Moreover, the new knowledge reacts on older information, shaping it for interpretation and making it more valuable. From a knowledge, for example, of the elastic constants of crystals, the forces between the atoms themselves may be calculated as soon as the architecture of the crystal is known. It will be possible to make use of facts concerning cleavage planes, occurrence of certain natural faces and not of others, etching figures, and the like. Light will be thrown on the meaning of valency and on all that lies at the root of chemical action. If the atomic forces can be calculated, an explanation of the form of the wave-surface of light within a crystal will be at hand.

X-rays have been applied with ever-increasing success to medicine and surgery; their extraordinary power of revealing the interior of a body without disturbing its exterior are beginning to be recognised as a trustworthy aid to industry, as, for example, in the detection of flaws of construction otherwise invisible; and their use in observing the crystalline state is already being considered as a probable and welcome aid to metallurgical problems. But still the richest mode of their employment is by the indirect methods of pure science. Their unique properties help as nothing else can to a knowledge of the relations between radiation and matter, ether-waves and electrons, atoms and the forces that bind them together, which are among the greatest of the fundamental problems of physics.

X-RAYS IN MEDICAL SCIENCE.

By A. C. JORDAN, M.D., M.R.C.P.

THE discovery of X-rays in 1895 was justly hailed as one of the greatest scientific marvels of any age. Medical men eagerly grasped the possibilities of these rays, which enabled them to see the internal organs of their patients actually at work, hitherto impossible even to surgeons, who in the course of their operations had the organs exposed to view, but only under conditions of anæsthesia.

The first practical uses to which X-rays were applied were: (1) In the detection and localisation of metallic foreign bodies, such as needles and bullets; (2) in the detection and localisation of metallic or other foreign bodies that had been swallowed; (3) in the diagnosis of fractures of bones: this branch of radiology has made enormous strides during the war, and has led to a vast improvement in the treatment of fractures and to the saving of countless limbs; (4) in the diagnosis of calculi in the urinary tract and elsewhere: these foreign bodies throw shadows which have to be distinguished from concretions in the bowel and calcareous deposits: many pitfalls lie in wait for the unwary observer, and the right interpretation of these shadows, even at the present time, calls for skill, patience, and discrimination; (5) in the diagnosis of diseases of the chest: the appearance of the normal movements of respiration and of the beating heart was closely observed, and as a result of these observations upon healthy subjects this branch of physiology has had, to a large extent, to be re-written. The position of the heart and vessels in the chest—in the midst of the air-filled lungs—rendered accurate diagnosis difficult by the older methods of physical examination, but by means of X-ray examinations with the fluorescent screen the mechanism of the heart has been closely studied and its diseases accurately diagnosed.

In regard to diseases of the lungs, pneumonia, pleurisy, abscess of the lung, tumours, enlarged glands in the chest, and many other conditions produce characteristic shadows on the fluorescent screen, and enable the site, nature, and extent of the disease to be determined. In pulmonary tuberculosis the aid which X-rays have brought to its early diagnosis, and in defining its extent, has proved of such value that this means of diagnosing phthisis is playing an essential part in the campaign in progress for dealing with this scourge. X-ray study has shown that the first changes which occur in the lung in this disease lie so deeply buried in the chest—under cover of a thick layer of healthy lung—that they are quite beyond the reach of the older methods of detection by percussion and auscultation. By the time the stethoscope is able to discover the signs of consumption, the disease is probably so far advanced that the prospects of a cure are remote. The diagnostic utility of X-rays has increased steadily with the continued improvement in the apparatus and the increased skill and experience of those engaged in this branch of science.

The correct estimation of fractures and other injuries to bone and joints necessitated an accurate study of the form and texture of normal bones, as well as the individual variations that occur in the conformation of bones and their joint surfaces. This knowledge led at once to a most important extension of the diagnostic powers of X-rays—the recognition of disease in bone and the differential diagnosis of many diseases of bones and joints.

So far we have considered radio-diagnosis as dependent on differences of density among the tissues. Bone, with its lime salts, is far more opaque to X-rays than muscle: consolidated lung is more opaque than healthy, air-filled lung. At first sight this precludes from the range of radio-diagnosis a very important part of the body—the hollow viscera constituting the digestive tract. Very little information is to be gained from an ordinary X-ray inspection of the stomach and bowels, but the introduction of opaque substances into hollow organs with the object of determining their outlines and of observing abnormalities of size, shape, or function has opened up an entirely new extension of the science of radio-diagnosis.

An "opaque meal" consisting of a heavy insoluble salt, such as carbonate of bismuth, is given in a dose of 2–4 oz. Its progress is observed through the œsophagus into the stomach and duodenum, and observations are continued at intervals to note the position and behaviour of each part of the small and large intestine as the bismuth passes through. By this means much new information is being gained concerning the physiology and the diseases of the alimentary tract. Our views regarding the causation and nature of many of the affections of the digestive system have had to be reconsidered and modified.

Medical and surgical text-books of a few years ago contained separate chapters devoted to individual diseases, such as gastric ulcer, duodenal ulcer, gall-stones, and appendicitis, but when radiologists were called upon to aid in the diagnosis of these various diseases they tendered evidence that showed conclusively that these diseases were not isolated morbid affections of the organs concerned, but "end-results" of a more general derangement of the digestive system. In other words, the stomach or appendix does not "go wrong" by reason of any intrinsic vice, but because it is in an environment which has become vitiated or unhealthy.

An entirely different aspect of our subject is the application of X-rays to the treatment of disease. