, a brother of seven had a divided right clavicle, the ends of which were closely united; both the lowest transverse cervical processes were prominent. There was a history of club-feet in two of the family.

Dr. Carpenter gives references to seven published cases. To

* *Vide Lancet*, January 7, 1899.

† Perhaps also to their cartilaginous nature.

these may be added one described by Dr. Schorstein,* and published with an excellent full-page illustration of the plate taken at the London Hospital.

Cervical ribs can be readily demonstrated by the rays. A good case was recently described by Mr. Herbert Alderson, M.B.† The patient was a young lady twenty-one years of age, who complained of a swelling on the right side of the neck. A Röntgen photograph taken by Dr. F. H. Low showed two cervical ribs, that on the left being rudimentary, and consisting merely of head, neck, and tubercle, articulating with the transverse process of the seventh cervical, but without a shaft. The right rib was more developed, and possessed a shaft that passed downwards beneath the clavicle to the first intercostal space, where it appeared to join the second rib by a cartilaginous union. The shaft was divided by what seemed to be a false joint, which, from the history, might have been the result of a fracture.

Mr. Alderson quotes Professor Gruber, who collected seventy-six cases of cervical ribs in forty-five individuals, recorded between the years 1740 and 1809. To that number he adds a case met with in 1830 by Dymock, and published in the *Edinburgh Medical and Surgical Journal*, vol. xl.; and another in 1896 by Warren, in the *Boston Medical and Surgical Journal*.

To the foregoing may be added two fully-recorded cases by Dr. Danlos and Dr. Bonnarme.‡ Both were on the left side, the anterior end being free in the one case, and in the other having a subclavicular attachment, which appears not to have been exactly defined, but did not involve the collar-bone.

Anatomically, the vertebra is developed from eight points of ossification, three of which are primary and five secondary; sometimes it possesses an additional or costal centre of ossification. In the seventh cervical this makes its appearance in front of the transverse process, with which it usually unites about the fourth or fifth year. The abnormal development of this costal centre constitutes the cervical rib.

M. Blanchard has classified cervical ribs thus:

1. A complete rib, extending direct from the seventh cervical vertebra to the sternum.

2. A rib with cartilage joining that of the first rib.

* *Lancet*, January 7, 1899.
† *British Medical Journal*, December 4, 1898, p. 1638.
‡ 'Les Rayons *X*,' Paris, Num. 2 and 3, Février, 1898.

3. A rib with two osseous portions joined by fibrous tissue.
4. A rib with free end.

It is likely that cervical ribs are relatively more common than is recognised by anatomists, and that many such cases will be discovered by the Röntgen methods. The diagnosis is of some importance, as the abnormality may simulate aneurism or bony and other tumour, and may give rise to various symptoms by pressure upon nerves or bloodvessels.

Dress deformities may be demonstrated in a striking way by the Röntgen rays, which should place a new weapon in the hands of the advocates of rational dress. Thus, the distortion of the ribs due to the wearing of tight stays lends itself to this kind of illustration. Some time since a series of such radiograms was shown to the Académie de Médecine by Madame Gaches-Sarrante, a Paris physician. The Queen of Portugal is said to have produced some *x*-ray work in a similar direction. Boot deformities are also readily demonstrated, whether they take the form of dislocated phalanges, bone distortion or damage, bunions, or damage to the tarsal arch. The anatomical relations of an overriding second toe, with the condition of great-toe known as hallux valgus, can be studied in Fig. 83.

The various deformities due to hypertrophy and other changes in the structure of bone, as in rickets, gout, syphilis, Charcot's disease, have been already spoken of. They are all open to Röntgen ray exploration. The deformity of a hand due to rheumatoid arthritis is discussed on page 166.

(*e*) Diseases of Bone

As a bone casts a definite shadow under the Röntgen rays (when not obscured by the mass of surrounding tissues), it follows that bony outgrowths will do the same. In this way one can get a good *x*-ray record of osseous thickenings and exostoses. An outstanding enchondroma, when it consists of pure cartilage, will throw a faint shadow with a short exposure. As the growth, however, becomes ossified, it gives rise to a denser tracing on the sensitive plate. Subperiosteal thickenings, as in syphilis, may be readily demonstrated by means of the rays, and also the hyperplastic conditions met with in rickets and in Charcot's disease.

A good example of ossifying enchondroma is shown in Fig. 85.

It was taken from a man of about fifty who had sustained an injury to the hand many years previously. On a ray photograph the tumour presented the appearance shown in the figure. From its generally light shade, we may assume it to be composed either of spongy bone or of cartilage that has undergone partial ossification, the areas of the latter being shown by darker mottlings. An interesting point is that the form of the growth is distinctly traceable where it overlies the darker phalanx. This lighter colour may be due to its replacing the compact phalangeal tissue by new spongy bone. A somewhat similar appearance is to be found in Fig. 34, where absorption of the outer shell of the bone has followed the impact of a bullet. As already remarked, the record of spongy bones, such as the sesamoid, is comparatively faint in comparison with that of the medullated bones, an appearance that may be due to the relatively less amount of lime salts present. This difference is well shown in the pelvis, where the sacrum, a light spongy bone, appears faint by contrast with the deep shadows of the solid and compact iliac bones. Another observation that appears to bear upon this point is that of M. Potain, who recently reported to the Paris Academy of Sciences the occurrence of light spots on the radiograms of gouty bones.*

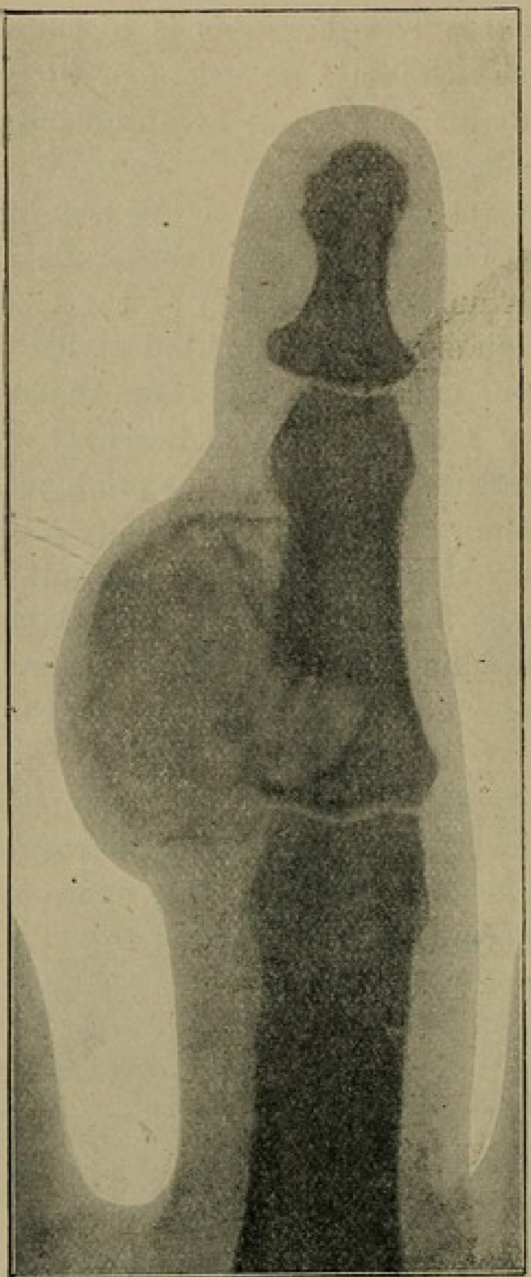


FIG. 85.—OSSIFYING ENCHONDROMA OF FINGER, OF OLD STANDING: FOLLOWING INJURY.

Messrs. Allen and Hanbury.

* *Medical Press and Circular*, March 10, 1897, p. 249.

Presumably, the compact tissue is more or less altered at the point of projection of these tophi.

This gouty translucency, if such a term may be applied, was explained by M. Potain in the following ingenious and suggestive manner: 'The change appears to be due to the substitution of urates for phosphates of lime. Comparing the different salts which enter into the composition of bone, they are found to be differently permeable to the Röntgen rays. Phosphate and carbonate of lime and chloride of sodium are little permeable, soda and magnesia more so, and urate of lime still more. By making use of two cardboard boxes, the one filled with urate of lime and the other with tribasic phosphate, and submitting them simultaneously to radiography, it is easy to ascertain that the urate of lime is eight times more transparent than the phosphate, because a precisely similar shade is only to be found where the thickness of the latter is eight times less than that of the former.'

In gouty bones, then, M. Potain concluded that the points where urates are substituted for phosphates become more transparent to the Röntgen rays. He further stated that the osseous thickenings due to chronic rheumatism or rheumatoid changes had an increased opacity. If these observations be correct, it follows that it is possible by means of the focus-tube to distinguish whether bony enlargements are the result of gouty or of rheumatoid changes. Assuming that the latter enlargements are more opaque, that condition must be carefully distinguished from the general atrophic state of the bones mentioned when discussing the hand affected with chronic rheumatoid arthritis, shown below in Fig. 86.

M. Potain has made the following practical application of his conclusions: 'In subjects affected with nodosities of Heberden, a lesion of which the gouty nature is still a debated question, very distinct transparent spots are found at the level of the phalanges, which appear to decide the dispute in favour of those who consider gout the primary origin of the affection.'

As regards the outlines of bones, then, the Röntgen rays may be expected to be useful in the hypertrophies due to syphilis, enchondroma, rickets, gout, and rheumatism, and also in the important class of subperiosteal thickenings. Thus, Heller has reported* a case in which a deposit of bone at the margin of a periosteal

* *Deuts. Med. Woch.*, 1898, xxiv., p. 74.

gumma was clearly shown by a Röntgen ray photograph. A beautiful example of a gumma of the ulna was exhibited at the 1898 meeting of the British Medical Association by Drs. Rainy and Stiles. It showed an irregular* erosion of bone in the centre of the growth, and a fresh formation (sclerosing osteitis) at the edges, and presented a clear picture of the macroscopical changes that were taking place.

The opacity of the rheumatoid peri-articular deposit is often well shown in a stiff ankle, while the opposite or general atrophic condition in the same disease is conspicuous in the accompanying radiogram, kindly placed at the disposal of the writer by Dr. J. R. Philpots (Fig. 86).

The subject of the photograph was a lady, aged thirty-one, who had suffered from the disease since the age of thirteen. Her father and mother both suffered from rheumatism, and a sister from osteo-arthritis. Her lower extremities were first affected, but later almost every joint of the body had been invaded, and some permanently stiffened.

On comparing the bones shown in this radiogram with those of a healthy hand, a marked difference will be at once detected. The rheumatoid bones look more fragile; in point of fact, they are atrophied, a condition which renders them more penetrable to the rays. Indeed, from their appearance, it may be pretty safely inferred that they are deficient in bone salts. Their outline is sharper and darker than normal, and their substance lighter. Their relatively small size—that is, for a person of that age—is doubtless due to the arrest of development from early disturbed nutrition. Their greater transparency can be best seen in the fifth metacarpal, whereas the darker look of other bones is most likely owing to the greater amount of tissue to be penetrated on account of the clawed-up hand. It will also be noticed that the bosses of ossified peri-articular cartilage on the phalanges are much of the same shade as the body of the bone. All the fingers are dislocated from the metacarpals. The base of the first phalanx of the fore-finger is apparently fixed against the distal ends of the second and third metacarpals, but the bases of the middle and third fingers appear to be partly wedged between the third and fourth and the fourth and fifth metacarpal heads respectively. The plate shows how a radiograph will afford anatomical data for the

* *Lancet*, April 15, 1899.

Fig. 86.—Hand deformed by Chronic 'Rheumatoid' or Osteo-Arthritis.
Somewhat reduced. Dr. J. R. Philpot's case.

explanation of such deformities. At the same time, however, it should be borne in mind that the proper reading of the facts of the radiogram is by no means always an easy matter. Lastly, it may be pointed out that the shadow of the thumb confuses the radial half of the figure.

Mr. Espin, of Newcastle, has noted a similar transparency in the bones of tuberculous subjects. In one case—that of a youth of sixteen, with a locked wrist following injury—he found 'the bones of the carpus ill-defined, and the ulna and radius, metacarpal bones and phalanges, abnormally transparent.' The transparency was in marked contrast with the appearance of the bones of the other wrist. His second case was that of a young man whose radius had been previously removed for tubercular disease, and who had also suffered from a tubercular abscess. On examination, he found that all the bones of both arms and legs showed an abnormal transparency.

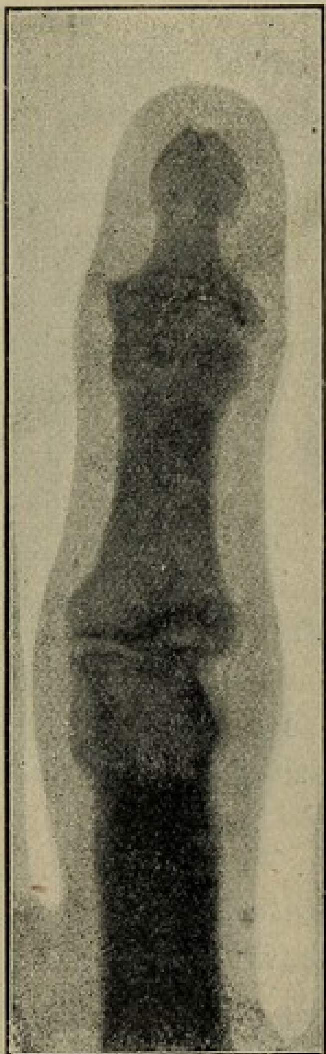


Fig. 87.—Finger of Cricketer, showing Absorption of Bone and Fibrous Adhesions of Joint.

Transparency, denoting malnutrition or atrophic changes, has been noted by various observers in such maladies as osteo-arthritis, osteomalacia, tubercle, and cancer, and also in the course of senile decay.

Another instance of absorption of bone, apparently after abscess, is the following: The patient, a healthy man, about thirty years of age, was struck by a cricket-ball at the end of the right ring-finger, which was painful and swollen for several months, and ultimately became stiff. Except for some awkwardness in writing, he suffered little inconvenience from the resulting deformity. Upon presenting himself at a Metropolitan hospital a radiogram was taken, which clearly showed osseous union at the terminal joint of the affected finger, while the base of the second phalanx was hollowed out, apparently as the result of an abscess. From the view here given (Fig. 87) it can be inferred that any union between the radial half of the joint surfaces is certainly fibrous, while that on the ulnar side is probably of the same nature.

The bony changes that take place in the various pulmonary and non-pulmonary osteo-arthropathies can be well demonstrated. A good Röntgen photograph of the hypertrophic non-pulmonary form of that condition was shown at the Edinburgh British Medical Association meeting by Dr. Steven, of Glasgow. The differing texture of the new and the original bone was well demonstrated in the record of the fresh osseous formation round the shafts of the radius and the metacarpal bones.

In subperiosteal thickenings the differing density of the new and the old bone is readily revealed by Röntgen methods. This contrast is especially conspicuous in cases where necrosis of the shaft is surrounded by an irritative hyperplasia of periosteal bone.

Hæmophilic Bone Conditions

The joint changes met with in hæmophilia can be studied conveniently by means of the rays. These enlargements are not infrequently diagnosed as cases of tubercular arthritis until the diagnosis is cleared up by aspiration. In one instance* a leg was amputated under the impression that the knee was affected with quiescent tubercular arthritis, and the patient, a boy of ten, died twenty-four hours later from uncontrollable hæmorrhage. Dr. Shaw gives an account of a case in the *Bristol Medico-Chirurgical Journal* (September, 1897). He describes enlargement of elbows and knees, which were attacked with acute recurrent peri-articular effusions, preceded by sensory phenomena. The afflicted joints were found on examination to be in a condition similar to that of osteo-arthritis, but, unlike that disease, it does not attack the fingers and toes. The articular ends of the bones were much enlarged, the cartilages extensively absorbed, with well-marked 'lipping' (osteoplasia) at the edges of the articular surfaces. An accompanying Röntgen photograph showed great enlargement of the head of the radius, some lipping at the edge of the sigmoid fossa of the ulna, and thinning of the articular cartilages. Other papers referred to are by Greig Smith (*Bristol Medico-Chirurgical Journal*, 1884, ii. 264) and Bowlby (*St. Bartholomew's Hospital Reports*, 1890, xxvi. 77).

* *Medical Record*, 1896, xlix. 336.

At the conversazione of the Röntgen Society in November, 1898, the author showed an x-ray photograph of two knees, one of which was subject to recurrent hæmophilic attacks. The case was sent by Dr. George Carpenter. The affected joint was hazy and indistinct in contrast to the sharp definition of the sound knee. A similar haziness is met with in other chronic periarticular affections, as in osteo-arthritis and tubercular synovitis, also in inflamed pleura and rheumatic muscles.

Fig. 88.—Knee in Hæmophilia.
Dr. Shaw's case.

Caries of Bone

Mr. Noble Smith* published an interesting case in which disease of the cervical spine was revealed by the radiograph. Various diagnoses had been made of the patient's condition, as, for example, hysteria. The Röntgen photograph, however, disclosed an irregular mass of bone replacing the upper four vertebræ of the neck. This evidence proved the existence of a severe lesion that had undergone extensive repair. Not only did it clear up the diagnosis of an obscure case, but it also yielded important indications for future treatment.

In another case recorded by the same surgeon, a provisional

* *British Medical Journal*, 1896.

diagnosis of caries of the cervical vertebræ had been suggested by the presence of torticollis and other signs and symptoms. However, the radiograph showed conclusively that the spine was not affected. This negative result warranted alternative positive conclusions as to the nature of the malady.

In some instances osteo-myelitis may be demonstrated by the rays. However, as pointed out by Geissler, the rarefactive change is in the majority of cases obscured by the shadow of the overlying necrotic layer.

The bone changes of osteo-arthritis were well illustrated by a case reported to the Paris Académie des Sciences by Professor Lannelongue.* A patient at the Hôpital Trousseau had been affected for several years with an osteo-arthritis of the knee-joint, which was anchylosed in an extended position. The diagnosis was fully confirmed by a radiogram, which showed hypertrophy of the lower end of the femur, together with atrophy of the upper epiphysis of the tibia. Between the two bones a light interval proved the absence of a bony union.

Fig. 89 shows a case kindly furnished by Mr. Lynn Thomas. The conditions of the knee-joint probably resulted from a former tubercular synovitis. There is extensive erosion of the tubercular surface of the femoral epiphysis, while the diaphysis is apparently healthy.

In a stiff joint, bony anchylosis usually shows under the rays as a continuity of osseous structure that is unmistakable. On the other hand, fibrous union, as we have seen, is inferred from the negative evidence of a light interval between the articular surfaces. Dr. Joachimsthal, of Berlin,† mentions a case in which a boy of sixteen had the knee excised. The site of the operation was examined by the Röntgen method eighteen years later, when the bones of the leg and thigh were seen to be welded together into one solid bone, bent at an obtuse angle. The compact tissue at the edges and the bars of the cancellous tissue both showed a perfect continuity. This adaptation afforded a good example of the change of structure and form that may follow altered function.

New growths in the substance of bone may at times be photographed by the Röntgen rays. The first case of the kind was recorded by König, who found a bright spot, with dark contour,

* Paris Thèse, No. 53, D. 23, Louis Laurent.
† *Therapeutische Monats.*, February, 1897.

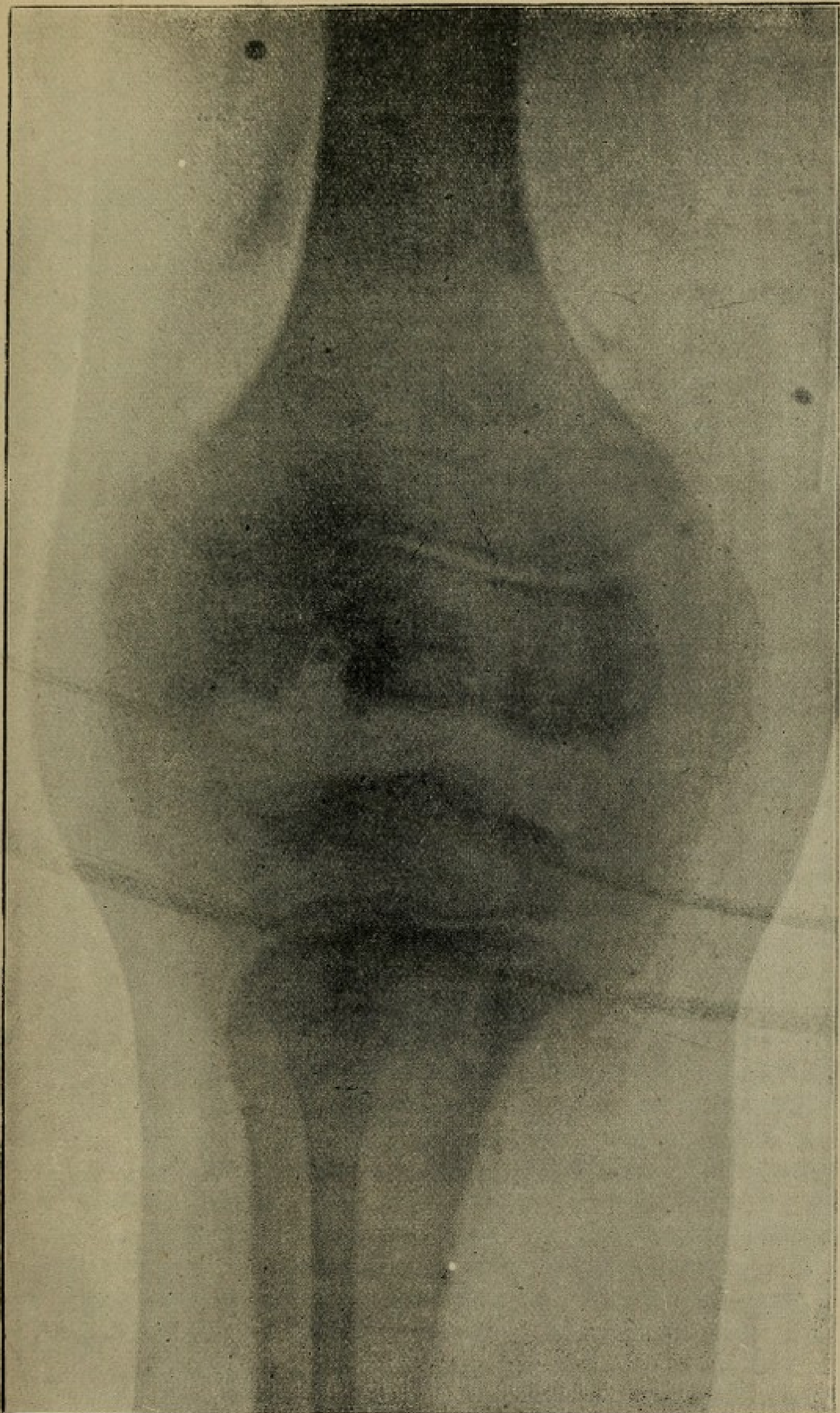


FIG. 89.—KNEE-JOINT SHOWING EROSION OF CARTILAGE OF FEMORAL EPIPHYSIS. SHAFT OF FEMUR HEALTHY.

Lynn Thomas.

the size of a shilling, in the upper part of the tibia to be due to sarcoma. Since that time many sarcomata of bone, central and otherwise, have been reported, some of them accompanied with fracture.

Dr. Richardson of Philadelphia says that by the aid of the fluoroscope he has been able to watch the growth of an osteo-sarcoma of the radius from day to day. His case is thus described :

'General W——, aged fifty-nine, had suffered for twelve months from a painful swelling of the right wrist. By means of the fluoroscope, the ulna was seen to be intact, the radius to terminate abruptly in the faint shadow of a carpal tumour. A thin shell of the radius could be seen remaining. The diagnosis of osteo-sarcoma of the radius, made from the history of the case and from inspection and digital examination, was practically proved by the fluoroscope and the skiagram. A previous consultant had assured this patient that the tumour was an aneurism of the radial artery. In a second skiagram, taken a month later, the shell of bone had entirely disappeared—a fact that demonstrated the bony origin of the tumour and the rapidity of its extension. The arm was amputated, and the disease proved to be an osteo-sarcoma of the radius.'*

Dr. Richardson of Boston has reported a case in which exploration of a tumour in the upper jaw of a woman of fifty-one revealed a sequestrum. Subsequent operation brought to light further extensive necrosis.

Bones in Leprosy and Syphilis

As an illustration of the unexpected way in which the x-rays come to the aid of science may be taken the researches of Dr. Ashmead, of New York.† For a long time there has been a dispute whether certain bone changes observed in Peruvian mummies were due to a pre-Columbian leprosy, the existence of which he denied. In the absence of radiographic evidence of absorption of the bones of the hand and falling in of the nasal bones, and of other bone changes connected with leprosy, he has confirmed the view already arrived at from other direc-

* *New York Medical News*, December 19, 1896.

† *The Canadian Journal of Medicine and Surgery*, vol. v., No. 3, March, 1899.

tions that there was no pre-Columbian leprosy in America. The conclusions of this most learned investigation, however, appear to point to the existence of pre-Columbian syphilis.

(*f*) Other Surgical Points

To ascertain Results of Osteoplastic Operation

An interesting case is recorded by Howard Lillienthal in which both the desirability and the results of a bone plastic operation were plainly indicated by the rays. His patient had lost the use of a leg after a severe injury. A radiograph showed considerable loss of substance of the body of the tibia. To remedy this state of things, the operation of tibio-fibular osteoplasty was performed by cutting through the fibula, and bending it over to lie obliquely in the long axis of the gap in the shin-bone. The successful result was proved some time afterwards by a Röntgen ray photograph, which revealed bony filling of the gap and restoration of the line of the fibula, with union of the two bones by an osseous bridge.

An important point is that when a piece of rabbit or other bone has been transplanted, the surgeon can ascertain whether it has or has not become established in its new position.

Ossifications of various kinds can be detected. Examples are those occasionally met with in muscle, as the adductors of a rider or the deltoids of a soldier, known respectively as 'rider's bone' and the 'drill-bone.' Another instance is the ossified insertion of the rectus femoris muscle in Charcot's disease.

A remarkable case of progressive myositis ossificans was reported in the *Lancet** by Dr. R. Crawfurd and Mr. Harry Lockwood. By means of radiograms, a tendency to overgrowth of normal prominences and processes was noted—a point of importance, as the new bony growths in the muscle are always in relation to the abnormal enlargements of protuberances. Microdactyly of the thumb was shown to be due to synostosis of the first and second phalanges. Another deformity, described as hallux valgus, present in both great toes, was really caused by synostosis of the metacarpal bone and the first phalanx. The latter deformity has been noted so often in relation with the disease, that the authors regard it as part and parcel of the malady.

* *Lancet*, April 15, 1899.

Ossifications of the costal cartilages are shown in old persons. One remarkable instance of premature ossification of the kind in a woman of twenty has been reported as disclosed by the rays.

Calcification of arteries has been shown in the neck and limbs. Atheromatous changes have also been frequently noted in the heart and larger deep bloodvessels.

The subperiosteal enlargements met with after injury in strumous subjects are well shown by the Röntgen rays. In one such case of 'strumous dactylitis' a boy of fourteen suffered from a swollen finger after a fall some weeks previously. A photograph taken by the writer revealed a considerable periosteal enlargement of the first phalanx of the third finger. The effused material, however, was not opaque as a whole, but showed a few granules, apparently of commencing calcification or ossification. The lower epiphysis appeared to be partly obliterated, probably owing to the tilting up of the inter-epiphyseal cartilage by the swelling of the finger, whereby the direct passage of the rays was prevented.

(*g*) Action of the Rays upon Micro-organisms

The Röntgen rays do not appear to exercise any injurious effect upon micro-organisms. Numerous experiments have been made. Thus, Professor W. W. Keen, of Philadelphia, reports* of pink streptococcus, anthrax, *Micrococcus prodigiosus*, *Micrococcus cereus flavus*, *Sarcina aurantiaca*, yellow sarcina, tubercle bacilli, that after exposures, first of half an hour, and then twice for fifteen minutes, neither lethal nor inhibitory effects were exerted upon the cultures. These experiments confirmed conclusions previously published by Dr. Davis in the same journal.

Berton† exposed bouillon cultures of the diphtheria bacillus to the rays for periods of sixteen, thirty-two, and sixty-four hours, but in no instance did he note any injury to the vitality of the organisms.

J. Brunton Blakie, M.B.,‡ as the result of numerous experiments carried out at the University of Edinburgh, concluded that the Röntgen rays have no visible influence on the growth of cultures of the tubercle bacillus, and that the delicate chemical

* *The American Journal of Medical Sciences*, March, 1896.
† *Bull. Gén. de Thérap.*, November 8, 1896.
‡ *The Scottish Medical and Surgical Journal*, May, 1897.

structure of diphtheria toxine, like the delicate chemical structure of the retina, is not affected by their vibrations. Similar conclusions were arrived at by Dr. Francis Pott with regard to the tubercle bacillus, which were unaffected by exposures of eleven hours' duration.

Different investigators have arrived at conflicting results. Thus, Dr. Rieder,* has reported an inhibitive bactericidal action of the x-rays upon cultures of diphtheria and tubercle bacilli, pyogenic cocci, and so on, with an exposure of one to three hours. He used various media on culture-plates beneath a sheet of lead with a round hole cut in it, and so arranged that the rays of a focus tube fell on one portion of the culture. Ordinary light was excluded by covering the aperture in the lead with black paper. He found that the various organisms flourished upon that part of the plate sheltered from the rays by the opaque leaden screen, while on the exposed part beneath the circular aperture they were either absent or feebly developed. From the fact that the gelatin was not liquefied, he thinks that heat was not the inhibitive agent; the chemical nature of the medium was not altered, as shown by the fact that cultures subsequently grew thereon; and ordinary light had been excluded by the black paper. His experiments are suggestive, and point to the possibility of inhibition of bacterial growth by the focus tube rays that are able to penetrate black paper, or to electrical influences.

Boromo† concluded that the rays are negative as regards chromogenic bacilli; that they quicken the sporulation of *B. subtilis*, and retard that of *B. anthracis*. At the fourth Congress for the Study of Tuberculosis, held in Paris in the autumn of 1898, the general opinion was that the rays possessed neither inhibitive nor destructive action upon micro-organisms.

Drs. Norris Wolfenden and Forbes Ross made a series of experiments with *Bacillus prodigiosus*. They found that up to the fifth generation the result of exposure of a culture for one hour to the x-rays was to increase the pigment-forming power, and to induce an exuberant growth.

That electricity exerts a strong modifying and germicidal action upon micro-organisms is well known, and that fact may possibly constitute the fallacy of experiment which accounts for the contradictory results reported by different observers. On the whole,

* *Münch. Med. Woch.*, 1898, No. 4, p. 101.
† *Bollett. della Soc. Lanc. degli Osp. di Roma*, xvii., par. i., p. 287.

the balance of probability appears to be that the x-rays produce no positive effect upon micro-organisms, and that apparent exceptions may be due to influences that have not been excluded by individual experiments.

III. MAPPING OF SKIN SURFACES

* In the course of certain experiments with the Röntgen rays the writer found that it was possible to obtain a record of the coarser fissures of the skin surface. The primary object of investigation was to note the results of radiographing *in situ* the commoner pigments and drugs applied to the skin. It was found that oxide of bismuth, powdered freely over the back of a finger, gave a good tracing of the creases over the knuckles. Following up this clue, a fairly perfect record was obtained of the skin surface, as shown in the plate at the beginning of this book. The best results were secured by kneading putty into the skin, then working up the surface with glycerine, and finally gently and smoothly rubbing with subnitrate of bismuth.

As to the practical value of such a skin map there is little to be said at present. That a record can be obtained in this way of every local peculiarity seems to be undoubtedly proved by the plate ; over the phalanx of the thumb a small convoluted cicatrix of the surface markings could be clearly seen in the original by means of a lens. Such a permanent record might be of value in the identification of criminals, after the fashion invented by M. Bertillon, of Paris. It seems more than likely, however, that a similar end may be obtained by far simpler means. A reference to the frontispiece of this book will show that the addition of the surface markings gives a striking perspective effect that is wanting to the ordinary radiogram. The lines are evidently due to the heaping up in the furrows of a substance opaque to the rays. Under the stereoscope the radiograms of a hand prepared in this way yield a most striking effect.

The surgeon does not always find it easy to cut down upon a needle, or other small object, even when it has been precisely localized by a Röntgen ray examination. In those parts of the body where well-marked skin furrows are found, it would be easy enough to reproduce them in the manner indicated. In that way a complete surface map, with lines of longitude and latitude, would be available as a guide to the knife of the operator.

* From the *British Medical Journal*, March 27, 1897.

B. DENTAL SURGERY

Now and then great practical help may be derived from the Röntgen rays in dental surgery. The teeth offer greater resistance than bone, and hence throw a distinct shadow when embedded in the less dense osseous substance. A good idea of the Röntgen ray photographs obtained from teeth can be gathered from the teeth shown in Fig. 90, taken from a private collection. They illustrate various pathological conditions, and may be briefly described, taken in series from above downwards, and in lines from left to right:

1. Upper molar, showing exceptional size of fangs and lateral carious cavity.

2. Upper molar, with carious cavity, nerve canals well shown.

3. Molar with carious cavity.

4. Molar with exostosis of fangs.

5. Upper central incisor: exceptional development of fang. Firmly united to its inner surface is a supernumerary tooth, faintly outlined in the radiogram.

6. Bicuspid: cavity of decay communicating with nerve canal.

7. Upper central incisor: showing sphere of erosion, which is indicated by a faint shadow at the neck of the crown. This curious pathological condition, the cause of which is not exactly known, is in its usual site partly above and partly beneath gum.

8. Upper bicuspid: eccentric distortion of fang. This shape is the result of pressure of neighbouring teeth in process of development. Absorption going on in centre of single fang is indicated by the darker area; that is, the thin plate of tooth substance has offered little resistance to the rays.

9. Upper central incisor: half the fang absorbed; small carious

cavity. This tooth is extremely opaque, shown by its relative white look and absence of dental canal tracing, a condition probably due to its necrosis.

10. Lower molar, with large amalgam stopping reaching nearly to apex of fang; that is to say, the filling is nearly all beneath the level of the gum. The metal shown by dense white patch. Compare this absolute density to the Röntgen rays with that of the preceding tooth.

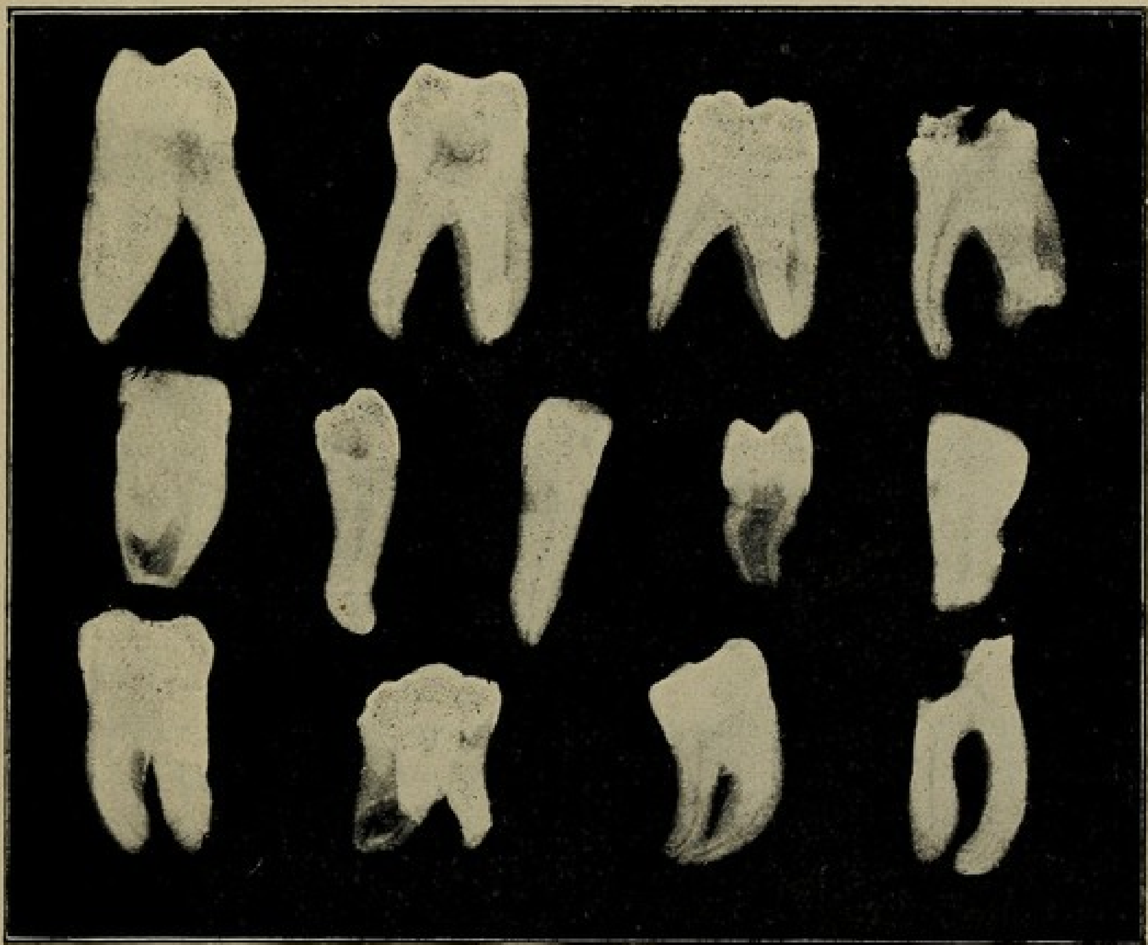


Fig. 90.—Skiagram of Teeth, showing Various Pathological Conditions.

11. Permanent upper molar: fangs absorbed by pressure of wisdom tooth, which was impacted between them.

12. Wisdom tooth: fangs sharply hooked.

13. Lower molar, showing convergent fangs and carious crown, rendering extraction difficult.

Mr. Frank Harrison published some of the earlier radiograms of teeth *in situ*. In the *Journal of the British Dental Association* for September, 1896, he has an excellent photograph of a portion of the lower maxilla of a girl of seven. The milk-teeth with their pulp-cavities and fangs are clearly visible, while below the roots of the first and second temporary molars are the permanent first and second bicuspids enclosed in their respective bony crypts. The internal dental structures of the lower jaw were displayed well-nigh as distinctly as would have been done in a dissected specimen.

Mr. Harrison observes: 'The *x*-rays promise to be of great use in dentistry, and will enable the dentist to observe in living tissues what was possible only a short time ago in the dead subject. The genesis of the teeth, the construction of artificial crowns, the anomalies of roots, the difficult eruption of teeth, and many other conditions of organs which are enveloped in tissue opaque under ordinary conditions, become visible by the illuminations of the *x*-rays.'

Dr. Kolle, of New York, has invented an ingenious little instrument for examining the teeth and alveoli, the dentiaskiascope, by which the operator is enabled to inspect teeth and their roots, one by one, with ease and comfort both to himself and to his patient.* It consists of a small fluorescent screen within an aluminium case, so placed that the screen-image is reflected upon a mirror, which the operator views through a tube. For taking photographs the screen is replaced by a protected sensitive film.

A number of interesting cases have been published from various parts of the world. Thus, Professor Amoedo† figured a lower jaw in which a wisdom tooth was planted at right angles to its proper axis, with the fangs buried in the ascending ramus. In the same journal M. Saussine‡ described a rare case in which an upper lateral incisor in a child of twelve lay horizontally in the bone with the fang pointing backwards. By an *x*-ray examination it was ascertained that the fang reached within 2 millimetres of the floor of the nasal fossa, and the appropriate treatment was indicated.

In one important particular the rays have proved of great service to the dental surgeon, namely, in the deformities of the jaws due to or connected with non-erupted teeth. In such cases he can ascertain with exactitude the position, shape, and size of

* 'The *X*-Rays,' by F. S. Kolle, M.D. New York, 1897.

† *Les Rayons X*, 2 Avril, 1898. ‡ *Ibid.*, 5 Mars, 1898.

the teeth within the bone. From the information thus gained he is able both to plan and to perform his surgical operations with exactitude, whereas under previous methods the most skilful man had to act upon probabilities. Lastly, two pathological conditions in which the new method will be now and then invaluable are the tooth-bearing cavity in the substance of the jaw, known as the 'dentigerous cyst,' and abscess of the antrum.

The method to be pursued in securing an x-ray photograph of the teeth in the living subject has been already described on p. 69.

C. NASAL AND THROAT SURGERY

There are several ways in which the specialist in nose and throat diseases may gain useful information from the rays. Foreign bodies may be detected in both cases. In the nasal cavity exostoses and abscesses of the antrum may be demonstrated either by a photograph or according to the method introduced by Dr. J. Macintyre, much on the lines of Kolle's 'dentiaskiascope.'

In describing this method of examining the hard and the soft tissues about the bones of the face, and those of the neck and larynx, Macintyre writes: 'The fluorescent screen is placed inside the mouth, and the lamp outside. Small discs of glass are coated with the salt and covered with aluminium, or, again, tongue-depressors, consisting of flat strips of glass covered and coated in the same way, may be employed. By placing the tube outside I am able to get an image of the septum and other parts of the cavity of the nose on the fluorescent screen in the mouth. In the same way the roots of the teeth may be seen. If the surgeon desire to examine the parts below or above the jaws, he simply puts the Crookes' tube below or above, and passes the rays through the tissues. If he desire to examine the tissues externally—that is to say, to pass the rays through the neck—he places a small fluorescent screen on one side and removes the Crookes' tube to a suitable distance. By this means I have been able to demonstrate the presence of foreign bodies, and need hardly add that they are more easily photographed.'*

Monnier† was able to discover by means of the Röntgen rays the cause of a chronic nasal suppuration, accompanied by

* *Glasgow Hospital Reports*, 1898, p. 306.
† *Archiv. Internat. de Laryngologie*, No. 3, 1898.

epiphora on the same side. The trouble was due to a lacrymal sound that had been broken off, and remained in the lower part of the nasal duct for no less a period than forty-two years. Partial occlusion of the trachea from the pressure of an enlarged thyroid gland has been reported, also cancer of the œsophagus.

The rays have not hitherto achieved much in the ear, but it is likely that abscesses in the mastoid region could be detected. At the Röntgen inaugural meeting in November, 1897, Mr. Griffith Wilkin showed some good ray photographs of detached temporal bones. The present writer has obtained excellent figures of the semicircular canals in infants. It seems likely that the presence of inter-cranial abscess in that region might be ascertained and its exact whereabouts localised for surgical purposes.

D. MEDICINE

IV. REGIONAL

(*a*) Thorax and Abdomen

It is still true that the most striking practical applications of the rays have been made in surgery, but at the same time there can be little doubt that the future has in store a brilliant field for Röntgen photography in clinical medicine. In the thorax a great deal has been achieved by demonstrating changes in outline of the heart and aorta, as well as in the substance of the lungs, mediastina, and pleura. As to the abdomen proper, results have so far not been very encouraging—at any rate, in the adult. It may be confidently hoped, however, that before very long we shall be able to explore all internal regions with fair accuracy.

Good results as to internal organs can be obtained in the case both of small lower animals and of children. In the illustration of the half-grown cat (Fig. 91), the windpipe and its divisions into bronchi bifurcating in the substance of the lung are well and clearly shown. The heart is outlined in front of the chest, and, so far as one can judge, the bones of the sternum are visible through the less opaque cardiac substance. The delicate shoulder-blade is well recorded, and the lower margin of the thoracic cavity sharply defined by the edge of the midriff. In the head, the fangs of some of the teeth can be seen in their bony sockets, especially in the molars of the lower jaw. The cartilages of the nose and the ears are faintly shadowed, and various muscular and tendinous structures can be made out in the neck.

The abdomen of this cat was by no means so clearly mapped out by the rays, but, nevertheless, contained several valuable indications. The main mass of the liver, for instance, was sharply outlined in its upper, but diffuse in its lower margin, while a light space beneath it corresponded with the stomach. The broad light band that curved from the centre of the diaphragm

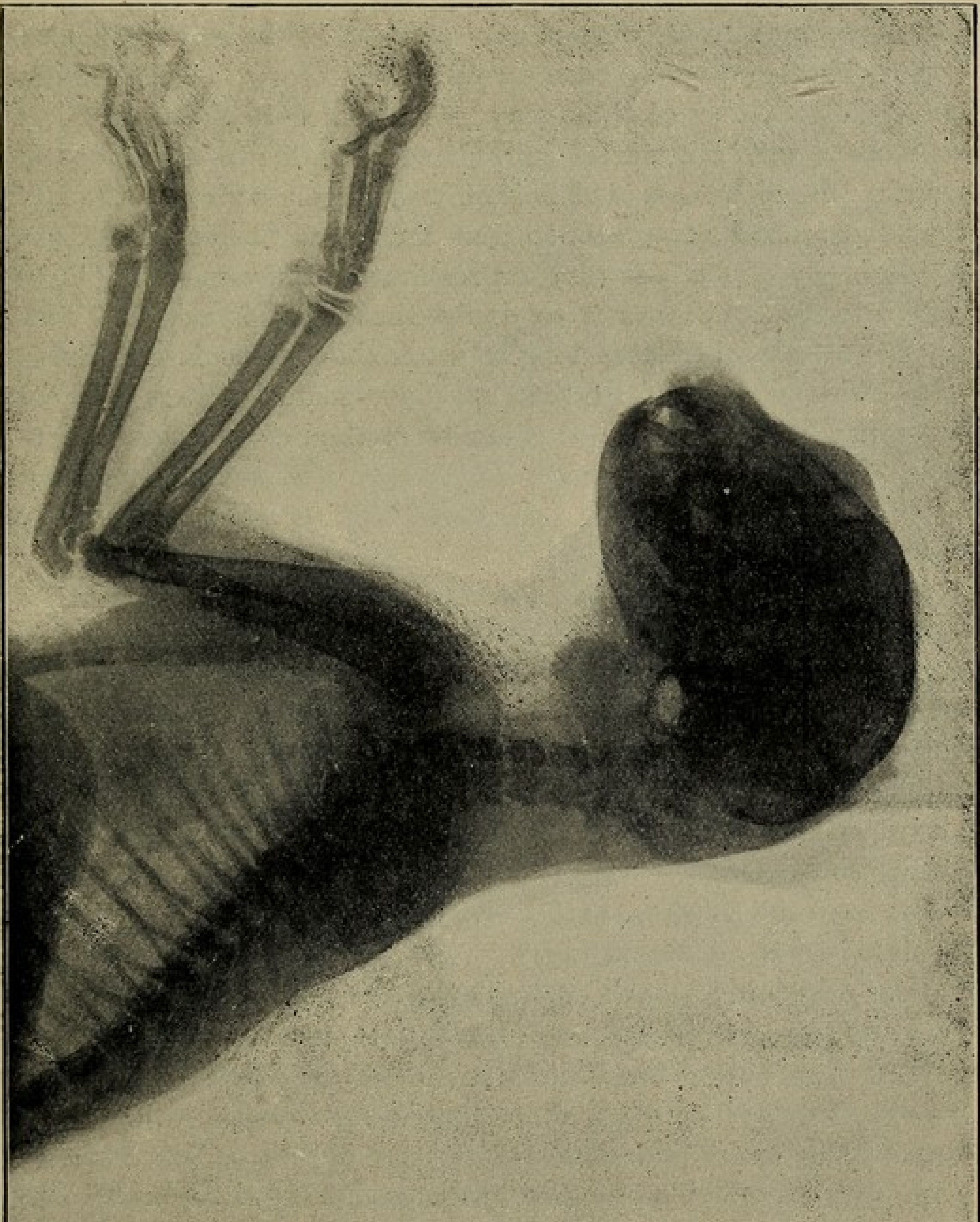


FIG. 91.—HALF-GROWN CAT, SHOWING BRONCHI, LIVER, HEART, ETC. Reduced one-half. By Mr. Cox, Parkstone.

to the lower part of the lumbar spine appeared to represent large intestine. Other convolutions of intestine were clearly shown, especially in the case of a coil of gut that had an extremely light record near the pelvis. This knuckle of intestine had, most likely, been full of gas, and had lain close to the surface of the sensitive plate during exposure.

The tendons, passing from the leg to the os calcis behind, and to the instep in front, were plainly pictured in the original print.

This photograph has been dwelt upon at some length because it gives a good idea of what may be hoped for in the future. It was taken with a powerful coil, giving a spark of over a foot in length. Its clearness of definition was largely owing to the fact that the animal was dead, so that there was no blurring of the shadows by the circulatory or respiratory movements. There seems to be little reason to doubt that what is possible with lower animals will before long be attainable in the case of living adult human beings, so that all deep-seated organs will be brought within the reach of this new method of exact investigation. In other words, the Röntgen rays will some day render to medicine services not less conspicuous than those already conferred upon surgery.

Dr. Macintyre,* who was the pioneer of deep tissue work in this country, has laid down the following rules: (1) A powerful current, 30 to 33 ampères, is necessary, so as to take the photograph instantaneously. (2) The transformer needs a large coil, which will give a 6, 8, or 10 inch spark. (3) It is best to use a small focus tube, which may require prolonged heating. (4) Rapid exposure is absolutely necessary. (5) A mercury interrupter is useful, instead of a spring. He usually places the lamp about 3 feet from the sensitive plate. This distance gives a well-defined shadow, but requires a strong light.

Dr. Campbell Thomson,† Medical Registrar of the Middlesex Hospital, some time ago observed that the fluorescent screen is quicker and better for clinical purposes. By that means it is possible to clear up many difficulties, such as exist in aneurism both of the heart and of the first part of the aorta. He has given several valuable practical hints upon chest radiography. To get a fixed location-point, he suggests a metallic button placed over the nipple, to which it may be secured by a piece of sticking-plaster. In order to secure a record of what is seen in the fluoroscope, he fastens to the back of the fluorescent screen a sheet of white paper, through which the rays would of course pass. He

* *Lancet*, August 22, 1896. † *Ibid.*, October 10, 1896.

then slides a flat metallic pen or pencil between the chest and the paper, and on the latter he traces the outline as projected in the fluoroscope. It need hardly be added that to carry out this manœuvre the observer would have to continue looking at the screen, so as to ascertain and control the movements of the opaque pen or pencil.

The shadow of the heart is lighter at the pulsating margin. Between it and the liver, upon taking a deep breath, a light interval appears. From the front of the chest the whole of the cardiac outline can be seen; but much less from the back, as the view is obstructed by the spine. From the back a definite shadow with well-marked external border can be seen on the left, and a smaller and less intense shadow, corresponding to the right auricle, on the right of the spine. Outside the body the valves of a heart emptied of blood can usually be well seen. Sometimes the valves, particularly of the right side, can be seen *in situ* in the living subject.

With the fluoroscope on the front of the chest, the position and outline of the heart is materially altered by deep inspiration. The normal state of affairs is thus well described by Dr. F. H. Williams:* 'In health the diaphragm lines move as follows: Quiet breathing, ½ inch; full inspiration, 2½ to 3 inches, a little more on the right than the left side. In health the outlines seen on the left of the sternum are as follows: A part of the aorta in some patients may be observed in the first intercostal space; in the second intercostal space a portion of the pulmonary artery; the left border of the ventricle is chiefly seen in full inspiration when the apex and a portion of the lower border are also visible; the maximum pulsation is at the point corresponding to the cavity of the ventricle, about where its outline crosses the fourth rib; during full inspiration the heart moves downwards towards the sternum. To the right of the sternum the outline of the large vessels is seen, and, less distinctly, the right auricle between the second and fourth ribs.'

From the front, then, the heart-shadow fuses on the left with that of the sternum, beyond which the right auricle projects from the third to the fifth ribs; on the right the auricular and

* See Paper at Montreal Meeting, British Medical Association, by F. H, Williams, M.D., Boston, U.S.A.; *British Medical Journal*, April 16, 1898, p. 1006.

ventricular line runs with a bold indented curve from the second to the sixth ribs. This latter line is raised and pushed upwards and outwards by the rising of the diaphragm in expiration. On the other hand, it is elongated and carried downwards and inwards towards the sternum in forced expiration, when a light fine falciform line or a broad band defines the apex and more or less of the lower border. Ordinarily the lower portion of the heart-shadow merges into that of the liver.

The shadows, whether seen from the front or the back, can be conveniently recorded on one of the author's clinical diagrams.

If a photograph be taken of the whole heart, it is best taken with the sternum next the tube.

The original of the accompanying radiogram of the thorax was taken early in 1897 from a boy of fourteen, lying on his back. The exposure was twenty minutes, distance of tube from plate 30 inches, spark 6 inches, Apps coil. A similar result would now be obtained in a period of, say, half a minute up to three or four minutes.

It should be borne in mind that fluoroscopy is an art that requires patient study. The education of the eye to recognise objects of varying opacity on the screen can be obtained simply and solely as a matter of practice. A similar observation is to a less extent true of the reading of ray photographs. Nor is it less obvious that the physician who wishes to avail himself of this branch of diagnosis must make himself familiar with the screen appearances of the heart and great vessels, and their relation to the chest walls and midriff, as above described. He must also learn to appreciate the variations of shadow produced by shifting the focus tube or the patient.

(*b*) Heart and Great Vessels: Aneurisms, Enlargements of Heart, and so on.

The fact that the lungs are full of air and easily permeable to the rays makes it possible to get a good outline of the human heart. As the result of a number of experiments on the dead body, Pöch demonstrated to the Vienna Gesellschaft in January, 1897, that it was possible in the empty heart to make out the valves and trabeculæ as clear spaces against a darker cardiac background. When the heart, however, was full of water or of blood no such differentiation could be made.

This relative opacity of blood is an important quality so far as concerns the Röntgen diagnosis of alterations in the form of the heart and bloodvessels. The reason why a bloodvessel should resist a long exposure is obscure. We know that after prolonged exposure both biliary and uric acid calculi will cease to cast any shadow, while a rib nearly ceases to do so, and a phosphatic shadow becomes much lighter (Dr. Swain's experiment, p. 119). Mr. C. W. Mansell-Moullin mentioned to the writer a case in which the abdomen was exposed for two hours. The bones left no record, but the abdominal aorta threw a strong shadow.

The future development of internal photography by Röntgen methods will greatly depend on the quickening of processes. The widespread movements of respiration affect more or less the whole contents of thorax and abdomen, while the heart and great vessels, normal and abnormal, are in a state of intermittent activity. Instantaneous photography, were it possible, would enable one to ascertain the exact position of any movable internal part at any fractional time within its periodical range of movement. Thus, some forms of rapidly expansile aneurisms are recognisable on the screen, whereas they cannot be photographed; nor can the latter result be hoped for until the instantaneous photography of the thorax is an accomplished fact.

So far as concerns the respiratory movements of the chest and abdominal walls, the present writer has now and then obtained satisfactory results by causing the patient to fix the part to be photographed by leaning it against a chair or other firm object, upon which the plate was placed. Thus, in taking gall-stones or a tumour in front of the kidney, the patient stood upright and leant against a projecting angle of wall; in examining an asthmatic lung, the patient sat astride a high-backed chair, against which one side of the thorax was pressed.

Dr. Disan* has introduced an ingenious method of recognising alterations in the cardiac outline. First of all he marked on the chest what should be the normal shape of the heart, and mapped out the area thus obtained with a copper wire, which he fastened to the chest with ordinary plaster. He then examined with the fluoroscope in the following way:

* *Dominion Medical Monthly*, February, 1897.

'At first the greatest strength of current obtainable from the apparatus is turned on. The observer then looks through the fluoroscope, and gets the chief landmarks of the chest—such as the scapula, ribs, spine and convexity of liver—the wire being at the same time in view. The current is then reduced until the heart becomes visible. The fluoroscope is applied to a spot marked at the left of the spine corresponding to the fourth intercostal space in front of the chest.'

In a case, under Dr. Coupland, of doubtful deep aneurism of the chest, the diagnosis was cleared up by the fluoroscope. From the front, slight hypertrophy was noted, and just above the junction of the left cardiac border with the sternum a faint indefinite shadow. From the back, a well-defined shadow was seen on both sides of the spinal column, at about the level of the fourth dorsal vertebra. On the right border this outline was convex and pulsating; the intensity of the shadow on that side was almost the same as that of the heart, while on the left it was lighter and less definite. The evidence thus obtained converted a doubtful into a certain diagnosis.

The pulsating margin of a non-cardiac shadow in the thorax other than fluid, of course, points to aneurism. The observer, however, should remember that bulgings are not uncommonly found in the aorta, and that movements may be communicated to tumours or enlarged glands.

Aneurisms may at times be detected by the rays in the thorax when their presence could not be demonstrated by percussion and auscultation. Several cases of unsuspected thoracic aneurism revealed by the screen have come under the observation of the present writer. In one instance he took a Röntgen photograph of the chest of an elderly asthmatic of heavy build. A good-sized aneurism was seen in the left upper thorax, where, owing to the large and emphysematous lungs, it could not be diagnosed by ordinary physical signs. Indeed, an experienced physician subsequently denied in court that an aneurism existed.

A dilated aorta can be seen from the back on the left side of the vertebral column. Bouchard says that when aortic insufficiency is present, pulsating aortic shadows are visible on both sides of the spine—that is, in the ascending and the descending portions of the aorta.

Hypertrophies of the heart are readily examined on the screen. In those of the left ventricle the apex elongates, and the clear space usually seen between the heart and liver on deep inspiration is either diminished or disappears altogether.

The screen phenomena of right-sided hypertrophy are thus described by Régnier: 'In hypertrophy of the right ventricle, the heart, drawn down at the base, tends towards a horizontal position. When the right ventricle undergoes excessive enlarge-

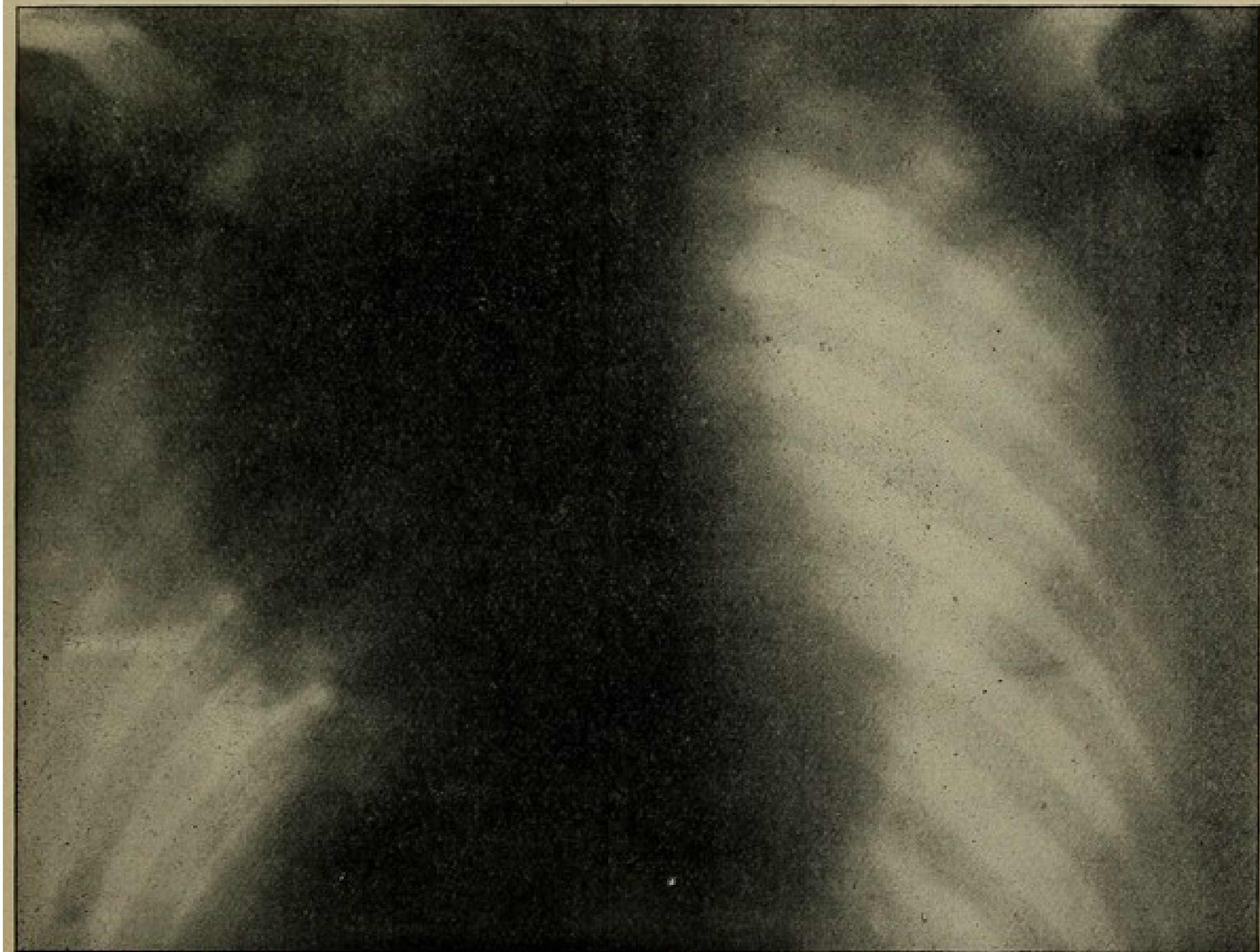


Fig. 92.—Aneurism of Aorta in which Physical Signs were absent. (Diagnosis, aphonia from recurrent laryngeal neurosis. Large fusiform aneurism involving entire arch of aorta. J. M. Scott, M.D., *American X-ray Journal*, July, 1898.)

ment, there may be twisting around the longitudinal axis of the heart, and the right ventricle is pulled to the front. One recognises that fact on the screen because the shadow of the right heart becomes more distinct when the patient is examined from the back than from the front. There may also be a twisting of the heart around the vertical axis of the body, the base being directed backwards and the apex to the front. This twisting is visible when one examines the patient from the left side: the cardiac cone is then sharply shown in its whole length. In compensatory hypertrophies of the heart from sclerosed arteries or renal cases, the auricles can be seen beating to the left of the sternum.'*

Dr. Régnier mentions a case which he saw under Professor Potain. The patient suffered from acute dilatation of the heart, and the condition was registered on several Röntgen photographs, which, in spite of their want of sharpness, nevertheless enabled one to follow the gradual disappearance of the dilatation and to preserve a graphic record of the occurrence.

Transposition of the Heart.—Many instances of this congenital abnormality have been published. When the heart is pushed over to the left side by the pressure of effused fluid, it is readily seen in its new position. An excellent illustration of a right-sided cardiac displacement in pyo-pneumothorax is given on p. 94.

Supposed Action upon the Heart.—Mr. Bezley Thorne† has made an interesting observation in relation to cardiac radiography. He noticed that the heart shrank visibly after thirty minutes' exposure to the Röntgen rays. In one case the lessening amounted to no less than 2 inches in the long axis of the viscus, and 1½ inches in the short diameter. There may, of course, be some fallacy involved in this observation. For instance, it is known that increased exposure to the rays or an alteration of current in many cases means greater penetrability of any given substance. So that the appearance of a light zone round the heart towards the end of a long exposure might mean that so much of the muscle had become fully penetrated, or that the electrical conditions had changed. In either case the dark core would probably represent blood or dense muscular tissue, or both.

Should, however, actual contraction be proved, it points to possibilities of importance. Without venturing too far afield in abstract speculations, it seems tolerably clear that, assuming such contraction, there might be direct tonic influence on heart muscle, while traumatic injury to deep organs from the Röntgen exposures might be connoted.

* 'Radioscopie et Radiographie Cliniques,' Dr. Régnier. Baillière, Paris, 1898.

† *British Medical Journal*, vol. ii., p. 1238, 1896.

Atheroma of the Aorta

Atheromatous patches have been demonstrated in the aorta, and are usually seen better on the screen than by means of photographs.

An interesting study in therapeutics has been made by Professor Grunmach. By means of the fluoroscope he traced the action of digitalis upon the heart in aortic and mitral insufficiencies, and other conditions resulting in cardiac dilatation and hypertrophy. He also made the practical suggestion that the action upon the heart of various medicinal and toxic drugs might be studied by means of the Röntgen rays.

(*c*) Lungs and Lung Diseases: Pleurisy, Pneumonia, Phthisis

On December 7, 1896, Professor Bouchard read a paper before the French Académie des Sciences on 'Pleurisy in Man studied by the Help of the Röntgen Rays.' He pointed out that the thorax, viewed from behind by a phosphorescent screen, when traversed by the rays, showed to the right of the spine and towards the middle of the dorsal region a pulsating shadow of the heart. At the same time the liver could by means of its shadow be seen rising and falling in the chest cavity as it followed the respiratory movements. Apart from the shadows of bones, heart, and liver, the rest of the interior of the thorax was transparent.

In a right-sided pleurisy with effusion, Bouchard found a darker shade on the affected side of the chest as compared with that of the sound. Further, the shadow indicated the upper limit of the effusion, as proved by percussion and by other ordinary methods of physical diagnosis. The tint, moreover, grew deeper from the upper border, where the layer of effusion was thin, to the lower part, where the shadow merged into that of the liver.

In three cases he also noted to the left of the vertebral column a triangular shadow, the base of which was continuous with the heart. This he explained as the mediastinum pushed over sideways to the left by the effusion. In a fourth case, retraction of the affected side had drawn over the mediastinum to the right.

In a further communication to the Academy (December 14), the Professor remarked that, in most of the cases of pleurisy with effusion previously described, he had noted with the fluoroscope that the lighter area increased from above downwards as the effusion lessened. In one case, however, the apex of the chest retained its shadow. This fact suggested consolidation of the lung at that spot, a suspicion that was confirmed by percussion and auscultation. In other instances tubercular deposits were localized by the same method.

'In all tuberculous subjects,' writes Dr. Bouchard, 'examined by the phosphorescent screen, I have established pulmonary lesions by a shadow, the area of which corresponded with that mapped out by other methods of physical examination, and the intensity of which was in relation to the gravity of the lesion. In two instances the appearance of clear spaces pointed to cavities, a diagnosis verified by auscultation. But in a third case, where auscultation led one to suspect the existence of cavities, nothing of the kind was visible on the screen. In another patient the general symptoms pointed to early phthisis, but no tubercle bacilli were found in the sputa, and the physical signs were indecisive. The skiascope showed that the apex of one of the lungs was less permeable to the rays, and in a few days both auscultation and bacteriological examination of the sputum yielded positive results.'

Some no less important reports were published by the same observer in the succeeding issue of the *Comptes Rendus* (December 28). In one case the whole left lung was obscured. This appearance was attributed either to pleurisy with effusion, or to general tuberculosis of the left lung. On further examination it was noted that the mediastinum was not pushed to the right. By a process of exclusion, therefore, the diagnosis of tubercle of the whole left lung was arrived at. In another case, on the left of the spinal column in a little girl, was demonstrated a tumour, due to adenoma of bronchial glands. In a third patient, a dark shadow on the right side of the chest, continuous with that of the sternum, was shown to be due to a transposed heart. Owing to the heart's impulse being on the right side, the presence of aneurism had been suspected. Other conditions recognised include aneurism of the arch of the aorta, with a clear view of its position, outline and size; pulsation of the aorta to the right

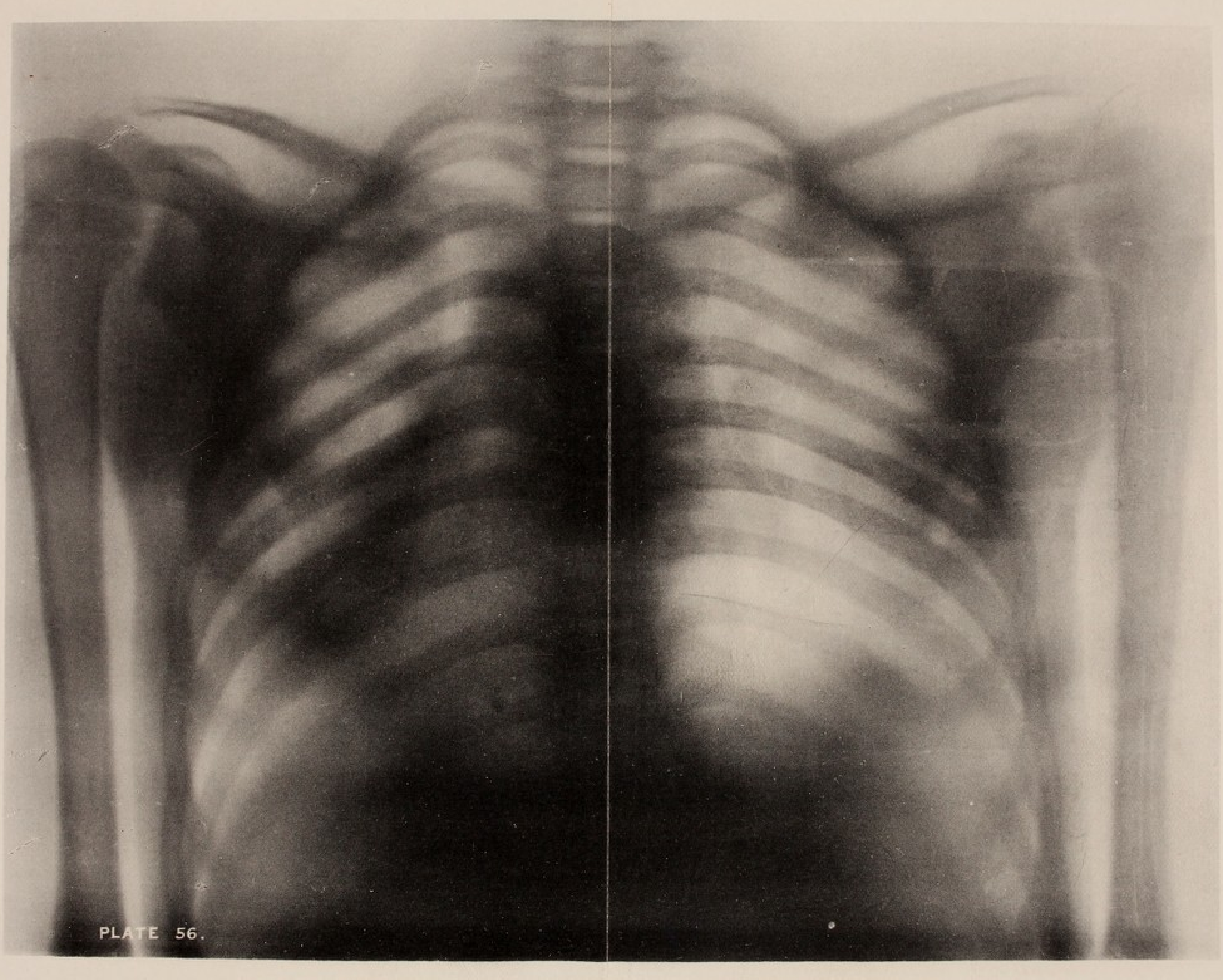


PLATE 56.

and left of the sternum; compensatory hypertrophy of the heart in arterio-sclerosis; and beating of the auricles to the right of the sternum, in dilatation due to kidney disease.

Bergoiné has repeated and confirmed the above observations.*

At the Medical Club in Vienna, in January, 1897, Professor Wasserman showed two cases that he had diagnosed by the Röntgen rays. The first was a case of phthisis in the right lung, where the cavernous signs could not be elicited by percussion and auscultation. Under the rays the left side of the chest appeared clear and healthy, while the right exhibited diffuse shadows representing infiltration; in one place a clear area, which to all appearance corresponded to a cavity, was brought out by the tube when applied either in front of or behind the right lung. The second case was that of an aneurism in the left mediastinum, where the fluoroscope demonstrated a dark space, the margin of which moved with a distinct impulse, and thus established the differential diagnosis between solid tumour and aneurism.

Lévy Dorn examined with the screen the chest of a patient suffering from chronic bronchitis and asthma. He observed that the left half of the diaphragm fell rapidly at each inspiration, while it rose by slow successive stages. The right half, on the other hand, remained from the first absolutely fixed in the position of extreme inspiration, only to rise at the termination of the attack with the expectoration of viscid mucus.

Tubercle of the lungs may sometimes be found by the Röntgen rays in an early stage, when it could not be detected by ordinary means. The importance of such early diagnosis in these days of improved treatment of pulmonary phthisis can hardly be overestimated. Another fact is that the rays not infrequently show the disease to be more extensive than had been mapped out by physical examination. When Koch's tuberculin treatment for consumption was on its trial, the writer recalls a case in which tubercle was diagnosed in the right apex, but careful and repeated examination revealed none in the left lung. The injection of the drug was followed rapidly by the appearance of a dull area at the left apex. Had the focus tube been available in that instance, there can be little doubt that the early invasion of the left lung could have been equally well demonstrated.

The localization of diseased areas in the lung is now brought

* *Gazette des Hôpitaux*, January 7, 1897.

within the reach of the surgeon, who has bitherto been hampered in his attempts at lung surgery by the often misleading nature of physical signs. Supposing a shadow to be fairly defined, its exact position could of course be localized by ordinary means. The altered density of tissue may show in various degrees from a slight haziness to a dark shadow; when extremely dark it is usually due to pleuritic thickening and adhesions. In tuberculous cases the collar-bone is often partly, or even at times altogether, obscured. A cavity, when empty, shows as a clear space. Pulmonary echinococcus has been noted.

An important case has been reported by Messieurs Varcot and Chicotot* of a child, nine and a half years of age, in whom the rays revealed a central pneumonia which was not revealed by the ordinary methods of percussion and auscultation.

The progress of the disease in the lungs can be accurately noted, and it will be possible to say with confidence whether the tubercular area has increased or decreased in size. A valuable graphic record of events can be preserved in the shape of a series of Röntgen photographs, or, failing that, of charts, mapping out the results of periodical screen examinations.

The causes of dyspnœa may sometimes be revealed by the rays when not ascertainable by other methods.

The various stages of pneumonia can be seen by the rays—consolidation, collapse, pleuritic effusion, displacement of heart, impaired respiratory descent of diaphragm. The gradual clearing up of the diseased process can also be followed.

Cirrhosis of the Right Lung with Displacement of Heart.—An interesting case of this condition has been published by Dr. Henry Waldo,† of Bristol. The patient was a boy of ten, with good family history. The heart's apex was found beating outside the right nipple; the whole right lung yielded an impaired percussion-note; and repeated examinations of the sputa failed to reveal tubercle bacilli. The Röntgen photograph showed great density of the affected lung, and absence of heart in left thorax. The case appeared to be one of diffuse interstitial pneumonia, affecting the whole lung, unconnected with tubercle, and by its contraction leading to an extreme displacement of the heart.

Impairment of respiratory movement is an important nega-

* *La Radiographie*, Avril, 1899.
† *British Medical Journal*, December 17, 1898.

tive sign. It is shown on the screen by the lessened movement of the diaphragm, both in ordinary and in forced respiration. According to Williams,* the lessened descent of diaphragm in some cases precedes the increased density of the lungs, and is therefore to be reckoned among the earliest signs of pulmonary disease. In pneumonia, the return of normal rise and fall of the diaphragm is a more delicate test than the opacity of the lung. In emphysema the diaphragm descends lower towards the abdomen than in health, and does not rise to so high a point as it should, while the lung area is brighter than normal. In pneumothorax the diaphragm is very low down on the affected side, and motionless, except at its median end, where it sometimes moves with the sound side. The diaphragm may also be restricted in its range by pleuritic adhesions.

The diaphragm may also be pushed up, and restricted in movement by various abdominal conditions, as dropsy or enlarged liver.

A most interesting case† was shown at the Vienna Medical Club, April 20, 1898, by Dr. R. Kienbock. The patient, aged twenty-four, came from the clinic of Professor Schroetter, and had suffered for five months from pyo-pneumothorax. The published details are so instructive that they may be reproduced at some length, especially as, thanks to Dr. Kienbock's courtesy, the description is accompanied by the original illustration :

'Examination of the patient by the screen, the patient being in the erect posture, gave the following results : Corresponding to the right lung there is a long, rather light zone, the upper part of which is darker. The left half of the thorax presents altogether different appearances. The upper third is fairly light, the middle very light, while the lowest part is very dark. The upper limit of this dark field behind corresponds to a horizontal line situated two fingers' breadth above the level of the angle of the scapula. The contrast between the transparency of the middle area and the opacity of the inferior area is very marked ; but even in the latter one can make out the form of the ribs, which appear as still darker lines. The dark shadow merges below into a lighter shadow of the abdomen without any distinct line of demarcation. The shadows thrown by the sternum, the great vessels, and the vertebral column are not broader than normal. The shadow of the heart is displaced far to the right, and it can be discerned extending some distance down into the dark zone.

'It is easy to detect various movements in the image. On the right side the shadow of the liver descends several centimetres with each inspiration, while on the left the level of the dark zone ascends during inspiration for three-quarters of the width of the intercostal space. The ribs are raised with inspiration on both sides. The shadow of the enlarged heart pulsates strongly and rhythmically,

---

* *British Medical Journal*, April 16, 1898.

† *Medical Press and Circular*, October 26, 1898.

corresponding to the pulse at the wrist. The pulsation can be perceived easily all over it, the lower half moving to the left during systole.

'The horizontal level is continually in movement. Apart from the respiratory change of position, there are undulations which are to some extent synchronous with the contraction of the heart; but this rhythm is disturbed by irregular waves which pass over the surface at the same time. When the patient holds his breath, one can see clearly the level rising at each cardiac contraction. The slightest movements of the thoracic floor show themselves on the surface level. This remains horizontal when the patient bends over to the right side or to the left. On percussion of the thorax the undulations above described become more pronounced, and they attain the height of ten centimetres when the patient is violently shaken. They may be compared to the oscillatory movements seen in a vessel filled with liquid when it is sharply agitated.

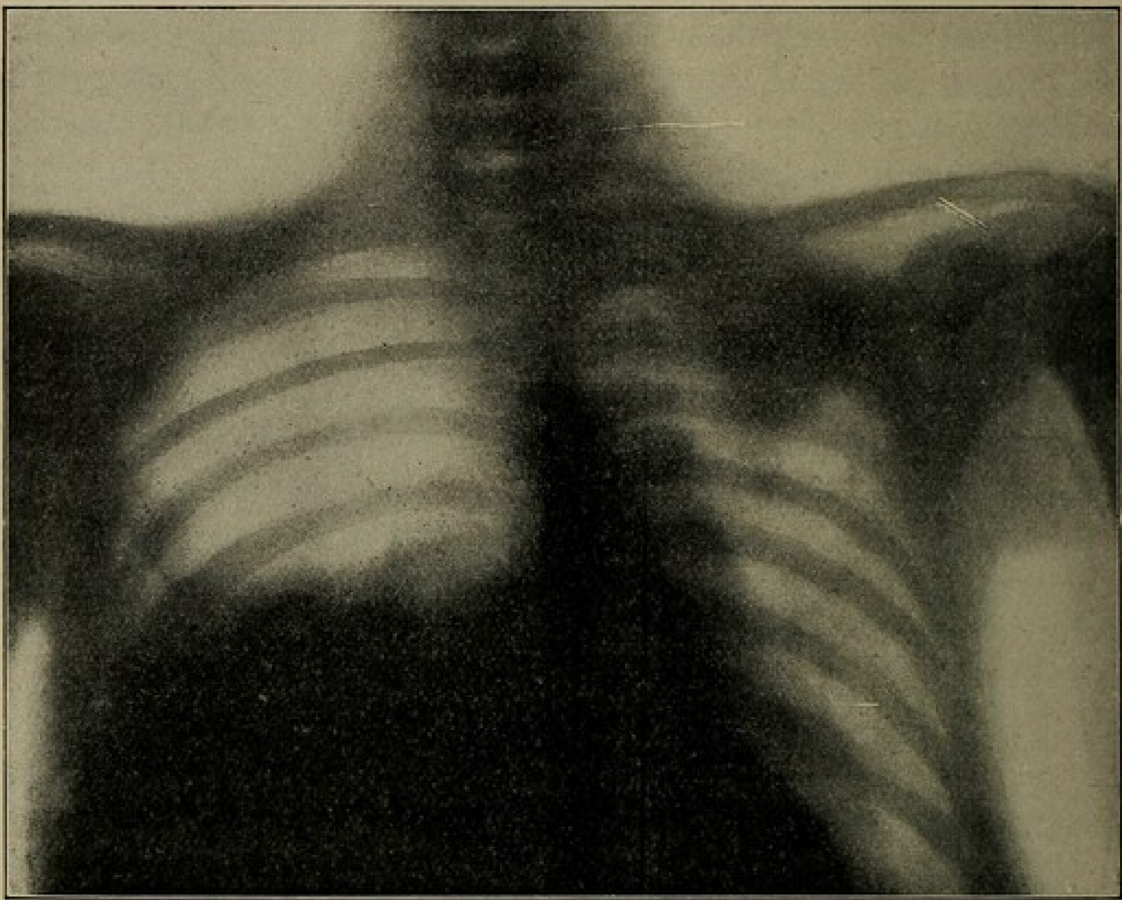


FIG. 93.

'The photograph reproduced in the accompanying illustration was taken with the patient sitting down, leaning his back against the case containing the photographic plate. The tube is 15 centimetres distant from the sternum, at the height of the surface level. The photograph reproduces very closely the description given of the image on the screen, but, of course, without the phenomena of movement.

'On examination of the patient lying down on his left side, the darker shadow is again seen undermost, but it now extends from the apex of the lungs to the diaphragm, and shows neither pulsatory nor respiratory movements. The median part of the left half of the diaphragm is visible in this position. It is obviously depressed, and does not appear to be moving distinctly. The shadow of the heart subsides to a slight extent into the left half of the thorax.

We may infer from these appearances that the right lung is diseased in nearly its whole extent, while on the left side there is pyo-pneumothorax. The comparative opacity of the right lung is to be attributed to compression, infiltration and thickening of the pleura ; the dark apex is characteristic of tuberculosis.

'The shadow in the upper part of the left pleural cavity is due to the adherent contracted apex of the left lung. Below it there is air, hence the marked transparency of this part as seen on the screen and in the photograph. The inky and lowest shadow is caused by liquid which amounts—judging from its height—to several litres. It is probably sero-purulent in character. The heart is enlarged and shifted into the right half of the thorax ; the pericardium appears to envelop it very closely. Its apex is directed to the left, and is immersed in the empyema fluid. The pulsation is strong and quick.

'These, of course, are all pathological changes which could be discovered by ordinary physical methods of examination.

'Although the Röntgen screen shows the level of the effusion two fingers' breadth higher than the limit obtained by percussion, this is very frequently observed, so that the contradiction in this respect is more apparent than real.

'The other observations on the Röntgen screen are, however, of the greatest interest. I mean the phenomena of motion ; first, the respiratory movements. There is an inspiratory ascending and an expiratory descending movement of the surface level.

'Various *explanations* of these phenomena have been suggested. I am disposed to think that the inspiratory dilatation of the right pleural cavity, by raising the pressure in the abdomen, tends to raise the paralytic depressed left half of the diaphragm.

'The second phenomenon is the *pulsatory* movement of the level. There is a wave moving from the heart to the left during its systolic contraction (*empyema pulsans*).

'The reason why the pulsation is not perceptible on the outside, either to the eye or the finger, may possibly be that the air-pressure in the pleural cavity is not sufficiently high. The elasticity of the air enables it to yield to the systolic shock of the liquid, and therefore the wall of the thorax is not concussed, in spite of the strong action of the heart ; further, the wall may be too rigid, or the pleura costalis too much thickened.

'The *third kind* of movements depend upon outside influences—the varying position of the patient, sudden movements, communicated vibrations, and particularly the great amplitude of the oscillations seen when the patient is violently shaken. We are thus enabled not only to hear, but also to see, the *succussio Hippocratis.*'

(*d*) The Abdomen

The application of the Röntgen rays to the adult abdomen has not hitherto yielded results to compare favourably with those derived from the thorax. The upper border of the liver, as already stated, can be well seen, and a hydatid tumour has been reported projecting from its convex surface ; but the lower border is rarely to be made out. The kidneys are not as a rule visible, although with a tube of good penetration, a powerful coil, and a short exposure, both kidneys and pancreas can be photographed. The stomach is sometimes faintly outlined, presumably most so when filled with gas. The intestines are at times to be dimly seen. In an experiment conducted by the present writer, a photograph was taken from a stoutly-built young officer thirty years of age.

He had been affected for many years with signs suggestive of intestinal obstruction following peritonitis. For a fortnight before the exposure he took 15 grains of bismuth three times a day. The result shows a faint outline of stomach and colon, with some coils of small intestine and sigmoid flexure. It seems fair to assume that this result may—in part, at any rate—be attributed to the opaque bismuth present in the intestine. The photograph was taken in the summer of 1897 with an Apps coil, 9-inch spark, and an exposure of 15 minutes, the patient lying on his belly.

After many exposures, the present writer succeeded in obtaining an *x*-ray record of a tumour about the size of an orange, apparently non-malignant and connected with the right kidney. The patient was a tall, stout woman, in whom the growth had existed for some years. At the time of examination the urine was normal, but the patient showed somewhat severe signs of pressure upon abdominal veins and lymphatics, and the general health was becoming affected. Hydatids had been suspected, and there were signs that pointed to possible implication of the gall-bladder. The Röntgen photograph showed an opaque mass, without detail, in the region implicated, and in that particular simply confirmed what was perfectly apparent to an ordinary physical examination. It showed, however, a point of some importance—namely, that the tumour was unconnected with the liver. A later photograph showed great detail, but diagnosis still remains uncertain with our present imperfect knowledge of many pathological shadows.

Kronberg* succeeded in obtaining Röntgen ray records of the intestines of small animals by filling the gut with metallic mercury. He also met with some success in larger animals and in the human cadaver. He suggests the use of that metal in the diagnosis of intestinal obstruction. He recommends the administration of a large dose (200 grains), which he states would be comparatively harmless, and suggests that by following its course with the Röntgen methods the seat of obstruction could be ascertained. At the same time it is claimed that the action of the mercury would be in some cases curative. He further suggests that the metal gallium might be substituted as less dangerous than mercury.

Drs. Lévy-Dorn and Boas† have introduced a method of

* *Wien. Med. Woch.*, May 23, 1898.

† *Deutsche Medicin. Wochenschrift.*

ascertaining the position of the fundus of the stomach, the existence of stenosis of the pylorus and the intestines, and the amount of contractility possessed by the gastric and intestinal muscles. They administer to the patients a gelatin capsule filled with metallic bismuth and coated with celluloid. The bismuth being opaque to the rays and the celluloid insoluble in the gastro-intestinal juices, its position may be ascertained by means of the fluorescent screen. In most cases the capsule was seen either on the great curvature of the stomach or in the cæcum near the ilio-cæcal valve. In cases of pyloric stenosis the capsule generally remained for several days in the stomach, a point of great diagnostic value. Otherwise the capsule was passed per anum in from two to six days. If the capsule be retained in the stomach it must be removed by operation.

Professor Rosenfeld, of Breslau, has obtained good results by inflating the stomach and intestines before the application of the rays.

In the case of cancerous masses of the stomach, Bouchard failed to obtain any positive result even with a coil that gave a spark of 15 inches. On the other hand, Rosenfeld reported to the Berlin Medical Congress of 1899 that he had made radiographic observations of diseases both of the stomach and of the liver in the living subject.

Murphy's buttons, coins, and other foreign bodies have been detected in the abdomen, more especially in the case of children. It is obvious that such localization might afford simply invaluable aid to the surgeon.

Calculus of gall-bladder, kidney, ureters, and urinary bladder have been often detected in the living adult. They are described more fully in the section upon 'Foreign Bodies' (p. 117). Results in each case, however, are still more or less uncertain. Much the same statement applies to the radiographic examination of the uterus, with its contents and appendages, a subject dealt with under the heading of 'Obstetrics' (p. 221).

Practical Conclusions

To sum up the applications of Röntgen rays to clinical medicine: First of all, we find that satisfactory results are confined chiefly to the thorax, although now and then useful information has been obtained from the abdomen. Secondly, in the lungs we can sometimes get early information as to tubercle, which may not be disclosed by ordinary means of physical or bacteriological examination, and effusion of fluid in pleurisy may be accurately estimated, as well as in pericarditis and in various non-inflammatory local dropsies. As to the heart and large vessels, enlargements and displacements can be readily demonstrated, together with thoracic aneurism. Such alterations can be detected when cloaked from ordinary examination by emphysema of the lung. The results of the Schott plan of treatment of heart diseases can also be followed.

One important point is the possibility of localizing patches of tubercular consolidations and cavities in the lung substance. Hitherto one of the chief obstacles to the progress of lung surgery has been the difficulty of exact localization. Thus, it not infrequently happens that the physical signs point to the presence of a cavity where that particular lesion, in point of fact, does not exist. If this diagnosis, then, could be cleared up definitely by a radiogram or by the fluorescent screen, the hands of the surgeon would be considerably strengthened in dealing with individual cases. It is hardly needful to remind the reader that the fact of a deep consolidation lying beneath healthy lung renders it extremely difficult or impossible to diagnose the trouble by percussion and auscultation.

As blood is opaque, a clot in the brain, especially if large in size and near the surface, may perhaps be radiographed.

V. OTHER MEDICAL POINTS

The Diagnosis between Gout and Rheumatoid Arthritis

In May, 1897, Messieurs Oudin and Barthélemy showed a series of Röntgen photographs of the hands and feet of patients affected with gout and with rheumatoid arthritis.* Normally the articular cartilages are transparent, and the dark shadows of the bones are separated by a clear band from 1 to 3 millimetres in width, a condition that is maintained to the end of life in the healthy subject. In gout these clear spaces are unaffected, but the disease is characterized by tophi, which appear as light patches on the denser bone. In rheumatoid arthritis, however, the clear spaces disappear, even in young subjects (see Fig. 86),

* *La France Médicale*, June 4, 1897.

and that fact, together with the bony outgrowth and deformity, furnishes diagnostic signs by the Röntgen methods.

Enlargement of the axillary glands has been seen in breast cancer.

Calcification of Arteries

As might be expected, a radiographic record can often be obtained of calcification in arteries, whether primary of the middle coats or secondary of the inner.

VI. ACTION OF THE FOCUS TUBE UPON THE SKIN AND DEEPER STRUCTURES

Soon after the Röntgen rays came into general use, as everyone knows, cases of resulting injury to the skin were reported. This ill effect was usually spoken of as '*x*-ray dermatitis,' but the present writer, in a paper* read before the Dermatological Society of Great Britain and Ireland in July, 1897, ventured to suggest the non-committal name of 'focus-tube dermatitis.' By either term is meant an inflammation of the skin following one or more exposures to a focus tube in action. The damage may be fleeting, nothing more than a slight reddening of the skin, with sudden onset and rapid disappearance, or the hairs of the affected part may fall out painlessly. On the other hand, it may be severe, coming on from a few days to three weeks after the exposure; the epidermis may peel off, or the underlying tissues may slough away, and leave an obstinate ulcer that takes months to heal.

The fleeting effect of the focus tube was well illustrated in a case where the present writer took two Röntgen photographs of a lady's hand with an exposure of four minutes, and the tube at a distance of 12 inches. Some days later the patient volunteered the information that she had felt something wrong with one of her fingers ever since the taking of the photographs. On examination, the nail of the ring-digit was found in a state of partial dusky erythema. This slight traumatism would almost certainly have been overlooked had not the patient herself drawn attention to the fact.

A large number of instances of severe damage have been recorded.

* See *Transactions Dermat. Society of Great Britain and Ireland*, vol. iii., p. 137.

* The existence of cause and effect in this condition has been established both by the large number of recorded cases and by certain experimental observations. Thus, Professor Elihu Thomson,† who was sceptical as to any such injurious action, exposed his hand for half an hour at a few inches' distance from a 'live' tube, and was rewarded by the appearance of an eruption nine days later. Then, again, it is claimed that dermatitis may be induced at will by placing active tubes of medium resistance for ten or fifteen minutes at a short distance from the surface of the body. That the reaction may often exist in a minor degree and not be recognised appears more than likely. Thus, a Röntgen ray worker whose hands were affected was surprised when the present writer pointed out the fact, especially as he had previously hinted his doubts as to the existence of such a condition. His fingers were red and leathery, and the nails, besides being brittle and broken, wanted the sharp groove that defines the lower border of a healthy nail—changes that had come on only after taking up Röntgen work. Making every allowance, however, for cases that are not recognised and for the far larger number that are not recorded, it nevertheless seems evident that the percentage of cases of dermatitis following exposure to the focus tube must be extremely small. Of late there has been a marked diminution of reported cases, a fact that appears to have some relation to the general shortening of exposures. Lastly, the affection seems to have involved an undue proportion of practical workers, who have been continuously exposed over long periods to the action of the focus tube, although the individual exposures may have been short.

There is nothing specific about the inflammation of the skin, nothing in its appearance that would proclaim it as due to the focus tube. It is a symptom of a remote exciting cause, and exactly resembles the dermatitis set up by a number of other external irritants, such as exposure to a hot sun, to a furnace, or to the action of a caustic alkali. The question before us in this particular case is the nature of the irritant peculiar to the focus tube.

If a multitude of persons be exposed to a hot sun, perhaps one out of a million will develop a severe dermatitis, exactly resembling

* The next few pages are from a paper read by the author before the Röntgen Society of London to introduce a discussion, December 6, 1898.

† *Johns Hopkins Hospital Bulletin*, No. 71, February, 1897.

that set up by the focus tube. In both instances there is a distinct, if imperfectly understood, *causa causans;* but something more is needed to account for the phenomenon of individual selection, and that we may express by the convenient term 'susceptibility.' In this way the extremely small proportion of persons attacked by focus-tube dermatitis may be so far explained: many are exposed to the irritant, but few are susceptible.

Other contributing factors are, seemingly, the nearness of the focus tube to the skin, the resistance of the tube, and the duration and frequency of exposure. These assumptions, in addition to a certain amount of evidence to be quoted forthwith, may be supported by the analogy of a hand held near a hot furnace: the nearer the hand to the fire and the oftener and the longer it be placed there, the greater will be the resulting damage. The proposition that the injurious effects of the focus tube are inversely to the distance of the tube from the skin and the length and frequency of exposure is supported by the following evidence:

1. Close proximity of tube and an exposure of ten minutes or a quarter of an hour is adopted in order to produce therapeutic or intentional dermatitis.

2. In most of the recorded cases of injury, severe or otherwise, the 'live' tube has been placed near the skin during a long time.

3. Repeated short exposures produce dermatitis in workers with the rays who are susceptible.

4. Professor Elihu Thomson's artificial dermatitis was produced by a near tube and a long exposure.

5. Negatively, no case has come to the writer's knowledge in which a short exposure with the tube at a fair distance has been followed by any seriously bad results.

These considerations seem well enough supported to help clear the ground in various directions. Thus, they show why cases of focus-tube dermatitis are so rare that their existence is denied by some persons, why practical workers are specially prone to attack, and why dermatitis has not occurred at all within the experience of some extensive workers with the rays.

Fortunately, when we come to the discussion of cases, we have a large number recorded by accurate observers. So long ago as February, 1897, Gilchrist* was able to publish a collection of twenty-seven cases. One remarkable instance under his own

* *Johns Hopkins Hospital Bulletin*, No. 71, February, 1897.

care was that of a demonstrator, thirty-two years of age, who, after frequent and prolonged focus tube exposures, developed a severe dermatitis. The bones of the hand became painful upon pressure, and a Röntgen photograph showed distinct osteoplastic periostitis, with a probable osteitis of the first and second phalanges of the index and middle fingers, and also of the heads of the metacarpal bones. Without endeavouring to make an analysis of all recorded cases, mention may be made of a few that raise points of special interest :

In the *British Medical Journal* epitome for August 15, 1896, the case of a young man of seventeen was reported. He was under the care of Marcuse, who found the patient suffering from a diffuse desquamative dermatitis of the face and back. There was also a partially-bald patch on the temple, from which the hairs could be easily extracted.

In the same journal for November 17, 1896, Dr. Drury described a case in which severe results followed two exposures, the first of an hour, the second of an hour and a half. A large surface of the epigastrium became erythematous and swollen ; it vesicated on the tenth day, and showed a profuse discharge on the twenty-fourth day. A troublesome ulcer which ensued was unhealed sixteen weeks later.

In the *Canadian Practitioner* for November, 1896, Dr. King of Toronto reported the case of a young man who for three months was engaged in demonstrating the Röntgen rays, with a daily average exposure of six hours. After about six weeks he had dermatitis of the right arm and hand, which recovered after discontinuing the exposure. On resuming work, however, he had another attack. In about six weeks the hand and face of the exposed side showed signs of a severe dermatitis. The eyelids were œdematous, and there was double conjunctivitis. On the left hand the nails exfoliated and the hairs were destroyed. On the left side the hair was gone from temple, eyebrow, upper lip, side of face, and neck.*

Dr. Radcliffe Crocker, in January, 1897, published the case of a lad who developed a large and obstinate ulceration of the abdomen after a single exposure of an hour's duration. The lower border of the inflammatory area was sharply limited by

* For abstract see *British Journal of Dermatology*, January, 1897.

the clothing, and six weeks later a small, painful ulcer was still left unhealed.

In February, 1897, Professor Waymouth Reid,* a highly-skilled and accurate observer, within four days underwent four exposures, of twenty, forty, fifty, and ninety minutes respectively, and afterwards suffered from a severe dermatitis in the exposed area. The skin lesions were healed by the thirty-third day, but sixty-nine days after the original exposures he reported to the present writer: 'There is no vestige of hair left upon the chest, and I have not been troubled with the shaving of my chin for the last six weeks, the hairs having come out by the bulbs to the touch of the razor twenty-two days after the chest exposure, after a slight preliminary erythema of the skin, not followed by loss of cuticle.' As always happens where the focus tube dermatitis has not caused deep sloughing of the skin, the hair afterwards grew again. Dr. Reid further placed on record the interesting fact that there was an erythema of the back as well as of the chest—that is to say, presumably at the points both of entry and of exit of the irritant rays, unless, indeed, we attribute the result to direct or indirect electrical influences.

The last-mentioned point may be compared with a case published by Mr. T. L. Gillanders, M.B. After several exposures, extending over twelve days and including screen examinations and photographs with final screen operation, the patient, while convalescing, developed dermatitis on both sides of the hand. It is not stated, however, that both back and front were not exposed to the focus tube.

Two other instances of double-surface injury are mentioned by Wolfenden† as having come to his knowledge.

Turning next to cases that have come under the author's personal observation, one has already been noted where congestion of a nail-bed followed twenty-four hours after a four minutes' exposure of a hand, with the tube a foot above the plate.

In July, 1897, the writer reported several instances of deep tissue traumatism. In one striking case the patient suffered from cerebral symptoms suggestive of sunstroke. For a long time he had been in the habit of demonstrating the Röntgen rays, and often had one side of his head within a few inches of a

* *Scottish Medical and Surgical Journal*, February, 1897.
† *Wright's Medical Annual*, 1899, p. 107.

focus tube, with only a wooden screen between. From time to time he suffered from a slight dermatitis, but at length he developed more serious symptoms, of which the chief were headache, vertigo, vomiting, dimness of sight, and great prostration. He placed himself under the care of a medical man at a seaside town, and that gentleman said at the time his symptoms were practically those of sunstroke, a view that he has since kindly confirmed. If we may on such evidence ascribe the cerebral attack to the influence of the focus tube, then its influence upon deep structures must be admitted.

Another case in point came under personal observation. A practical worker with the rays, a healthy middle-aged man, was carrying out a series of experiments that involved exposure of the region of the stomach for a period of about two hours daily. After some weeks he complained of abdominal symptoms, such as pain, tenderness, flatulency, and diarrhœa. He went away into the country for a fortnight, and got well. On his return he resumed his experiments, and after a fortnight experienced a second attack. He then shielded his stomach with a thin sheet of lead, and his symptoms finally disappeared. This history certainly suggests that in his case the rays of the focus tube caused a direct inflammation of the gastro-intestinal mucous membrane. Serious digestive disturbances have also been attributed to *x*-ray exposures by Messrs. Bergoiné and Teissier. They also hint at the possibility of pneumonia having been set up in the same way.

Another group of cases has been noted by the author, namely, those in which previously unsusceptible persons have been rendered susceptible by altered conditions of exposure. In July, 1897, he described to the Dermatological Society of Great Britain and Ireland an experience of Mr. Webster, a gentleman who has had a wide experience of Röntgen ray work. For a year or more he had undergone constant exposure to the focus tube without bad results. He then injured himself with a metol solution while developing photographic plates, and shortly afterwards a diffuse dermatitis appeared on the back of his hand. The interesting points are the previous damage of skin by the metol and the fact that the dermatitis coincided with the heating of the kathode end of the tube.

In another case kindly communicated by Mr. Webster, an individual had been exposed for something like a score of times within a period of six months. Six weeks after the last exposure the hair fell out from one side of the head. The only differing conditions of experiment, so far as could be ascertained, were that in the last, and presumably the damaging, exposure the kathode end of the Crookes' tube had been kept continuously heated.

A striking instance occurred in the person of a gentleman who had made some 2,000 Röntgen exposures, but, having seen no ill effects therefrom, not unnaturally doubted their occurrence. At the conversazione of the London Röntgen Society, held on November 21, 1898, he exposed his hand to a strange tube, and three days later developed a patch of dermatitis.

The author has twice suffered from mild dermatitis of the left hand. On each occasion the attack followed a prolonged demonstration of the rays with the hand close to the focus tube, from which several sparks passed to the skin surface.

We have thus four cases in which individuals unsusceptible to focus tube injury under ordinary circumstances became susceptible under altered conditions of experiment. The extent to which the heating of the kathodal end of the focus tube might be concerned in the result offers an interesting point for physical investigation. The kathodal rays strike the platinum anode, or anti-kathode, and often render it red-hot, and one is tempted to speculate whether their contact with the skin surface might not have a somewhat similar calorific effect. In other words, that focus-tube dermatitis may be a sort of burn.

The analogy is not a little striking between focus tube dermatitis and that produced in rare instances by a single exposure to a hot sun, or at any time by sufficiently close or prolonged contact with the heat of a furnace. With regard to all these conditions, we may observe :

1. That the dermatitis may result from a single exposure.
2. That bronzing may occur.
3. That the injury is excluded by clothing.
4. That chemical rays exist in each source of injurious influence.
5. That deep as well as surface tissues may be affected.

1. That dermatitis may follow a single exposure to a hot sun is an established medical fact. In his smaller Clinical Atlas (Plate CX.), Mr. Jonathan Hutchinson gives an excellent picture of a most severe eruption following that circumstance.

2. Another remarkable resemblance is found in pigmentation. Bronzing, as everyone knows, is a constant result of exposure to the sun; and most folk would connect the black skin of the negro with some inherited peculiarity acquired by ancestral life under a tropical sun. Bearing upon this point is the case where Despeigne used the focus tube rays to alleviate the pain of cancer, and after the eighteenth sitting found the exposed skin almost as black as that of an African negro. In this connection may be mentioned the bronzing sometimes seen in those exposed to the prolonged influence of powerful electric light.

3. The third point is illustrated by the protection afforded by clothing against sun damage, and in the case of the focus tube by Dr. Crocker's case, where the inflammation was sharply delimited by the clothing. Nor is it possible to recall a case in which either sun or focus tube dermatitis has occurred in parts protected by clothes. Clearly, this observation alone, if established, would suffice to absolve the x-rays pure and simple from any suspicion of traumatic agency, for there is no ordinary clothing which they would not readily penetrate. It is also worthy of note that an assumption of the innocence of the x-rays themselves has been implied in the attempts to prevent injury by interposing shields of indiarubber, vulcanite, and other materials which offer no resistance to the rays. One may remark, by the way, that the use of such protective appliances involves an obvious fallacy of numbers, inasmuch as persons working under unprotected conditions are so rarely attacked that the vulcanite or other screen would have to be applied in an enormous number of exposures to enable one to arrive at any trustworthy conclusion. If the gentleman already spoken of, who made the 2,000 exposures without bad results, had used a vulcanite shield, he might naturally have ascribed the absence of dermatitis to that precaution, although he would, nevertheless, have thereby strayed into a logical pitfall. A rational method would be to test the results of protected and unprotected exposures on different portions of the body of persons of proved susceptibility. It would be easy to devise a series of experiments under those conditions, planned so as to exclude all the less penetrating rays from the skin surface.

4. That chemical rays are emitted from sun, focus tube, and furnace is a simple physical proposition, capable of ready proof.

5. With regard to the fifth point—namely, that of effect upon deep tissues—that result is recognised in the case of sun-rays, and instances have been adduced to show that a similar action may be exerted by the focus tube. Other facts pointing to deep action of the latter are the relief of pain, noted by Despeigne and others, and the local tremors that not infrequently attend exposure. The writer has observed tremor of a limb in one of two feet photographed on one plate (Fig. 82). The analogy between sun and focus-tube action is amplified by a case, seen at hospital in the summer of 1898, of pronounced sun dermatitis, the onset of which was attended by fine tremors, exactly like those set up by the focus-tube.

This point of the similarity of the focus-tube lesion to that of severe sunburn is admitted by Gilchrist, who says, however, that the two things are different, because in solar eruptions there is no alopecia and no periostitis. His objection, however, does not appear altogether sound, because there is obviously traumatism to some of the deep structures in sunstroke (whether direct or indirect does not here affect the argument), and it would be impossible, so far as one can see, in our present state of knowledge to demonstrate the selectiveness or otherwise of any particular structure by that deep injurious action. Further, one would be inclined to connect the thickness of the negro skull in various ways, perhaps both individual and inherited, with prolonged exposure to tropical suns. The following observation, if confirmed, would point to the protective nature of the negro skin. Mr. Albert Walsh, of Port Elizabeth, communicated to the writer that he could not detect a bullet in a black man's thigh, although his apparatus was in good working order, and produced good results in the case of a white man. This observation he has since confirmed, and imagines there may be some special resistance offered to the rays by the colouring matter of the negro skin.

In the first edition of this book the view was expressed that, 'on the whole, it seems not improbable that some common agent exists in the rays of the sun, of the focus tube, and of the electric arc light capable of stimulating the human cutaneous surface, and sometimes the deeper tissues of the body, in varying degrees of severity, which are in some way determined by personal predisposing peculiarities.'

A curious confirmation of that hypothesis has been since advanced by Professor Schiff at the Austrian Gesellschaft der Aertzis.* At that society he showed a patient who had been treated with the focus tube rays for lupus. He attributed the successful result to the chemical action of the rays, and quoted Finsen of Copenhagen, who recorded equal success with rays not produced by Röntgen apparatus. His statement was confirmed by Spiegler, who said he had worked personally with Finsen while carrying out the treatment in question. The sun's rays were usually utilized for the purpose, and were passed through lenses to decompose the light before it was allowed to reach the morbid structures. At a later stage of the experimental treatment an electric arc light was used. 'Little glass plates were laid over an illuminated surface, to produce a sort of anæmia, or the acting ray would have checked the circulating blood altogether.'

It may here be stated generally that the view that the injury is not caused by the x-rays, but by some accompanying influence, appears to have gained most favour in France, Germany, and America.

Various theories have been advanced to explain focus-tube dermatitis. Of these the chief attribute the bad results to:

1. Ozone generation in the skin.
2. Flights of minute platinum atoms.
3. Ultra-violet rays.
4. Radiant energy.
5. Rays of x-ray order most readily absorbed.
6. Electrical induction.
7. De-electrification.

1. Tesla's view, that the damage is due to ozone generated in the skin, does not account for injury to deep tissues, if we accept that result.

2. There does not appear to be any general acceptance of the theory of the projection of streams of solid particles through the walls of the tube.

3, 4, and 5 may be taken together; the term 'chemical rays' is perhaps wide enough to include them. Dr. Philip M. Jones, of San Francisco, in a paper read before the California State Medical Society, April 20, 1897, attributed the dermatitis to the absorption of radiant energy by the cells of the skin, and thought the process

* *Medical Press and Circular*, November 23, 1898, p. 540.

parallel with the changes effected in the photographic emulsion. He agrees with the majority of observers that a bad result is more apt to follow exposure to a tube of low than of high vacuum. The latter fact further tends to exonerate the x-rays, for, as Mr. Gardiner has demonstrated to the Röntgen Society,* 'the greatest production of x-rays takes place in tubes of high resistance'—that is to say, the very tubes that, according to most authorities, are the least likely to do harm. Under the same heading of radiant energy comes the contention of Elihu Thomson, that 'the burns are produced chiefly by those rays of the x-ray order which are most readily absorbable by the flesh.'

6. The theory of electrical conduction appears to be controverted by an experiment of Elihu Thomson's. In a sheet of lead he cut a window, which was divided in two by a strip of tinfoil; one of these he covered with a double layer of aluminium foil, while the other was left bare. This compound shield he placed on a finger, and exposed it to the action of a focus tube. Two burns resulted, one on the part under the aluminium foil and the other on the bare spot. Professor Thompson thinks it inconceivable that any electrostatic effect could have been produced through the aluminium foil more than through the tinfoil or the lead, as all three metals were in electrical contact and subjected to the same conditions.

A further argument against the induction theory may be found in the great amount of harmless electrification of skin often involved in therapeutic or experimental work. At the same time, it seems likely we have yet to learn a good deal about the electrical states that are set up thereby in the skin. In that structure we find externally a thin, hard, horny, non-conducting layer, which lies upon the middle layer of so-called 'prickle' cells, which are bathed in serum, a warm salt fluid. The prickle cells are cut off by the close layer of columnar cells known as the 'palisade' layer from the underlying tissues, charged with warm alkaline blood and serum. All these layers are pierced by the hairs and the sweat-ducts, both hair-bulbs and sweat-glands being in the deeper tissues. When this combination of solid and fluid tissues is injured by exposure to the action of the focus tube, there is a tendency to pick out certain structures, as the hair-bulbs and the palisade layer. In cases of moderate damage, the brunt of

* *Archives of the Röntgen Ray*, May, 1898, p. 70.

the mischief is borne by the palisade layer and by the hair-sheaths. As regards the hairs, one might almost imagine they had acted as conductors of some injurious electrical agency either to or from the body; any way, the reason why hairs alone should be selected by the focus tube is not apparent. The anatomical arrangement of the skin would appear to favour complicated electrostatic conditions. Lastly, it is a noteworthy fact that under certain circumstances the sweat may become acid, a fact which may have a bearing upon the little-understood problems of individual susceptibility.

7. De-electrification, suggested by Dr. Lowe of Lincoln and others, an action known to be brought about by the rays of the focus-tube. This hypothesis might explain the very peculiar inflammatory selection of the hairs already spoken of.

The following propositions seem to be fairly well established:

1. A dermatitis of varying severity, with a tendency to destroy hairs, the deep layer of the epidermis, and the subcutaneous tissues, may be set up by exposure to a 'live' focus tube.

2. The particular damage usually follows either a number of short exposures or a single long exposure with the tube close to the skin.

3. While the injury as a rule affects susceptible people only, it may, nevertheless, be induced at will under certain conditions in any individual.

4. The inflammation is probably due, not to the *x*-rays pure and simple, but in some way to chemical rays generated in the focus tube, or to electrical conditions produced in the skin, or to a combination of those agencies.

Many other similar cases have been recorded. When the rays are directed upon the scalp, they appear to cause shedding of hair without any severe reaction. The nutrition of the hair-bulb is interfered with, possibly by some vascular changes leading to exudation and intrafollicular pressure. At the Vienna Gesellschaft, in January, 1897, Zemann stated that he found many different changes in hairs that have been treated by the Röntgen rays. The hair-root was always thinner, and the shaft brittle; the hair itself might be of the usual thickness, or often cone- or spindle-shaped, with fibrous swellings. At the same meeting, Kaposi remarked that the hairs shown by Zemann were like those met with in the microscopic examination of alopecia areata, and he thought them due to a similar pathological change. This last point is interesting as tending to throw some sort of side-light on alopecia areata. It would seem that by bringing a focus tube near the scalp, and exposing the latter to a somewhat prolonged action of the rays, we can produce an artificial *area*. Not only that, but we have the high authority of Kaposi that the pathological hairs resulting from the ray exposure cannot be distinguished from the diseased hairs of alopecia areata.

The tendency of most observers now appears to be towards the view that the dermatitis has a distinct relation to the length and frequency of the exposures, as well as to the distance of the focus tube from the skin surface.

Lastly, we have the important influence of idiosyncrasy. Many people are exposed both to hot sun and to Röntgen ray demonstrations, but comparatively few suffer in consequence. Predisposition of some kind appears to be an absolutely essential factor. The peculiarity may lie in the skin, but it seems more likely to be in the blood, especially as the latter is attracted to the skin in greatly increased volume in response to many external irritant influences. It may be that the focus tube rays, like the sun and other external irritants, stimulate the excretory function of the skin into unusual activity, and that the outward passage of some irritant from the blood sets up the dermatitis.

Mr. C. Mansell-Moullin, Dr. Lewis Jones, Dr. Wolfenden, and others seem inclined to attribute the injury to deep nerve and vaso-motor disturbances.

On the whole, it seems not improbable that some common agent exists in the rays of the sun, of the focus tube, and of the electric light, capable of stimulating the human cutaneous surface, and sometimes the deeper tissues of the body, in varying degrees of severity, which are in some way determined by personal predisposing peculiarities.

VII. THERAPEUTICS

The possible curative action of the focus tube rays has given rise to many proposals. There can be no doubt that under some imperfectly understood conditions they are able to exert considerable influence on the cutaneous surfaces of the human body.

Whether this be due to the unmixed Röntgen rays, or to a ray of some other kind, need not be further considered here. It seems clear that rays of various qualities are combined in their exit from the Crookes' tube, but they must be treated as a whole in considering their effect upon living tissues. At first it was generally assumed that the effects, varying in degree from simple congestion to severe destruction of tissue, have been confined to cutaneous surfaces. More recent observations, however, point to an action of the Röntgen rays upon the deeper parts of the body.

The belief appears to be now pretty generally accepted, that a cutaneous inflammation can be produced at will by the prolonged exposure of an ordinary focus tube at a short distance from the skin. As a surface caustic, however, the focus tube does not appear to have a remote chance of coming into general use among dermatologists, for reasons that will readily be recognised by the medical reader.

There are two affections in which this method of destructive treatment has been advocated, namely, hypertrichosis and lupus. As regards hypertrichosis, or superfluous hair, in mild cases, after a focus tube exposure the hair falls out with little or no inflammatory reaction, simply to grow again after the lapse of a longer or shorter period. On the other hand, when a severe dermatitis is set up with sloughing of the parts, the wound may take months to heal, and the hair will grow again after recovery unless the cicatrization is so deep as to have completely destroyed the hair-bulb area of the subcutaneous tissue. The latter event must necessarily be attended with unsightly scarring, as would occur in a burn of an equal degree of severity. The following instance of the mischief that may be caused by attempts to apply this treatment came under the notice of the present writer: A lady, afflicted by an abundant growth of hairs on the lower part of the face, applied to a non-medical operator with the *x*-rays. Her chin was subjected to four exposures of about half an hour each, with the focus tube at a distance of 6 inches from the face. The first two exposures were made on successive days, the third and fourth each after a clear interval of two days. Some ten or twelve days after the commencement of this treatment a severe inflammation of the chin set in, attended by much sloughing and lasting for months. The hairs came off, but the lower part of the face was covered with a deep scar, such as would result from a burn, and became the seat of a chronic irritating and eczematous type of inflammation.

In a case of the above kind it may be well to note that the person who applies the treatment may place himself in a false position. As he is not a medical man, and is applying treatment not generally recognised by the medical profession, he would possibly be mulcted in heavy damages should the patient bring an action against him for personal injury. He would hardly find a specialist in skin diseases ready to endorse the practice.

It may, perhaps, be added that there is only one scientific method yet available for the removal of superfluous hairs, namely, their destruction by electrolysis. This plan, though tedious, and applicable only when the growth is scattered, has the supreme advantage over chemical depilatories and mechanical epilation that, if properly performed, it is not followed by re-growth.

Drs. Schiff and Freund* remove superfluous hairs with a current that does not exceed 2 ampères and a tension of $11\frac{1}{2}$ volts. The tube is placed at 20 to 25 centimetres from the skin for an exposure of ten minutes, and is applied for thirteen to seventeen sittings. In some of the cases it was noted that the skin showed a brownish discoloration, and black hair turned white before it fell out. For the treatment of lupus vulgaris a current of 3·5 ampères and 12·75 volts was used with the tube at 10 centimetres distance.

Turning to lupus, we find ourselves faced with somewhat similar considerations. That the malady may sometimes be cured by exposure to a focus tube is undeniable, and the focus tube must be allotted a place in the list of remedies, especially in obstinate and ulcerative cases. At the same time, the fact must be borne in mind that it often disappears under various approved forms of treatment, such as scraping and caustics, and even of internal medication. The present writer has used the focus tube rays in the treatment of lupus of the nasal mucous membrane inaccessible to ordinary methods of treatment.

Dr. Thurstan Holland reported one case of lupus vulgaris of five years' duration, that had been subjected to scraping and other forms of treatment. Eighteen exposures of fifteen minutes each

* *Wien. Med. Wochen.*, Nos. 22, 24, 1898.

were made, extending over a period of two months. The ulcerated lupus patch healed entirely, and three months later was free from recurrence. Dr. Holland has also reported excellent results in the treatment of chronic ulcers by the same plan.

Dr. J. Rudis-Jicisky* reported the cure of a case of lupus erythematosus of the leg by frequent short exposures. The healthy tissues were protected with stanniol, and the tube was placed at a distance of from 15 to 18 inches from the skin. He also found markedly beneficial effects in the treatment of ulcerative lupus vulgaris.

Freund† has applied the method with some success to an extensive nævus pigmentosus pilaris in a child. Whether the depilation thus obtained can be rendered permanent remains to be seen. Certainly, in the cases hitherto reported the hair has sooner or later reappeared. Again, there is no certainty in the resulting depilation. Dr. Low has informed the writer that he tried on various occasions to depilate a hairy mole in a child sent to him for treatment, but without success.

It is evident, then, that we have in the focus tube rays an agent capable of acting powerfully upon the skin and its appendages. At the same time, while similar effects can be obtained by simpler and safer means, the action is so uncertain, so difficult to regulate, and so apt to be attended with serious complications, that it is not likely to have any but an extremely limited application to the therapeutics of the cutaneous surface.

Deep Therapeutic Action

Turning next to the possible therapeutics of the focus tube rays upon the deeper structures, we find ourselves confronted with several interesting and suggestive facts, in addition to the deep tissue traumatism already spoken of (p. 206).

In some instances exposure to the rays has been followed by a cessation of pain, but the casual relationship between the two conditions can hardly be regarded yet as scientifically demonstrated. Probably the first notice of the kind was by Dr. Richardson‡ of Boston, who wrote to a medical journal on August 31, 1896, describing the results of an examination by the rays. The

* *American X-Ray Journal*, October, 1896.
† *Medical Press and Circular*, January 27, 1897.
‡ *Boston Medical and Surgical Journal*, September 3, 1896.

patient was a stout woman of fifty, who had been complaining of pain on and off in an old fracture near the ankle-joint. She had an exposure of five minutes, and three weeks later wrote stating that, in the interval, not only had she been free from pain, but that swelling and soreness had also disappeared.

A striking case has been recorded by Dr. Stern of Philadelphia, who detected a fragment of steel in the vitreous by means of the rays. Almost coincidently with the exposure there was a cessation of pain, so that the patient could both work and sleep.

M. V. Despeigne,* of Lyons, reported a case under the care of L. Voight. The patient suffered from a small epithelial cancroid nodule of the mouth. The rays were applied twice daily for periods of half, and sometimes a quarter, of an hour. The pain, which had been considerable, almost immediately ceased, so that the medical attendant was enabled to discontinue the morphine. The patient died eventually of pneumonia, but a prolonged palliative effect had followed the effect of the rays.

In a previous case in his own practice, M. Despeigne found that a cancer actually decreased in volume under the influence of the focus tube. His conclusion from both cases is that, when applied to cancer, the rays have a distinct anæsthetic effect, and cause a general improvement in the condition of the patient, but exert little influence upon the growth. If this be the case, surgeons will be provided with a new anæsthetic for the relief of malignant growths far less disastrous in its general results than the evils incident to morphinism.

Relief of pain has been reported by Gocht in trigeminal neuralgia and mammary sarcoma.

Some observers have also met with success in the treatment of elephantiasis.

There have been many unfounded rumours as to the action of the Röntgen rays upon blind eyes. It seems, however, that where the optic nerve remains intact the visual sensations can be excited by the rays transmitted through media that have become opaque to ordinary light, as in cataract. The scanty nature of the evidence as to the action of the rays upon the optic nerve-endings may be gathered from the following reports :

The case of a blind man was reported to the North-Western Electrical Association by Mr. Hoskin. The patient was unable

* *Lyon Medical Journal*, December 28, 1896.

to see the light of an arc lamp close to his face. His eyes appeared normal, but he had been completely blind for two years. On being placed before a Röntgen apparatus in action, he was able to describe the general outline of the tube. A sheet of cardboard interposed cut off all visual impressions.

In this case, accepting the above statements, as Röntgen rays penetrate cardboard, any visual stimulation must have been due to some other kind of ray. If the media were transparent, and the optic nerve insensitive both to day and to ordinary electric light, then it follows, if the focus tube rays stimulated the nerve, that there must be special nerve-endings excited by the rays, although not by ordinary light, supposing the action to be local. Of course, it is not impossible that the rays might have penetrated the brain and stimulated the perceptive centres. In that case, however, we should expect to have had a similar phenomenon recorded by non-blind persons; beside, there is no reason why the figure of the tube should be fixed on the perceptive centre. In short, the case does not bear analysis.

Professor Fox,* of Philadelphia, stated that a patient with corneal opacity saw nothing with an Edison's fluoroscope, whereas with the naked eye he could accurately describe the phosphorescent colour of a Crookes' tube. He conjectures that Röntgen rays will not pass through cicatricial corneal tissue. If correctly reported, this opinion seems to be based on a confusion of fluorescence (both of screen and of tube) with the actual Röntgen rays.

The retina, it should be borne in mind, is a transforming apparatus which stands between outside rays of light and the percipient nerve and nerve centres. There is, again, a purely psychic blindness of hysterical nature, and any strong impression might cause a person affected in that way, not only to see for a time, but to be permanently cured. Clearly, were an experience of that kind to be encountered by an experimenter unversed in medical matters, he might well imagine he had found a talisman for sightless orbs, and telegraph to that effect across the Atlantic.

This subject was investigated by Professor Murani, of Milan. He took five patients, of whom one had been born blind, two had acquired that condition, and the remaining two perceived light but could not distinguish objects. When placed before an active focus tube, the visible light of which was cut off by a sheet of

* 'Ulcers of Cornea,' lecture, October 30, 1896, *Medical Bulletin*, Philadelphia.

black cardboard, the results with all five were negative. When exposed to brilliantly-lighted screens of platino-cyanide of potassium and tungstate of calcium, three perceived nothing; but the last two saw the glimmer of the screen, and one could count the shadows of the finger-bones of the hand, although he could not distinguish the form of keys.

It may be concluded, then, that the focus tube will not restore sight to the actually blind.

Effects of X-Rays in Colour-blindness

It has been stated in various quarters that the *x*-rays had a peculiar effect on the retina of colour-blind persons. In order to test the assertion, Mr. Sydney Stephenson and the writer made the following investigation.

Four colour-blind children were tested, two of them aged eight, one nine, and the fourth eleven. They were defective to red-green; their form-sense was normal, and their intelligence good. An ordinary bianodal focus tube, and a 12-inch induction coil, working at 9 inches, were used.

Perception of light and form proved normal when tested by the screen enclosed in a bellows fluoroscope. When the children looked steadily at the fully-lighted bare tube, they showed no signs of photophobia or dazzling. They all recognised objects, such as keys, when held against the bare tube or against the screen. The after-phosphorescence of the tube was seen by all of them, as well as the greater intensity of the area of the tube in front of the anti-cathodal plane when viewed sideways. Lastly, there was no sensation of light when the eyes were shut and bandaged, and the children put in front of the live tube.

To sum up, there was no reason to suppose that the retinæ of these colour-blind children reacted to the Röntgen rays in any way differently from those of ordinary people with full colour-sense.

Effects in Tuberculosis

Messrs. Lortet and Genoud* have experimented on guinea-pigs, with a view to ascertaining whether the tube rays had any restraining effect upon acute tuberculosis. Eight of those animals were inoculated with tubercle culture, and three submitted daily to the

* *La Revue Scientifique*, J. L. Breton, p. 106; Paris, 1897.

action of the x-rays. At the end of six weeks the latter presented considerable differences from the others that had not been so treated. Those that had undergone the exposures had no abscess at the point of inoculation, the glands were well defined, and their generally good condition was proved by an increase of weight. On the other hand, the inoculated guinea-pigs that had not been under the rays showed abscess at the point of inoculation, enlarged glands, and bad general condition with loss of weight.

Mr. Brunton Blaikie, of Edinburgh,* found that the Röntgen rays had no visible action upon the growth of cultures of tubercle bacillus (see p. 174). He also found that guinea-pigs inoculated with diphtheria toxine, and exposed to the rays, lived actually a shorter time than those not exposed.

These experiments are worthy of further careful investigation.

* *Lancet*, July 25, 1896.

E. OBSTETRICS AND GYNÆCOLOGY

OBSTETRICS

At first it was hoped that the Röntgen rays would prove of great service in obstetric medicine. In practice, however, up to the present time, experimenters have found its application to the pregnant uterus surrounded with many difficulties. The chief obstacles are: (1) The thickness of the parts to be penetrated; (2) movements, abdominal, uterine and fœtal; (3) the difficulty of keeping a pregnant woman for any length of time in a constrained position; (4) the distance of the uterus and its contents from the sensitive plate. However, when our methods have improved, there is every hope that, with a short exposure and tubes of strong penetration, the rays will furnish obstetric physicians with an additional means of exact investigation, not only as to maternal condition, but also as to the position, and even the sex, of the child.

The advantages of a good pelvic record of the kind are so obvious that they need hardly be mentioned at length. It would be possible, for instance, to ascertain the presence of twins, superfœtation, lithopædia, monstrosities, fœtal deformities, and malpresentations; while in any case pelvic deformities and exostoses could be demonstrated with ease and certainty. The demonstration of moles and of extra-uterine fœtations offers another attractive field of research.

There is one direction in which Röntgen diagnosis may prove of the utmost value to the obstetrician, namely, in the exact estimation of pelvic diameters and deformities. By means of localization precise measurements of all the bony outlets can be obtained, and the desirability of inducing premature labour or the necessity of removing a full-term fœtus by operation thereby indicated. This fact reduces pelvimetry to an exact and easily applied art. In France much attention has been bestowed upon this practical point by Professors Budin and Pinard. A stereoscopic view of a pelvis, it may be added, furnishes the observer with a perfect apprehension of the relation of all bony structures.

When taken from the uterus, an x-ray photograph can be readily obtained of the fœtus, such as that shown in 1896 by Dr. Oliver. His patient, a woman of thirty-nine, was diagnosed as having an extra-uterine fœtation, some two months beyond full term. An unsuccessful attempt was made to secure a record of the tumour in the living body. Upon operation an ovarian sac was removed containing a nine-months fœtus, of which the accompanying excellent picture was obtained (Fig. 94). The interesting observation was made that the ovarian sac was very opaque to the rays. Since then many similar photographs have been published of the human fœtus in various stages of development.

A further important contribution to the study of fœtal radiography was made by Professor Davis, of Jefferson College.* He published a radiogram which showed a faint tracing of the fœtal skull, contrasting strongly from the dark pelvis in which it had been placed. He further pointed out that the fœtal skull generally, except some portions at its base, offered little resistance to the Röntgen rays.

The same observer, moreover, after several unsuccessful attempts, succeeded in obtaining a faint outline of the fœtus in the living uterus. The fœtal shape could be recognised, and the position of the limbs was evident, but the head was hidden by the maternal pelvis. No fœtal skeleton could be distinguished. The experimenter concluded that the fœtal body and limbs were differentiated by the rays from the darker uterine walls and amniotic fluid.

Other observers have arrived at more or less similar results.

Thus, Imbert showed at the Montpellier Congress of Medicine a record obtained from a young woman of twenty-five, in whose case Professor Tedenat had diagnosed extra-uterine fœtation. Several of his *confrères*, on the other hand, suspected a hæmatocele or a tumour. All doubt was done away with by the Röntgen photograph, which clearly showed the existence of a

* *American Journal of the Medical Sciences*, March, 1896.

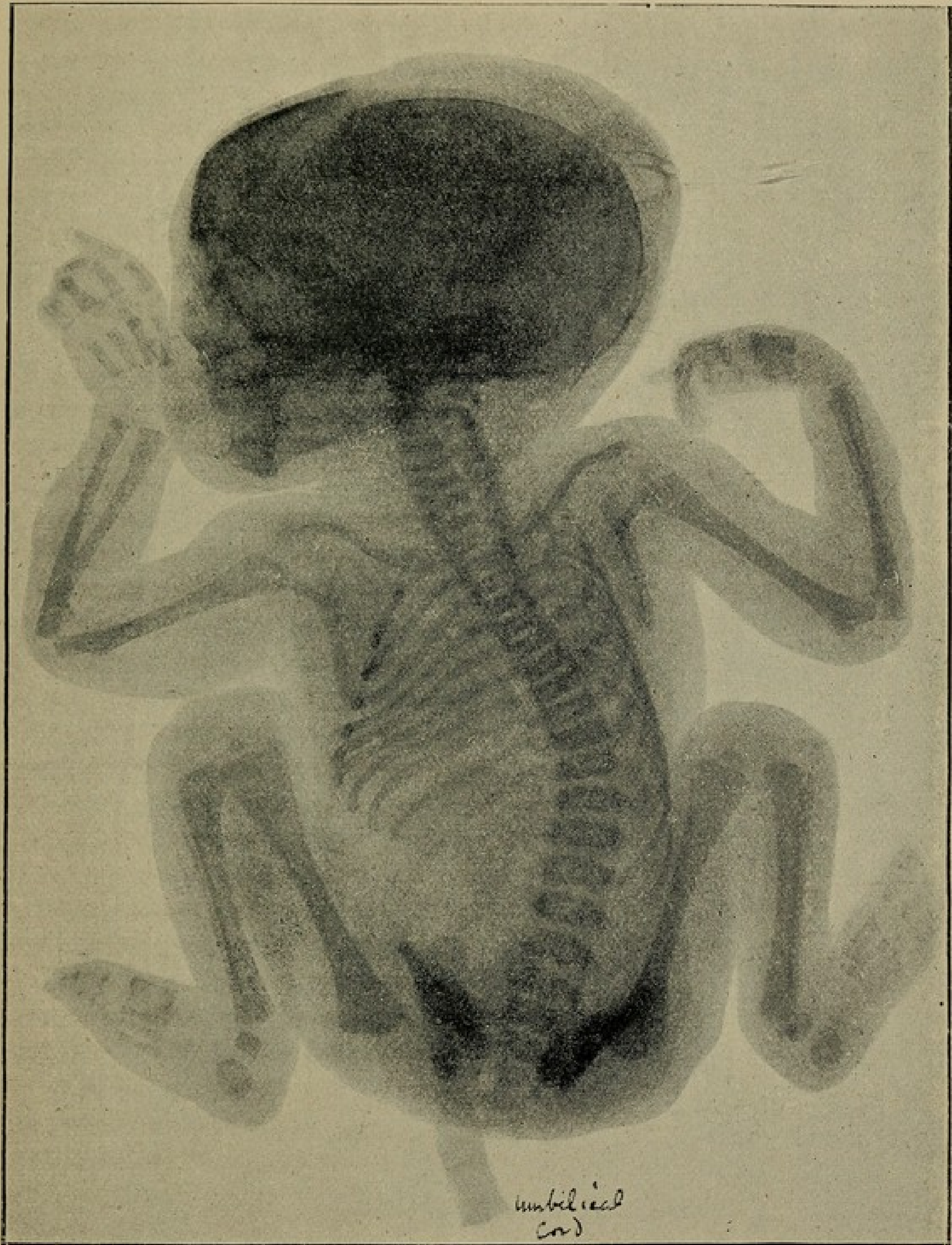


Fig. 94.—Fœtus from an Extra-uterine Fœtation.
Dr. Oliver's case.

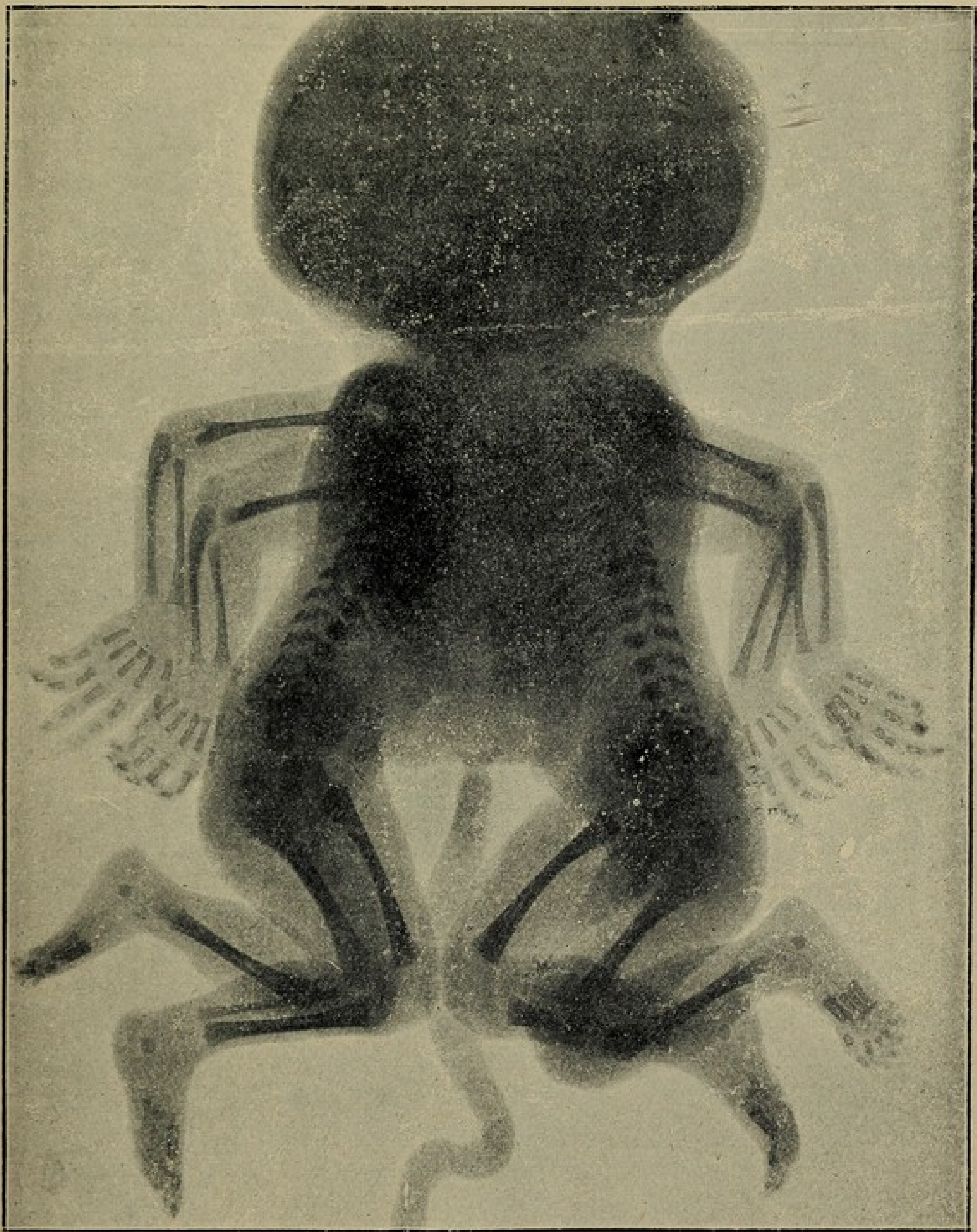


Fig. 95.—Fœtal Monster.

five or six months fœtus, of which one could see the head, the trunk, and the lower limbs.

M. Varnier showed to the Paris Society of Gynæcology and Pediatry, on March 31, 1899, a dozen radiographs showing the position of the fœtal head in the living pregnant uterus. They were obtained with exposures of three minutes.

Messrs. Chappuis and Varnier, quoted by Dr. Mandras (Paris Thesis), took a Röntgen photograph directly after death of a guinea-pig far advanced in gestation. They obtained details of the maternal pelvis and silhouettes of four fœtuses. Negative results were obtained from a chloroformed guinea-pig.

The same experimenters showed the possibility of getting good anatomical and pathological results with the rays from the gravid uterus after removal, both when hardened in alcohol and when frozen.

Messrs. Varnier and Chappuis have obtained a Röntgen ray picture of several fœtuses in the uterus of a living guinea-pig.*

Most interesting *x*-ray pictures can be obtained of fœtal monstrosities, after removal from the body, which convey anatomical information that could otherwise be obtained only by a tedious and difficult dissection. The illustration of a two-headed fœtus shown in Fig. 95 was taken from a photograph by Mr. Lynn Thomas.

In the case of conjugate twins that survive and grow to maturity, such as the Siamese Twins and the Two-headed Nightingale, it is likely that the rays might afford pictures of much anatomical interest.

At the end of the year 1896, Dr. Davis summed up the position of fœtal radiography as follows: 'The writer's experiments with the Röntgen rays upon pregnant women showed that it is perfectly possible to obtain an outline of the living fœtus in the body of the mother. The difficulties to be surmounted are the thickness of the tissues and the distance at which the Crookes' tube is necessarily placed from the fœtus itself. Anatomical specimens of uteri and their contents, removed from the body, should occasion no difficulty whatever. By varying the electric force employed and the time of exposure, it is undoubtedly possible to obtain a useful picture of the contents of the living womb.'

In France a special means of examining the pelvis by means of

* *British Medical Journal*, May 30, 1896.

an instrument called the endodiascope has been introduced by Bouchacourt. A long metal shielded prolongation of a focus tube is passed into vagina or rectum. It is open to question whether sufficiently good results cannot be obtained by less complicated procedures.

GYNÆCOLOGY

As methods improve, there is every reason to hope that valuable information will one day be obtainable, by means of the focus tube, as to many pathological conditions of the soft tissues of the pelvis, such as ovarian tumours, fibroids, sarcomata, and various malformations. At present the shadows obtained are too diffuse and lacking in detail to afford much help to the gynæcologist.

F. LEGAL MEDICINE

In a number of cases Röntgen-ray photographs have been produced in the law-courts. The evidence they afford is mainly corroborative, and must be taken as furnishing grounds for the testimony of expert witnesses. Their special value is that exact evidence apparent to the senses of everyone concerned is rendered available by the use of unerring scientific apparatus. With the average juryman an ounce of such fact is likely to outweigh a ton of theory obtained from roundabout deductions. To put the matter in another way, the testimony of a general practitioner armed with a corroborative Röntgen photograph would go far towards upsetting the contradictory statements of the most highly-skilled surgeon, provided the opinions of the latter were based upon nothing more tangible than the ordinary methods of examination. This point has been ably insisted upon by Mr. Howard Marsh* in the following passage : 'The information given by this method may be absolutely conclusive, and may directly contravene the best opinion that the most highly-qualified observer has had it in his power, under the difficult circumstances of the case, to form. With a photograph before him, any layman can see what by any other means could be only a matter of probability, balanced by other probabilities of almost equal weight.' The latter sentence describes the precise position of a juryman called upon to settle the nature of an injury in the face of conflicting skilled testimony. To such a man an *x*-ray photograph would often indicate a simple way out of the difficulty.

Dr. Richardson, of Boston, has quoted the following views of an American judge: 'It is the opinion of some of the judges of Massachusetts that *x*-ray photographs are not admissible as

* Technique des Rayons X,' A. Hébert, Paris, 1897, p. 105.

evidence. One judge holds that it has not been demonstrated as a scientific fact that they are accurate. The process has not become such a matter of common knowledge that the court will take judicial notice of it. No man can tell by ocular or other sensory evidence that the reproduction is accurate. The truthfulness of the photograph is a matter of reasoning.'

In considering the foregoing passage, which is a readily-understood, cautious legal attitude, it should be added that the opinion does not appear to be generally shared by other American judges. Broadly speaking, expert witnesses will, as a rule, be able to assume a strong position as to the absolute value of evidence derived from the Röntgen rays. Scientific evidence, it should be noted in this connection, is daily tendered and accepted in court with regard to new drugs and other medical discoveries, while photographs, in Great Britain, at any rate, have long been admitted in evidence.

The radiograph may be valuable in any of the following medico-legal points arising in civil or criminal cases :

1. Evidence of injury, or of the presence of a foreign body.
2. Evidence of bodily identification.
3. Evidence of pregnancy.
4. Evidence of age of fœtus, or of live birth.
5. Evidence of death.
6. Evidence in action for malpraxis.

I. EVIDENCE OF INJURY

It is clear that the presence either of a foreign body, as a bullet, or of an injury to bone, such as a fracture, can be clearly proved by means of a radiogram. In some cases this may be taken a long time, very many years, after the original accident or injury. Thus, a fracture often leaves a lifelong and unmistakable record of its occurrence, and a dislocation may be photographed by the Röntgen rays at any time previous to its reduction.

Already numerous cases have occurred where x-ray evidence has been produced in court. One such instance was mentioned in the *British Medical Journal* for June 6, 1896, where a bullet in a hand formed the object of a criminal prosecution.

A case occurred early in 1897 in Dunfermline. A boy was accidentally shot by a rifle discharged by an unseen person at a great distance. The presence of a rifle bullet buried in the boy's lung was admirably shown by a radiogram taken by a local operator. In that case the man charged was dismissed for want of exact identification with the person who fired the shot.

An important trial has been reported from America.* The charge was one of murder against a man who, on July 8, 1897, shot his wife's paramour in the head with a revolver. The wounded man was taken to a hospital, where, on the fifteenth day, his temperature, pulse, and respiration sank to a nearly normal condition, and he recovered so far as to be able to walk about the wards. He was then put under ether for fifty minutes, and a Röntgen exposure made for thirty-five minutes. The tube, placed at a distance of one and a half inches from the skull, was excited by a Holtz static generator, with a capacity of half a million volts. No picture of the bullet was obtained. Within a few hours of the exposure the temperature rose from normal to 100·4° F. From that time to his death on August 12, twenty days, his temperature fluctuated between two degrees above to a little below normal, with a rise at death. The medical man who made the post-mortem examination reported to the coroner that, in his opinion, deceased came by his death from injuries to the brain caused by a gunshot wound, anæsthetics, and the x-rays.

Nowadays, fortunately, long exposures and closeness of tube to object are not required in the radiography of the skull.

Generally speaking, in any action for injury due to negligence, if a bone be fractured or displaced, the plaintiff may obtain valuable corroborative evidence from a Röntgen photograph. Or the defendant, on the other hand, may be enabled to show thereby that the plaintiff's injury is exaggerated, misrepresented, or non-existent. A careful distinction must be made as to the injuries of soft tissues, which are rarely shown by the Röntgen methods, but are often just as disabling or fatal to the patient.

II. EVIDENCE OF IDENTIFICATION

The x-rays may be useful in several ways in identifying both the living and the dead. For instance, they may prove the presence of former injuries, such as fractures. In the well-known case of Dr. Livingstone, the African explorer, an x-ray picture of

* *American X-Ray Journal*, March, 1899.

the false joint in the arm due to the bite of a lion, an injury from which he was known to have suffered, would have afforded valuable corroborative evidence of identification.

Another way in which the rays might be useful would be in determining the age of a body up to early adult life, from the union or non-union of bony epiphyses. Any conclusions on this point, however, would have to be formed with a due regard to the varying ages of epiphyseal union. Observations so far show that, apart from early bone disease, there is apparently a good deal of individual difference in the time of fusion of epiphyses. This point is dealt with more fully in a later section on Anatomy.

Professor Amoedo proposes to take the measurements of the pulp-cavities of the teeth as a test of age. He states* that in 1844 Carabelli, of Vienna, Kory in 1885, and Boedeker, of New York, in 1894, made investigations on this point, but were obliged to work by the laborious method of cutting sections. Thanks to radiography, however, a number of teeth may be measured exactly within a short time. He points out that the pulp-chamber of the first molar is smaller than that of the second, a fact which he attributes to its prior eruption by six years, as one knows the cavity enlarges with age.

III. EVIDENCE OF PREGNANCY

Up to the present some uncertainty attends the diagnosis of pregnancy by the Röntgen rays—at any rate, in the early stage of the living subject. It may be stated, however, that a good picture of the fœtus may be obtained *in utero* after removal from the body. Moreover, an outline of the fœtus has been frequently obtained by several experimenters in the living subject. One result of a more perfect process would be to enable the English criminal law to replace by exact scientific methods the 'jury of matrons,' whose verdict decides whether a woman condemned to death is pregnant or otherwise. Even in these modern days, the question is on rare occasions still settled by that ancient tribunal.

* *Les Rayons X*, 2 Avril, 1898, p. 5.

IV. EVIDENCE OF AGE OF FŒTUS

A perfect Röntgen record may be obtained of a fœtus after removal from the uterus. In this way the stage of ossification can be exactly estimated, in a way that could be otherwise attained only after a tedious and difficult dissection. Moreover, by injecting the bloodvessels with a preparation of red lead, the radiogram might be made to reveal the state of the fœtal circulation.

When medico-legal evidence is required of the viability of a fœtus, however, the Röntgen photograph is only, as a rule, of corroborative value, inasmuch as it reveals the full-term bony development or otherwise. It is never likely to supersede in any way the evidence now tendered and accepted as to live birth, such as, for instance, the hydrostatic lung test. Viability, it should be remembered, is possible at seven months. The material things that may be readily demonstrated in court by means of a radiogram are fractures of the skull and other parts of the body, and the appearance of the osseous nucleus of the inferior femoral epiphysis, to which Husband, in his 'Forensic Medicine,' as a result of the examination of nine intra-uterine fœtuses at the ninth month, ascribes a maximum length of 2 lines. The subject of fœtal ossification is an interesting one, and no doubt the conclusions now laid down by anatomists will, sooner or later, be widely tested by the convenient Röntgen methods.

Positive *x*-ray evidence, however, as to the fact of separate existence of a child has been suggested by M. Bordas.* On June 8, 1896, he laid before the Paris Société de Médecine Légale two Röntgen photographs of fœtal lungs which showed the presence of air-bubbles in those who had breathed, as against absolute opacity in the still-born.

V. EVIDENCE OF DEATH

It has been proposed to apply the rays as a test of death, on the assumption that there would be increased resistance on the part of dead tissues; but it has not been found possible to carry out the suggestion in that way. The desired test, however, has been found in another direction, namely, by taking an *x*-ray

* 'Technique des Rayons X,' A. Hébert, Paris, 1897, p. 105.

observation of the heart. During life the pulsating upper cardiac margin, as seen from the back, throws a diffuse shadow on screen or negative, whereas the non-pulsating dead heart yields a sharp record, both fluoroscopic and photographic. In this way an important yet simple addition has been made to the trustworthy signs of death; and the discovery of Röntgen should thus bring comfort to those whose minds are possessed of the time-worn fables of premature burial.

VI. EVIDENCE IN ACTION FOR MALPRAXIS

The Röntgen rays may prove of great value to the protection of medical men, when otherwise it might be difficult to meet a charge of negligence. This point is put in a nutshell by Dr. Richardson,* of Boston, who writes: 'Indeed, an early fluoroscopic examination of every fracture may be required of every surgeon for the protection of the patient, and an early photograph for the protection of the surgeon.' At the beginning of the same year Mr. Howard Marsh advanced the statement: 'From a medico-legal point of view the Röntgen photography will clearly play a leading part in cases where surgeons are charged with having overlooked a fracture or a dislocation, when no such injury is present.'

In one instance the present writer was called upon to make a Röntgen ray examination in an action brought against a medical man for negligence in overlooking a broken rib or ribs. The plaintiff, an elderly, stout, asthmatic man, had been thrown out of a vehicle, and fell lengthwise, with his right nipple line along the edge of the kerbstone. As the alleged injury was in front of the body and over the site of the liver, it was found impossible to photograph the ribs in that position, although the writer has since succeeded in getting a perfect picture of the front ends of the lower ribs in a living adult man of average build. Although the result proved negative, so far as the plaintiff's ribs were concerned, it nevertheless revealed the fact that he was suffering from aneurism and from bronchiectatic cavities of the lung. The existence of the aneurism, by the way, was denied by the plaintiff's physician, but it should be noted that in so large a chest it would have been well-nigh impossible to discover, under

* *Boston Medical News*, December 19, 1896.

the particular circumstances, the aneurism by any means other than the rays. The plaintiff failed to bring any positive evidence as to the alleged fracture, and his case broke down after the examination of the defendant.

As regards one branch of irregular or quack medical practice the *x*-ray photography is likely to do yeoman's service. The bone-setters are a fraternity who batten on the ignorance and the credulity of their victims. Their almost invariable plan is to tell the sufferer that a 'bone is out,' or is 'broken,' or 'has not been properly set.' In all these conditions the Röntgen rays may be trusted to reveal the truth or otherwise of the assertion. Hence it will be wise in future for everyone who consults a member of that fraternity to verify the resulting diagnosis by an appeal to the rays before he submits to any manipulations. There is one form of fixed joint after injury, due to fibrous adhesions between the articular surfaces. In such a case the bone-setter declares the joint is dislocated, and breaks down the adhesions by a sudden wrench. Now, in such a fixation the Röntgen examination shows the absence of dislocation. On the other hand, if a clear space indicates a joint not filled with osseous or other opaque matter (fibrous bands being transparent), then the immobility of the joint may safely be ascribed to fibrous anchylosis. Several cases of this kind, based on the negative evidence of a clear tracing of the joint space, and the positive evidence of a normal relation of bones of a fixed joint and of a previous injury, are given in the section upon 'Bones' (see p. 131).

Mr. Howard Marsh has observed of the method: 'It would have furnished valuable information to a patient met with some years ago, who had slight lateral curvature of the spine. This patient was told by a bone-setter that "his pelvis had opened, and both his hips were out." The reassurance and the mental calm which a Röntgen photograph could now bring to anyone who, having nothing seriously wrong, had been told he was the subject of such a formidable condition of things, can be easily imagined.'

It may be hoped, then, that the Röntgen rays will help to rid the world of this class of harmful social parasites. Sooner or later the strong hand of Science must infallibly cut the ground away from under the feet of all such pretenders.

HINTS IN PREPARING EVIDENCE

In seeking Röntgen ray evidence, it is clear that the wisest course will be for the lawyer to go at once to a skilled medical operator. There is no process that needs more accurate general and special knowledge than that involved in preparing x-ray medical evidence. Pitfalls await the unwary or the non-medical witness on every hand, as he and his principals may find to their cost on his appearance in the witness-box. The following hints may possibly be of some service to those who are called upon to furnish legal evidence of the kind:

Make a note of patient and of his case, with full details, such as name, address, date, history, and symptoms. If possible, make the examination in the presence of the medical man or men engaged on the opposite side. All notes to be reduced to writing at the earliest opportunity.

Never neglect to make a screen as well as a photographic examination.

Make an identifying mark (to be entered in notes) on all photographic plates. Keep all negatives and photographs under lock and key, and under no circumstances allow the originals to leave your possession. Neglect of this precaution may lose a suit.

Remember that the Röntgen method reveals mainly injuries to bone, whereas soft-tissue damage may be quite as disabling to the patient.

Be careful to guard against fallacies such as those due to position of parts in relation to the tube. This can be done by having comparative photographs of the corresponding sound parts; indeed, that should be the invariable rule in legal cases. Wherever possible, make an exact localization.

Sometimes firm union occurs in a fracture, although the Röntgen photograph may not register bony union for many months afterwards.

An ununited epiphysis may be mistaken for a fracture, or the injury disclosed may be one of old standing.

Negative evidence, *e.g.*, the absence of a bullet, is often as valuable as positive.

Think out all the points of the case, and make no statement which you cannot justify in the witness-box. Carefully sift out matters of fact from matters of opinion.

It is well to have an understanding as to the amount of fee to be tendered for expert evidence before attending court. In one case brought to the attention of the writer, a medical operator was appealed to *ad misericordiam* to accept a nominal fee in an action brought against a brother professional; the latter won the day, and costs fell upon the other side, but no increase was made in the sum first agreed upon.

G. ANATOMY

A GOOD deal of light has been already acquired in relation to the age at which union of bony epiphyses takes place. It seems likely, in view of the facts afforded by Röntgen ray researches, that much of the information upon this point contained in the anatomical text-books will have to be rewritten. It appears certain, for instance, that the variation of the individual in this matter is much wider than hitherto recognised by the anatomists. The new method offers obvious advantages in obtaining data for general conclusions as to ages of ossific union. Supposing, for instance, it be desired to study the epiphyses of the humerus at the age of fourteen. A sufficient number of Röntgen photographs of the humerus of persons of that age—carefully verified, it need hardly be said—would have to be procured, and the results compared at leisure. This method would be rapid and accurate as compared with the tedious and more or less uncertain observations to be gleaned from the alternative plan of many laborious dissections. Moreover, the rays could be applied to the living as well as to the dead, and also to bodies where post-mortem examination would be impossible.

The most authoritative tables yet drawn up on this subject are those of Mr. Poland, quoted on page 152.

ANATOMY OF BLOODVESSELS

The injection of bloodvessels by some material opaque to the rays, and then subjecting them to the new method, opens up a wide field of anatomical investigation. In this way Dr. F. J. Clendinnen, of Melbourne,* demonstrated the arteries of a seven-

* *International Medical Journal of Australasia*, October 20, 1896, p. 611.

months fœtus, which he had injected with a solution of red lead. That particular salt was used because, as the result of previous experiments, he had come to the conclusion that red was more opaque than other colours. His record afforded a sharp and beautiful diagrammatic view of the arteries, even where they passed behind the fœtal bones. A peculiarity such as that of double high division of the brachial artery was well shown.

In a later issue of the same journal (January 20, 1897), Dr. Clendinnen published some further illustrations obtained in a similar way. They showed the arteries about the knee and the

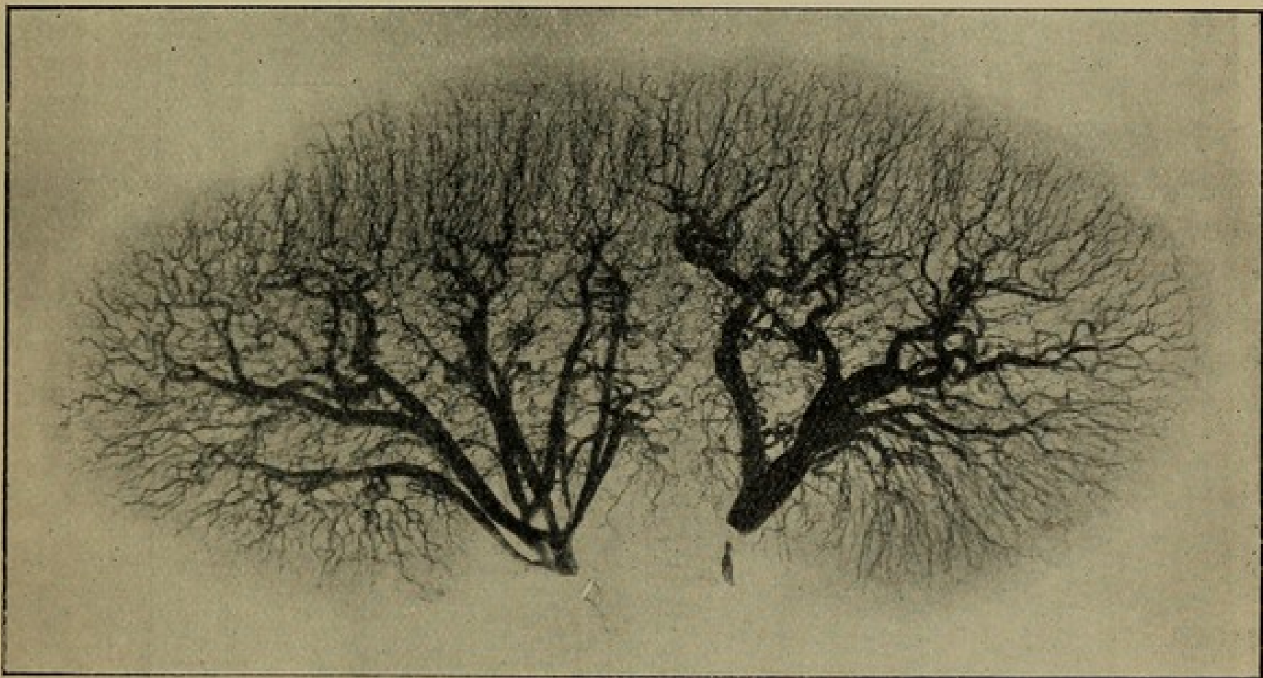


FIG. 96.—INJECTED BLOODVESSELS OF HUMAN KIDNEY.
By Dawson Turner.

ankle-joint. The small muscular twigs and other minute branches were reproduced with the utmost fidelity.

There can be no doubt that this method may now and then afford a valuable means of showing in a graphic manner the facts of local blood-supply, both in normal and in pathological specimens. As an instance of the latter, a perfect picture could be obtained of circulation by anastomoses, say, in a case where during life the femoral artery had been tied for aneurism, or in the stump of an amputated limb.

Dr. Clendinnen adds that in one case he obtained from the living body a good record of the popliteal artery. This observavation is valuable, and perhaps points to the time when a fuller knowledge of conditions in relation to results will bring the blood-vessels under command of the Röntgen ray worker.

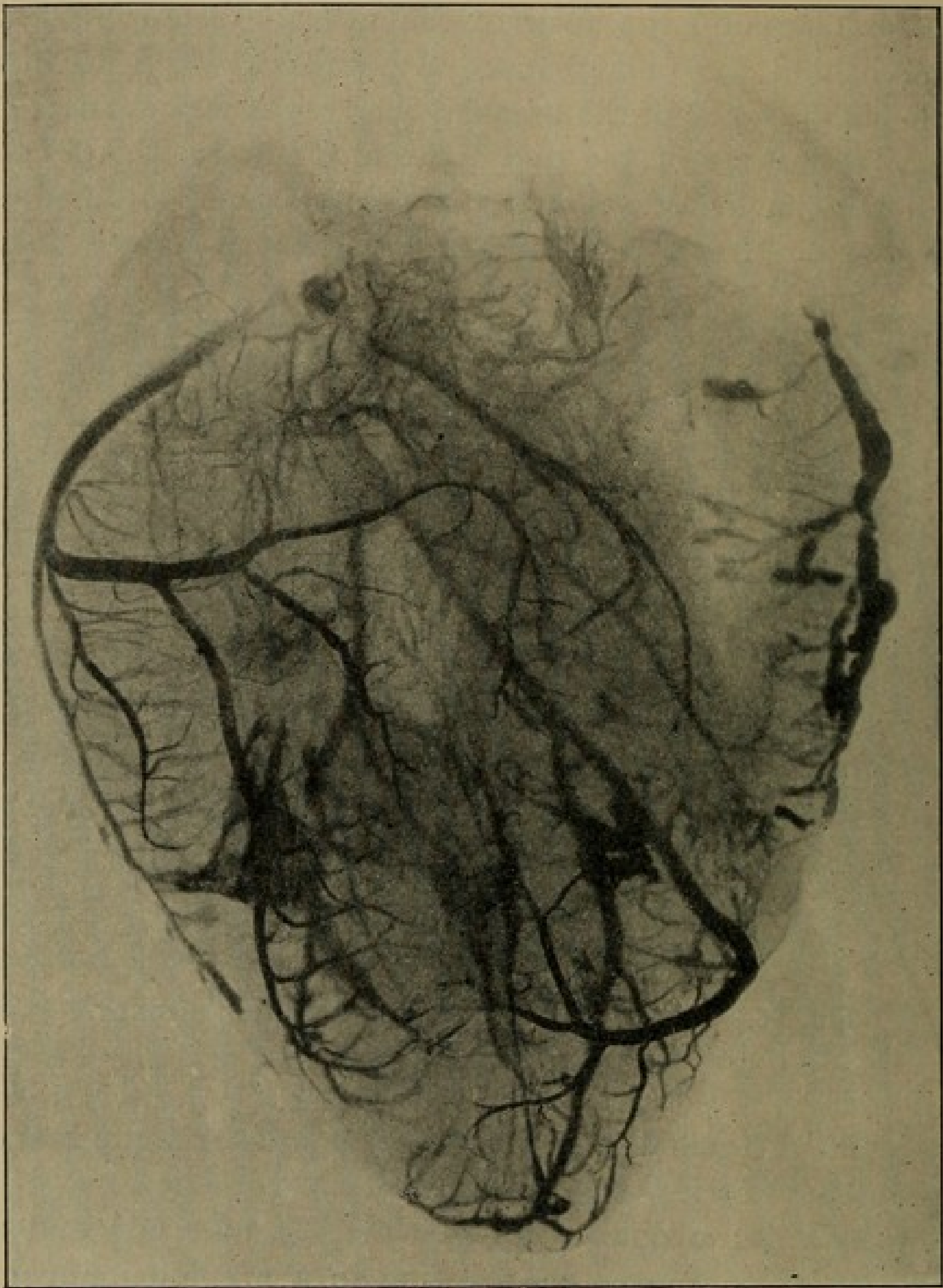


FIG. 97.—INJECTED BLOODVESSELS OF HUMAN HEART.
By Dawson Turner.

Messrs. Rémy and Contremoulins have made similar observations by injecting the arteries with a solution of wax in alcohol charged with various metallic powders.

Dr. Nathan Raw showed to the Manchester Pathological

Society, in December, 1896, Röntgen photographs of arteries injected with plaster of Paris and carmine.

Another application of this principle of opaque injection was brought forward by Poncet, of Lyons.* He presented the Academy of the town mentioned with a series by Destot and Bérard, showing the arterial and venous circulation of the kidney in various pathological conditions of that organ.

Some of the interesting conclusions as to normal vascular supply may be quoted. Thus, it was found that the circulation in the kidney is lobar and terminal, and permits the differentiation of an independent anterior and posterior kidney, except the artery of the superior lobe, which often divides into two branches, so that, when it is injected, the entire upper portion is permeated. Professor Dawson Turner has kindly allowed a reproduction of photographs of an injected human kidney and heart (Figs. 96 and 97), prepared by the slow injection of an ordinary dissecting-room preparation made rather thin.

Some beautiful and instructive views of the circulation in internal organs, such as the brain or the liver, may be obtained by stereoscopy.

The bearing of researches of this nature upon the study of the evolution of organs is obvious.

Another field in normal anatomy is the relation of parts in the various internal regions of the body. The exact relation of the bladder and urethra, for instance, might be studied by filling the organ and passages with melted paraffin, holding in solution some opaque mineral substance, as zinc or lead oxide.

In pathological anatomy, it is possible that not a few points of interest might be solved by injecting the hollow viscera with opaque solutions, and then taking a radiogram of the result.

* *Gazette des Hôpitaux*, December 31, 1896.

H. PHYSIOLOGY

INTERESTING results have been obtained by Messrs. Hébert and Bertin-Sans from the study on the screen of the movements of joints, more especially in the case of the wrists. The observations will no doubt be sooner or later considerably extended.

A number of interesting observations have already been made upon the movements of the heart, and also upon the varying relationship between the pulsating heart and the diaphragm.

M. Bouchard* has reported marked dilatation of the auricle when the intra-thoracic blood-pressure was raised during inspiration. The same condition could be artificially brought about by endeavouring to inspire with the glottis shut, and occurred naturally during the violent inspirations of a paroxysm of whooping cough. He also noted a clear space between the heart and diaphragm during forced, but not during ordinary inspiration.

Schott† found it easy to cause transient dilatation of the heart by hard muscular exercise.

Wherever in the interior of the body there is pulsation in any organ open to the *x*-rays, the process of chrono-photography will be available. The possible presentation of a pulsating human heart upon a lantern screen, by a method so young that it is yet barely articulate, speaks volumes for the energy of latter-day science.

Dr. Macintyre has produced cinematographic views of the human body. This branch of the subject is likely to be greatly advanced when it is possible to take flash exposures of deep adult structures.

Professor Benedikt, of Vienna, has found that movements of

* *Lancet*, September 10, 1898.

† *Deutsch. Med. Wochen.*, vol. xxviii., p. 495, 1897.

the heart are best studied in young or emaciated subjects. He noted during cardiac systole a shortening between apex and base, and concluded there was only a systolic lateral apex impulse. Further, during systole the heart is not entirely emptied of blood, for a shadow cast by residual blood is recognisable. The bloodless heart is relatively transparent, but even thin layers of blood cast a shadow. These observations certainly seem to upset Skoda's teaching, that the apex beat is due to the resistance of the blood.

One of the most interesting investigations in physiological movements has been made on the fluorescent screen by Scheir, of Berlin, who reported his results to the Congress of Medicine in August, 1897. If the rays passed through the head laterally, the naso-pharyngeal space and upper part of the pharynx were seen as clear shadows, and if the person under examination uttered a vowel sound, the velum was seen to be raised and to take up a position in the naso-pharyngeal space, varying according to the nature of the sound. With the vowel *a*, the velum was raised the least, and was successively raised more and more by the succeeding vowels *e, o, u, i*. The velum was more raised in high than in low tones. The form of the mouth in the pronunciation of the different consonants could also be plainly seen. The shape and position of the tongue, the lips, and the jaws could also be distinguished. The rays clearly showed the movements of the larynx, velum, and other parts in swallowing, breathing, and sneezing, and in pathological conditions the irregularities could be determined with precision.*

Messrs. Sabrazès and Rivière in 1897 announced to the Paris Academy of Science that the rays had no influence either upon the action of white blood corpuscles, or upon the phenomena of phagocytosis, while a frog's heart exposed to the rays for several hours appeared to undergo no alteration of movement.†

* *Medical Press and Circular*, September 1, 1897, p. 212.
† *Lancet*, May 29, 1897, p. 1505.

I. THE RAYS IN VETERINARY SURGERY.*

A GOOD deal of work has been done with the Röntgen rays in veterinary practice by Professor Hobday and others.†

The horse's hoof he found to be readily penetrable by the rays, so that a foreign metallic body, such as a misdirected nail, could be at once detected in that region, and he obtained excellent radiograms of dogs and cats suffering from various accidents. In the *Veterinarian* for September, 1896, Professor Hobday and Mr. Johnson wrote: 'In conclusion, the authors consider that the Röntgen rays can be successfully applied to the smaller animals without much difficulty. In the horse, the mechanical difficulties of restraint have been successfully overcome. . . . For diagnosis of abnormalities of the bones of the limbs, such as suspected fracture of the pastern, small ringbone, sidebone, or foreign body in the hoof, the results demonstrate that this method can be applied successfully. With the bones of the neck, too, no great difficulty is anticipated.'

Since that time further work has been done by Major Frederick Smith, of the Army Veterinary Department, and Professor Hobday, the results being to effect a great reduction of exposure and to bring the method within more practical limits, also to show the value of the screen in certain cases.

The main difficulties have arisen in connection with the diagnoses of spavin and navicular disease. In spavin the closeness of the bones to each other, their curved articular surfaces,

* This section has been kindly revised by Professor F. Hobday, of the Royal Veterinary College, London.

† *Journal of Comparative Pathology and Therapeutics*, vol. ix., p. 58; *Veterinary Record*, September, 1896.

the presence of overhanging ridges so frequently found in normal hocks, together with the fact that the bones are placed one behind the other, made the task of unusual difficulty.

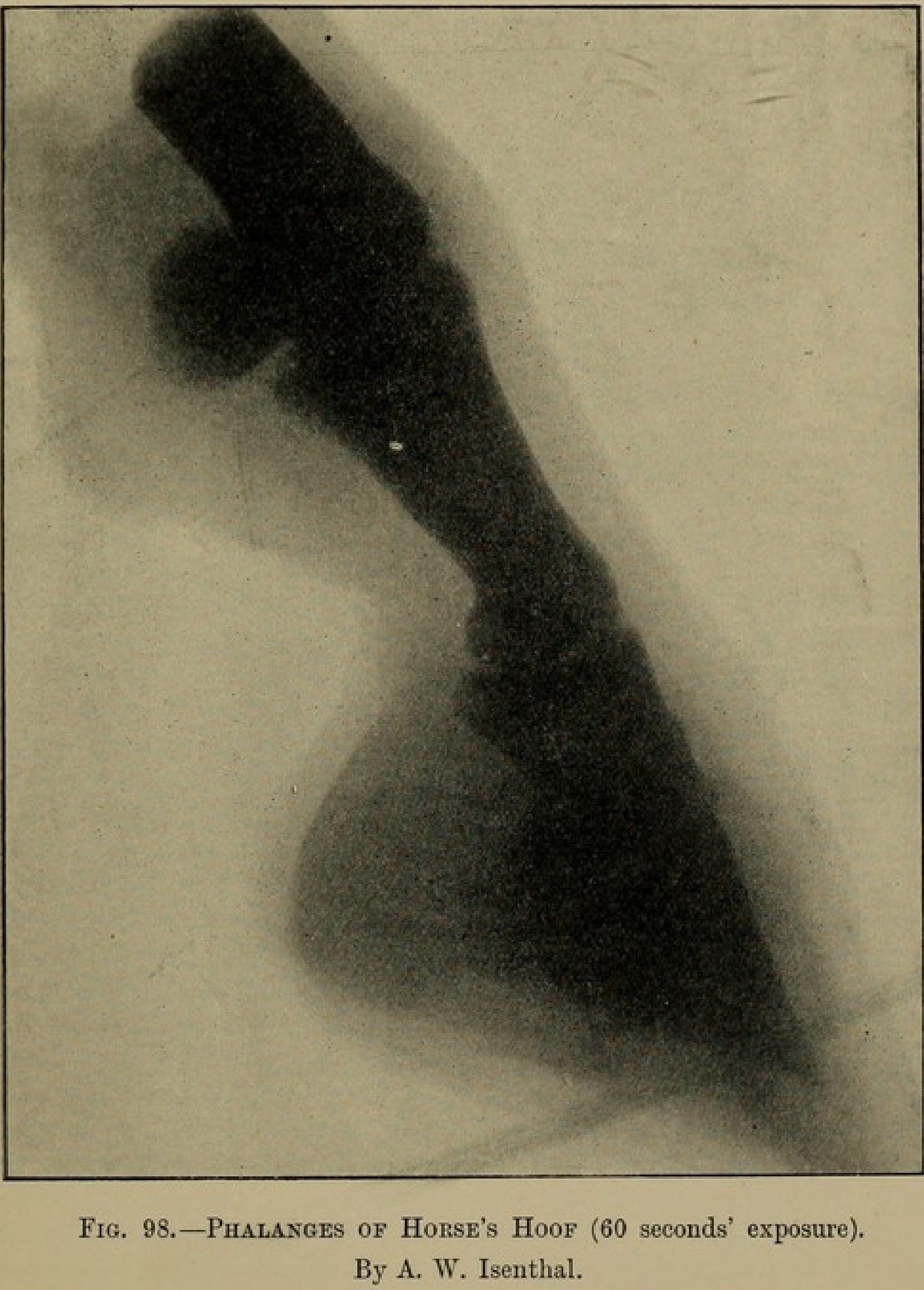


Fig. 98.—Phalanges of Horse's Hoof (60 seconds' exposure). By A. W. Isenthal.

In navicular disease the experimenters have up to the present had to acknowledge failure, as the position of the bone in regard to its surroundings and the nature of the lesion render attempts to further diagnosis by the application of the x-rays abortive.

APPENDIX

A NEW FORM OF RADIATION

BEING A PRELIMINARY COMMUNICATION TO THE WÜRZBURG PHYSICO-MEDICAL SOCIETY, BY PROFESSOR WILHELM KONRAD RÖNTGEN, DECEMBER, 1895.

1. IF we pass the discharge from a large Ruhmkorff coil through a Hittorf or a sufficiently exhausted Lenard, Crookes, or similar apparatus, and cover the tube with a somewhat closely-fitting mantle of thin black cardboard, we observe in a completely-darkened room that a paper screen washed with a barium-platino-cyanide lights up brilliantly and fluoresces equally well whether the treated side or the other be turned towards the discharge-tube. Fluorescence is still observable 2 metres away from the apparatus. It is easy to convince one's self that the cause of the fluorescence is the discharge from the apparatus, and nothing else.

2. The most striking feature of this phenomenon is that an influence capable of exciting brilliant fluorescence is able to pass through the black cardboard cover, which transmits none of the ultra-violet rays of the sun or of the electric arc, and one immediately inquires whether other bodies possess this property. It is soon discovered that all bodies are transparent to this influence, but in very different degrees. A few examples will suffice. Paper is very transparent ;* the fluorescent screen still lighted up brightly when held behind a bound volume of 1,000 pages ; the printer's ink offered no perceptible obstacle. Fluorescence was also noted behind two packs of cards ; a few cards held between tube and screen made no perceptible difference. A single sheet of tinfoil is scarcely noticeable ; only after several layers have been laid on top of each other is a shadow clearly visible on the screen. Thick blocks of wood are also transparent ; fir-planks from 2 cm. to 3 cm. thick are but slightly opaque. A film of aluminium about 15 mm. thick weakens the effect considerably, though it does not entirely destroy the fluorescence. Several centimetres of vulcanized indiarubber let the rays through.† Glass plates of the same

* By the 'transparency' of a body I denote the ratio of the brightness of a fluorescent screen held right behind the body in question to the brightness of the same screen under exactly the same conditions, but without the interposing body.

† For brevity's sake I should like to use the expression 'rays,' and to distinguish these from other rays I will call them 'x-rays'

thickness behave in a different way, according as they contain lead (flint glass) or not; the former are much less transparent than the latter. If the hand be held between the tube and the screen, the dark shadow of the bones is visible within the slightly dark shadow of the hand. Water, bisulphide of carbon, and various other liquids behave in this respect as if they were transparent. I was not able to determine whether water was more transparent than air. Behind plates of copper, silver, lead, gold, platinum, fluorescence is still clearly visible, but only when the plates are not too thick. Platinum 0·2 mm. thick is transparent; silver and copper sheets may be decidedly thicker. Lead 1·5 mm. thick is practically opaque, and was on this account often made use of. A wooden rod of 20 by 20 mm. cross-section, painted with white lead paint on one side, behaves in a peculiar manner. When it is interposed between apparatus and screen it has almost no effect when the x-rays go through the rod parallel to the painted side, but it throws a dark shadow if the rays have to traverse the paint. Very similar to the metals themselves are their salts, whether solid or in solution.

3. These and other experimental results led to the conclusion that the transparency of different substances of the same thickness is mainly conditioned by their density; no other property is in the least comparable with this.

The following experiments, however, show that density is not altogether alone in its influence. I experimented on the transparency of nearly the same thickness of glass, aluminium, calcspar, and quartz. The density of these substances is nearly the same, and yet it was quite evident that the spar was decidedly less transparent than the other bodies, which were very much like each other in their behaviour. I have not observed calcspar fluoresce in a manner comparable with glass.

4. With increasing thickness all bodies become less transparent. In order to find a law connecting transparency with thickness, I made some photographic observations, the photographic plate being partly covered with an increasing number of sheets of tinfoil. Photometric measurements will be undertaken when I am in possession of a suitable photometer.

5. Sheets of platinum, lead, zinc, and aluminium were rolled until they appeared to be of almost equal transparency. The following table gives the thicknesses in millimetres, the thicknesses relative to the platinum sheet, and the density:

Thickness.	*Relative Thickness.*	*Density.*
Pt 0·018	1	21·5
Pb 0·05	3	11·3
Zn 0·10	6	7·1
Al 3·5	200	2·6

It is to be observed in connection with these figures that, although the product of the thickness into the density may be the same, it does not in any way follow that the transparency of the different metals is the same. The transparency increases at a greater rate than this product decreases.

6. The fluorescence of barium-platino-cyanide is not the only recognisable phenomenon due to x-rays. It may be observed, first of all, that other bodies fluoresce—for example, phosphorus, calcium compounds, uranium glass, ordinary glass, calcspar, rock salt, etc.

Of especial interest in many ways is the fact that photographic dry plates show themselves susceptible to x-rays. We are thus in a position to corroborate many phenomena in which mistakes are easy, and I have, whenever possible, controlled each important ocular observation on fluorescence by means of photography. Owing to the property possessed by the rays of passing almost without any absorption through thin sheets of wood, paper, or tinfoil, we can take the impressions on the photographic plate inside the camera or paper cover whilst in a well-lit room. In former days this property of the ray only showed itself in the necessity under which we lay of not keeping undeveloped plates, wrapped in the usual paper and board, for any length of time in the vicinity of discharge-tubes. It is still open to question whether the chemical effect on the silver salts of photographic plates is exercised directly by the x-rays. It is possible that this effect is due to the fluorescent light which, as mentioned above, may be generated on the glass plate, or perhaps on the layer of gelatine. 'Films' may be used just as well as glass plates.

I have not as yet experimentally proved that the x-rays are able to cause thermal effects, but we may very well take their existence as probable, since it is proved that the fluorescent phenomenon alters the properties of x-rays, and it is certain that all the incident x-rays do not leave the bodies as such.

The retina of the eye is not susceptible to these rays. An eye brought close up to the discharge apparatus perceives nothing, although, according to experiments made, the media contained in the eye are fairly transparent.

7. As soon as I had determined the transparency of different substances of various thicknesses, I hastened to ascertain how the x-rays behaved when passing through a prism—whether they were refracted or no. Water and carbon disulphide, in prisms of about 30° refractive angle, showed neither with the fluorescing screen nor with the photographic plate any sign of refraction. For purposes of comparison the refraction of light rays was observed under the same conditions; the refracted images on the plate were respectively about 10 mm. and 20 mm. from the non-refracted one. With an aluminium and a vulcanized rubber prism of 30° angle I have obtained images on photographic plates in which one may perhaps see refraction. But the matter is very uncertain, and even if refraction exists, it is so small that the refractive index of the x-ray for the above materials can only be, at the highest, 1·05. Using the fluorescent screen, I was unable to discover any refraction at all in the case of the aluminium and the rubber prism.

Researches with prisms of denser metals have yielded up to now no certain results, on account of the small transparency, and consequently lessened intensity, of the transmitted ray.

In view of this state of things, and the importance of the question whether x-rays are refracted on passing from one medium to another, it is satisfactory to find that this question can be attacked in another way than by means of prisms. Finely-powdered substances in sufficient thicknesses allow only a very little of the incident light to pass through, and that is dispersed by refraction and reflection. Now, powdered substances are quite as transparent to x-rays as are solid bodies of equal mass. Hence, it is proved that refraction and regular reflection do not exist to a noticeable degree. The experiments were carried out with finely-powdered rock salt, with powdered electrolytic silver, and with the zinc powder much used in chemical work. In no case was any difference observed between the transparency of the powdered and solid substance, either when using the fluorescent screen or the photographic plate.

It follows, from what has been said, that the x-rays cannot be concentrated by lenses; a large vulcanized rubber and glass lens were without influence. The shadow of a round rod is darker in the middle than at the edge; that of a tube filled with any substance more transparent than the material of the tube is lighter in the middle than at the edge.

8. The question of the reflection of the x-rays is settled in one's mind by the preceding paragraphs, and no appreciable regular reflection of the rays from the substances experimented with need be looked for. Other investigations, which I will describe here, lead to the same result. Nevertheless, an observation must be mentioned which at first sight appears to contradict the above statement. I exposed a photographic plate to the x-rays, protected against light rays by black paper, the glass side being directed towards the discharge-tube. The sensitive layer was nearly covered, star fashion, with blanks of platinum, lead, zinc, and aluminium. On developing the negative, it was clearly noticeable that the blackening under the platinum, lead, and especially under the zinc, was greater than in other places. The aluminium had exercised hardly any effect. It appeared, therefore, that the three above-mentioned metals had reflected the rays. Nevertheless, other causes for the greater blackening were thinkable, and in order to make sure I made a second experiment, and laid a piece of thin aluminium, which is opaque to ultra-violet rays, though very transparent to x-rays, between the sensitive layers and the metal blanks. As again much the same result was found, a reflection of x-rays by the above-mentioned metals was demonstrated. But if we connect these facts with the observation that powders are quite as transparent as solid bodies, and that, moreover, bodies with rough surfaces are, in regard to the transmission of x-rays, as well as in the experiment just described, the same as polished bodies, one comes to the conclusion that regular reflection, as already stated, does not exist, but that the bodies behaved to the x-rays as muddy media do to light.

Again, as I could discover no refraction at the point of passage from one medium to another, it would seem as if the x-rays went through all substances at the same speed, and that in a medium which is everywhere, and in which the material particles are embedded, the particles obstruct the propagation of the x-rays in proportion to the density of the bodies.

9. Hence it may be that the arrangement of the particles in the bodies influences the transparency ; that, for example, equal thicknesses of calc-spar would exhibit different transparencies, according as the rays were in the direction of the axis or at right angles to it. Researches with calcspar and quartz have yielded a negative result.

10. It is well known that Lenard, in his beautiful investigation on Hittorf cathode rays passed through thin aluminium-foil, came to the conclusion that these rays were actions in the ether, and that they pass diffusively through all bodies. I have been able to say the same about my rays.

In his last work Lenard has determined the absorption coefficient of various bodies for cathode rays, and among other things for air atmospheric pressure at 4·1, 3·4, 3·1, per centimetre, and found it connected with the exhaustion of the gas contained in the discharge apparatus. In order to estimate the discharge pressure by the spark-gap method, I used in my researches almost always the same exhaustion. I succeeded with a Weber photometer (I do not possess a better one) in comparing the intensity of the light of my fluorescing screen at distances of about 100 mm. and 200 mm. from the discharge apparatus, and found in the case of three tests agreeing well with one another, that it varied very nearly inversely as the square of the distance of the screen from the discharge apparatus. Hence the air absorbs a very much smaller fraction of the x-rays than of the cathode rays. This result is also quite in agreement with the result previously mentioned, that the fluorescing light was still observable at a distance of 2 metres from the discharge-tube.

Other bodies behave generally like air—that is to say, they are more transparent for x-rays than for cathode rays.

11. A further noteworthy difference in the behaviour of cathode rays and x-rays consists in the fact that, in spite of many attempts, I have not succeeded, even with very strong magnetic fields, in deflecting x-rays by a magnet. The magnetic deflection has been, up to now, a characteristic mark of the cathode ray ; it was, indeed, noticed by Hertz and Lenard that there were different kinds of cathode rays, ‘ distinguishable from one another by their phosphorescing powers, absorption and magnetic deflection,’ but a considerable deflection was nevertheless observed in all cases, and I do not think this characteristic will be given up without overwhelming evidence.

12. After experiments bearing specially on this question, it is certain that the spot on the wall of the discharge apparatus which fluoresces most decidedly must be regarded as the principal point of the radiation of the x-rays in all directions. The x-rays thus start from the point at which, according to the researches of different investigators, the cathode rays impinge upon the wall of the glass tube. If one deflects the cathode rays

within the apparatus by a magnet, it is found that the x-rays are emitted from another spot—that is to say, from the new termination of the cathode stream.

On this account, also, the x-rays, which are not deflected, cannot merely be unaltered reflected cathode rays passing through the glass wall. The greater density of the glass outside the discharge-tube cannot, according to Lenard, be made responsible for the great difference in the 'deflectability.'

I therefore come to the conclusion that the x-rays are not identical with the cathode rays, but that they are generated by the cathode rays at the glass wall of the discharge apparatus.

13. This excitation does not take place only in glass, but also in aluminium, as I was able to ascertain with an apparatus closed by a sheet of aluminium 2 mm. thick. Other substances will be studied later on.

14. The justification for giving the name of 'rays' to the influence emanating from the wall of the discharge apparatus depends partly on the very regular shadows which they form when one interposes more or less transparent bodies between the apparatus and the fluorescing screen or photographic plate. Many such shadow-pictures, the formation of which possesses a special charm, I have observed—some photographically. For example, I possess photographs of the shadow of the profile of the door separating the room in which was the discharge apparatus from the room in which was the photographic plate ; also photographs of the shadows of the bones of the hand, of the shadow of a wire wound on a wooden spool, of a weight enclosed in a small box, of a compass in which the magnetic needle is completely surrounded by metal, of a piece of metal the lack of homogeneity of which was brought out by the x-rays, etc.

To show the rectilinear propagation of the x-rays there is a pinhole photograph, which I was able to take by means of the discharge apparatus covered with black paper. The image is weak, but unmistakably correct.

15. I looked very carefully for interference phenomena with x-rays, but unfortunately, perhaps on account of the small intensity of the rays, without success.

16. Researches to determine whether electrostatic forces affect x-rays in any way have been begun, but are not completed.

17. If we ask what x-rays—which certainly cannot be cathode rays—really are, we are led at first sight, owing to their powerful fluorescing and chemical properties, to think of ultra-violet light. But we immediately encounter serious objections. If x-rays be in reality ultra-violet light, this light must possess the following characteristics :

(*a*) It must show no perceptible refraction on passing from air into water, bisulphide of carbon, aluminium, rock salt, glass, zinc, etc.

(*b*) It must not be regularly reflected to any appreciable extent from the above bodies.

(*c*) It must not be polarizable by the usual means.

(*d*) Its absorption must not be influenced by any of the properties of substances to the same extent as it is by their density.

In other words, we must assume that these ultra-violet rays behave in quite a different manner from any infra-red, visible, or ultra-violet rays hitherto known. I could not bring myself to this conclusion, and I have, therefore, sought another explanation.

There seems at least some connection between the new rays and light rays in the shadow-pictures and in the fluorescing and chemical activity of both kinds of rays. Now, it has long been known that, besides the transverse light vibrations, longitudinal vibrations might take place in the ether, and, according to the view of different physicists, must take place. Certainly their existence has not up till now been made evident, and their properties have not, on that account, been experimentally investigated.

May not the new rays be due to longitudinal vibrations in the ether?

I must admit that I have put more and more faith in this idea in the course of my research, and I therefore advance that surmise, although I know that such an explanation requires further corroboration.

INDEX.

ABDOMEN, foreign bodies in, 107
,, radiography of, 182, 197
Abdominal aorta shown by rays, 187
Abscess of bone, 167
Absence of collar-bone, congenital, 160
Absorption of bone, 79, 88, 167
Accumulators, 23
Action of focus tube upon micro-organisms, 174
Action of focus tube upon skin and deeper structures, 201
Adhesions, interarticular, diagnosis of, 131, 167
Adhesive plaster, opacity of, 127
Adjustable focus tube (Swinton's), 41
Age of fœtus, 229
Alderson on cervical ribs, 162
Alternating current for coil, 27
,, ,, interrupter, 27
Ammeter, 24
Anæsthetic effect of rays, 209
Anatomy, 234
Anchylosis of joint, bony, 170
,, ,, fibrous, 79, 170
Aneurism, aortic, diagnosis by screen, 188
Aneurism, unsuspected, 230
Antikathode, 28
Aorta, aneurism, 188
,, atheroma, 191
,, dilated, 188
Apparatus (Davidson's) for eye localization, 114
Apparatus (Sweet's), 113
Apps' induction coil, 31
Army work, needs of, 82
Arteries, calcification of, 201
,, injected in fœtus, 234
,, of kidney, 235
Arthritis, bones in rheumatoid, 165
Astragalus, dislocation of, 144
,, fractures of, 144
Atheroma of aorta, 191
,, arteries, 191
Author's case of loin tumour, 121
,, experiment on bone shadows, 123
Author's method of mapping skin, 172

Bacilli, tubercle, rays negative, 220
Bacteria, negative action of rays upon, 173
Barton's fracture of lower end of radius, 139
Barwell on talipes, 156
Batteries, bichromate, 18
,, Bunsen, 18
,, Edison-Lalande, 19
,, Grove, 17
,, primary, 17
,, secondary, 22
,, wet, 17-22
Battersby's experiences in Soudan, 82, 84
Beatson, bifid thumb phalanges, 159
Beevor's experiences in Chitral, 81
Bertillon method of identifying criminals, 172
Bianodal tube, 40
Bichromate battery, 19
Bifid terminal thumb phalanges, 159
Bismuth in skin tracings, 172
,, opaque, as a dressing, 127
Black skin, resistance of, 209
Blacker, Dr. Barry, teeth in gullet, 105
Blindness and the focus-tube rays, 217
Blood relatively opaque to the rays, 187
Bloodvessels, anatomy of, 234
,, injection of, 235
,, of heart, 236
,, of kidney, 235
Bodily identification, evidence of, 227
Bone abscess and absorption, 79, 88, 167
,, caries of, 169
,, diseases of, 163
,, experiment as to opaque element, 123

Bone, in gout, translucency, etc., 164
,, injuries, value of Röntgen diagnosis, 132
Bone necrosis, 168
,, translucency in tubercular, 167
,, tumour, 164
Bones, sesamoid, of end joint of thumb, 125
Bones, sesamoid, shadows of, 125
Bonesetters, discomfiture of, 130, 225, 231
Boot deformities, 163
Bouchard on pleurisy under the rays, 191
Brain, bullets in, 97
Bronchial glands, enlargement, 192
Bronzing of skin after focus-tube exposure, 215
Buckle in baby's gullet, 106
Bullet, Greenhill's experiment, 90
,, in brain, localization, 98
,, in lung, 104
,, in os calcis, 86
,, in shoulder, 87
,, in skull, 98
,, in spine, 102
,, wound of thumb, 88
,, detection, 81
Bunsen battery, 18
Burton, fractured ribs, 147

Calcification of arteries, 173, 201
Calculi in various positions, 117
,, of gall bladder, 117
,, of urinary bladder, 117, 121
,, relative opacity, 119
,, renal, 118, 120
Callus, its translucency, 72
Campaign in Chitral, 81
,, in Cuba, 85
,, in Greece, 81
,, in Soudan, 81
Cancer of stomach, negative results, 199
Cancer, pain controlled by focus-tube rays, 209
Cardiac dilatation and hypertrophy, 191
Caries of bone, 169
,, of neck vertebræ, 169
Carpenter's case of absent collar-bones, 160
Cartilage, erosion of, 170
Cartilages, ossification of, 173
Cat, radiogram of, half grown, 182
Cats, diagnosis of injuries in, 240
Cell, bichromate, 19
,, Grove, 18
Cells in multiple series, 20
,, in parallel, 20
Cells in series, 20
Cervical caries, 169
,, fracture, 133
,, ribs, 162
Chest exploration by rays, 191
Chitral, x-rays at, 81
Chromo-photography with x-rays, 238
Cinematograph with x-rays, 238
Cirrhosis of lung, 194
Clavicles, congenital absence, 160
Clothing, removal of, 68
Club foot, Mr. Barwell's cases, 156
Coil, Apps-Newton, 32
,, Cox, 32
,, how to work, 64
,, Rochefort and Wydt's, 36
,, Ruhmkorf, 31
,, Tesla, 37
,, the induction, 31
Coins in gullet, 107
Collar-bone fractures, 133
Collar-bones, absent, 160
Colles' fracture of radius, 129-133
,, ,, ,, double, 133, 134
Collins, Treacher, on foreign bodies in the eye, 114
Colour-blindness, focus tube in, 219
Comparative photographs, need of, in fractures, 128
Congenital deformities, 156
Consolidation of lung, 192-197
Consumption, rays in, 192
Contact breaks, 32
,, ,, Apps, 33
,, ,, electro-magnetic, 34
,, ,, mechanical, 34
,, ,, mercury, 34
,, ,, motor, 34
,, ,, Vril, 32
,, ,, Wehnelt, 35
Continuous current, 26
Couch, operating, 63, 64
Court, cases in, 232
Court, how to prepare evidence for, 232
Coxa vara, 141
Cricketer, finger of, 167
Crookes' tube. *See* Tube, 39
Cross-radiogram, 89
Cryptoscope, 47
Current, alternating, 27
,, continuous, 25
,, rate and pressure required, 21

Dactylitis, strumous, 174
Daily Chronicle: Röntgen outfit for Græco-Turkish war, 81
Davidson's localizer, 93
Deep tissue work, 184
Definition, how to test, 55

Definition, sharpness of, 55
Deformities, congenital and acquired, 156, 158, 159
Deformities due to dress, boots, etc., 163
Deformities due to various diseases, 156
,, of spine, 137, 148
Dental surgery, 176
Dentiaskiascope, 178
Dentigerous cyst, 179
Depilatory action of focus-tube rays, 214
Dermatitis after Röntgen-ray exposure, 201-213
Dermatitis, 'burn' theory, 207
,, compared with sun dermatitis, 207, 209
Dermatitis, idiosyncrasy to, 213
Destot, fractures of astragalus, 144
,, ,, of wrist, 139
Developing solutions, 48
Developmental defects, 159
Diaphragm, altered position in disease, 195
Diaphragm, movements in health, 195
,, partial paralysis of, 195
Diseases of bone, 163
Dislocation, backward, of forearm, 150
,, ,, of thumb, 151
,, congenital, of hip, 141
,, of ankle, with fracture, 144
,, of astragalus backwards, 152
,, of thumb, 151
Dislocation, suspected, negatived, 152
Dislocations, 126, 149
Distortion of images, 128
Double Colles' fracture, 133
Downie, Dr. Walker, pin in larynx, 103
Dress deformities, 163
Dressings, warning as to opaque, 127
Dynamos, 25

Eastman's photographic paper, 53
Edison-Lalande cell, 19
Electrolysis in removal of hairs, 215
Elephantiasis, 217
Enchondroma, ossifying, 164
Epiphyses, separation of, 152
,, union of, 153
Evidence, how to prepare, 232
,, of age of fœtus, 229
,, of death, 229
,, of identification, 227
,, of injury, 226
,, of malpraxis, 230
,, of pregnancy, 228
,, value of radiogram in, 226
Exostosis, 164
Experiment, Lynn Thomas', 129
Experiments on micro-organisms, 175
Extra-uterine fœtation detected, 222
,, fœtus after removal, 222
Eye, foreign bodies in, 111

False joint, 131
,, teeth in gullet, 105
Fallacies, 71
Femur fractures, 141
Fluorescent screen, 46
,, ,, to make tracings by, 47
Fluorometer, the Dennis, 97
Fluoroscope, 47
Fluoroscopy, 104
Focus-tube, action upon skin and deeper structures, 201
Focus-tube dermatitis, 201-213
,, how to exhaust, 43
,, stand, 43
,, the, 38
Fœtal monster (two-headed), 222
,, radiography, 221
Fœtus, evidence of age of, 229
,, extra-uterine after removal, 222
Foreign bodies, 77
,, ,, in abdomen, 107
,, ,, in brain, 91, 97
,, ,, in eyeball, 111
,, ,, in gullet, 105
,, ,, in intestine, 108
,, ,, in larynx, 103
,, ,, in neck, 103
,, ,, in œsophagus, 105
,, ,, in orbit, 111
,, ,, in pelvis, 108
,, ,, in pleura, 104
,, ,, in spine, 102
,, ,, in stomach, 108
,, ,, in thorax, 103
,, ,, their localization, 89
Fracture, Barton's, 139
,, Colles', 133
,, complicated, 131
,, greenstick, 74
,, impacted, 134
,, Lane's screws in, 130
,, mal-united, 131
,, 'nailing,' 129
,, of astragalus, 144
,, of collar-bone, 133
,, of elbow, 135
,, of femur, 141
,, of fibula, 144
,, of foot, 144
,, of forearm, 133-139
,, of hip, extracapsular, 141
,, ,, intracapsular, 141
,, of humerus, 132
,, of kneecap, 141

Fracture of leg, 142
,, of lower leg (Potts), 144
,, of metacarpal, 140
,, of patella, 141, 142
,, of pelvis, 140
,, of radius, 139
,, of ribs, 147
,, of scapula, 133
,, of skull, 145
,, of thigh, 141, 142
,, of tibia, 142
,, of tibia, with dislocation of ankle, 144
Fracture of vertebræ, 145
,, of wrist, 139
,, rare spiral, of tibia, 143
,, unsuspected deformity, 143, 144
Fracture, unusual, of tibia, 143
,, wiring, 129
,, with dislocation, 144
Fracture-dislocation of ankle, 144, 145
,, ,, of neck, 146
Fractures, advantages of x-rays in, 132
,, and dislocations, 126
,, fallacy in recording, 128
,, metatarsal, 144
,, need of comparative photographs in, 128
Fractures, special, 133
,, tarsal, 144

Gall-stones, 117
Garibaldi, bullet in ankle, 80
Gastric disturbance from focus-tube exposure, 206
Geissler tube, 38
Gilchrist, cases of dermatitis, 203
Glass, its opacity to the rays, 77
Gout, diagnosis between, and rheumatism, 200
Gouty bone, translucency of, 165
Græco-Turkish war, the Röntgen rays in, 81
Great toe, deformity, 163
Grove cell, 18
Guinea-pig, fœtus radiographed in living uterus, 223
Gullet, foreign bodies in, 105
,, teeth and coins, etc., in, 105
,, watch and chain in, 110
Gunshot wounds in civil practice, 85
Gynæcology, 222

Hæmophilia, joints of, 168
Hair, shedding, after focus-tube exposure, 212
Hairs, superfluous, removal, 214
Hallux valgus, 163
Heart, apparent shrinking beneath rays, 190
Heart, dilatation, 190
,, hypertrophy, 188
,, movements, 185
,, proposed study by rays of cardiac drugs, 191
Heart, shadow upon screen, 185
,, showing valves, etc., when empty, 186
Heart, to recognise alterations in shape, 185, 187
Heart, transposition, 190
Heberden, nodules of, 165
Hip deformities, 141
,, fractures, 141
Hobday, Professor, on veterinary x-ray work, 240
Horse, diagnosis of abnormalities in, 240
Horse, x-ray methods with, 240
Hydrometer, 24
Hypertrichosis, 214
Hypertrophies of bone, 165

Idiosyncrasy in dermatitis, 213
Indiarubber drainage tube in chest, 104
Induction coil, 31
Injuries to epiphyses, 152
,, deep, from x-rays, 205-207
Injury, evidence of, 226
Instruments, combined use, with screen, 107
Intensification of plates, 51
Intensifying screen, 53
Internal radiography, Dr. Macintyre's rules, 184
Intestines, author's experiment with bismuth, 197
Iodoform opaque to rays, 127

Jackson's focus-tube, 38
'Jackstone' (toy) impacted in gullet, 105
Joint, false, 131
,, fibrous adhesions, 131

Kathodal rays in dermatitis, 207
Kathode, 38
Kidneys, circulation in, 234
Kienbock's case of pyopneumothorax 195
Knee-cap, fracture of, 141
Knee-joint, tubercular, 170

Lacrymal sound in nasal duct, 181
Larynx, movements of, 239
,, pin in, 103
Lead, its opacity to the rays, 79

Legal aspects of Röntgen rays, 225
,, medicine, 225-233
Leprosy, pre-Columbian, investigated, 171
Lime-salts of bone, causing opacity, 72
Localization, 57
,, Davidson's method, 93
,, in eyeball, various methods, 111
Localization of foreign bodies, 89
,, of lung lesions, 193, 200
,, of pin in larynx, 62
Localizer, Dennis fluorometer, 97
,, Hall-Edwards', 97
,, Hedley's, 96
,, Mackenzie Davidson's, 93
Low, Dr., case of fractured leg, 143
,, ,, renal calculus, 120
Lumière sensitive plates, 47
Lunatics, Röntgen ray diagnosis in, 147
Lung, cirrhosis, 194
,, diseases, 191
,, impairment of movements, 194
,, localization in, 200
,, surgery, *x*-rays in, 104
Lungs, consolidation detected, 192-197
Lupus, treatment by *x*-rays, 215

Machine, statical, 28
Malpraxis, evidence in action for, 230
Mapping of skin surfaces, 172
,, ,, ,, in stereoscopy, 172
Mediastinum, displacements of, 191
Medical men as *x*-ray operators, 14
Medicine, Röntgen rays in, 182
Metacarpal, fracture of, 140
Micro-organisms, action of rays upon, 173
Military surgery, the rays in, 80
Monster, fœtal, two-headed, 223
Movements of heart, 185
,, of larynx, 239
,, of lung, impaired, 194
Murani's experiments on blindness, 218
Murder trial, *x*-rays in, 227
Murphy's buttons, 199
Muscles, ossification of, 173
Myositis ossificans, 173

'Nailing' fractures, 129
Nasal duct, occlusion of, 181
,, suppuration, 181
,, surgery, 180
Navicular disease, 240
Neck, fracture-dislocation of, 146
Necrosis of bone demonstrated, 156, 171
Needle discovered by rays, 78
Negro skin said to resist rays, 209
Nélaton's probe, 81
New growths in bone, 170

Oberst on union of fractures, 149
Obstetrics, 221
Omdurman, *x*-rays at, 84
Operating tables, 62
Operation under screen examination, 107, 205
Ossifications of cartilages, 172
,, of muscle, 172
Osteitis from *x*-rays, 204
Osteo-arthritis, 170
Osteo-arthropathies, 168
Osteo-myelitis, 170
Osteo-plastic operation, to ascertain results of, 172
Osteo-sarcoma, 171
'Ostrich man,' stomach of, 109

Pain, effect of focus-tube rays upon, 217
Pain, relief of, by focus-tube exposure, 209
Paper (*x*-ray), 53
Patella fracture, 129
Pellets in arm, 86
,, in eyeball, 111
Pelvic deformities, 156
Pelvis, injuries of, 140
Penetrator tube (Watson's), 41
Periostitis following focus-tube exposure, 204
Phagocytosis unaffected by rays, 239
Philpot's case of old fractured metacarpal, 140
Phosphatic calculus, 119
Photographic paper (*x*-ray), 53
,, plates, 47
,, ,, carrier, 54
,, printing, 51
Photography, 47
Phthisis, 191
Physiology, 238
Pigmentation of skin after exposure to rays, 207
Plaster of Paris, opacity of, 127
,, ,, substitute for, 127
Plate-holders, 54
Pleurisy effusion demonstrated, 191
Pneumonia, 191, 194
,, deep patch detected, 194
Poland on injuries to epiphyses, 152
Polydactylism, case of, 158
Potain, experiments on density of gouty deposits, 165
Pregnancy, evidence of, 228
Pregnant uterus, difficulties in radiographing, 221

Primary batteries, 17
Pulmonary osteo-arthropathies, 168
Pulsating shadows in chest, 188
Pump, the exhaust, 43
Punktograph, 102
Pye-Smith, fracture - dislocation of neck, 146
Pyopneumothorax, 195

'Queen' tube, 41

Radiant matter, 38
Radio-ulnar ligament, rupture, 135
Radius, fractures of, 139
Reeves' case, thumbless hands and deficient limb, 159
Reid, Professor Waymouth, bullet localization, 98
'Record' tube (Cox's), 40
Renal calculi, 117
,, author's supposed, 121
,, Dr. Low's case, 120
,, Dr. Macintyre's case, 118
,, Dr. Swain on, 119
,, Mr. Fenwick's special fluoroscope, 122
Renal calculi, Mr. Davidson's case, 122
,, Messrs. Leon and Laurie's case, 119
Resistance coil, 26
Retina, action of rays on, 218
Rheostat, Schall's, 26
Rheumatism, diagnosis between, and gout, 200
Rheumatoid arthritis, bones in, 166
Rib cartilages, ossification of, 173
Ribs, cervical, 162
,, fractures of, 147
,, photograph of front of, 230
Rochefort and Wydt's coil, 36
Rowland's focus-tube stand, 61
Ruhmkorf coil, 31
Rupture of radio-ulnar ligament, 135

Sarcoma in bone, 171
Schott treatment of heart, rays in, 200
Sciameter, 42
Screen, fluorescent, 46
,, how to work, 69
,, used in operations, 107, 205
Screws in fractures, 130
Secondary battery, 16
,, cell, 23
Separation of epiphyses, 152
Sesamoid bones, shadow of, 125
,, bone of end joint of thumb, 125
Shaw's case of hæmophilia, 168
Shot embedded in arm, 86
,, in eyeball, 111
Shrinking of heart shadow under rays (apparent), 190
Signs of death, 229
Skin, action of focus-tube rays, 201
Skin inflammation from focus-tube, 201-213
Skin surfaces, mapping of (author's method), 172
Skin therapeutics of focus-tube rays, 213
Skull, fracture of, 145
Smith, Dr. Blaikie, bullet in brain, 97
Smith's, Noble, caries of neck, 169
Soudan, *x*-rays in, 81
Sources of electricity, 17
Spavin, 241
Spine, bullet in, 102
,, deformities of, 157
Spiral fracture of tibia, 143
Splints, opaque and otherwise, 127
Sprengel exhaust-pump, 43
Stands for tubes, 61
Statical machine, 28
Stephenson and Walsh on colour-blindness, 219
Stereoscope (Wheatstone's), 59
Stereoscopy, 58
Stomach, foreign bodies in, 108
,, methods of examining, 199
,, to outline, 111
Stone in bladder, how to take, 117
Storage or secondary batteries, 22
Storage or secondary batteries, to charge, 23
Strumous dactylitis, 174
Styloid process of ulnar, separation in Colles' fracture, 133
Subperiosteal thickenings, 174
Sun dermatitis compared with that of focus-tube, 207
Sunstroke simulated by exposure to focus-tube rays, 205
Suppression of collar-bones, 160
,, ,, thumbs, 159
,, ,, toes, 158
Swain on density of calculi, 119
Swinton's adjustable tube, 41

Tables, operating, 62
Tachometer, 35
Taft's, Dr., case of spiral fracture, 143
Talipes equinus, 157
Teeth as test of age, 228
,, false, exploration for, 105
,, how to take, 69
,, not erupted, 179
,, screen for examining, 178
,, various pathological conditions, 176-179

Temporal bones, 181
Tesla coil, 27, 37
,, oscillator, 37
,, transformer, 27
Theory of the Röntgen rays, 72
Therapeutics, 213
Thomas, Lynn, on fallacies of fractures, 128
Thomas, Lynn, distortion experiment, 128
Thoracic aneurisms, 188
Thorax, 182
Thumb, bifid end phalanges, 159
Thumbless hand, 159
Tibia fractures, 143
Toepler mercury pump, 43
Toes, suppression of, 158
Tracings of heart, 184
Transformers to high potential, 31
Traumatism after focus-tube exposure, 201, 206
Tremors following focus-tube exposure, 57
Trial for murder, x-rays in, 227
Tube, adjustable focus, 41
,, bianodal, 40
,, changes in, 42
,, focus, 38
,, for alternating current, 39
,, how to exhaust, 45
,, how to test, 42
,, 'penetrator,' 41
,, 'Queen,' 41
,, the vacuum, 38
Tubercle bacilli, x-rays negative, 220
Tubercular bones, translucency, 167
Tubercular consolidation of lung, 192
,, knee-joint, 170
Tuberculosis in guinea-pigs treated by focus-tube rays, 219
Tumour in upper jaw, 171
,, of kidney, 198
,, ossifying cartilaginous, 164

Union of epiphyses, table, 153
Uratic deposits, translucency of, 117
Uric acid calculus, 117
Uterus, difficulties of examination, 221

Value of Röntgen photograph as legal evidence, 225
Van Duyse's experiment on eyeball, 111
Vertebræ, fracture of, 145
Veterinary surgery, rays in, 240
Vitreous humour, steel fragments in, 115
Voltmeter, 24
'Vril' contact breaker, 33

Waldo's case of cirrhosis of lung, 194
Walsh's method of marking skin, 172
Watch and chain in gullet, 110
Wehnelt's electrolytic contact-breaker, 35
Wheatstone's stereoscope, 59
Wilkin, Griffith, temporal bones, 181
Wimshurst machine, 28, 82
,, ,, 'sectorless,' 31
Wiring fractures, 129

X-ray paper (Eastman's), 53
,, ,, dermatitis, 201

THE END.

Baillière, Tindall & Cox, King William Street, Strand.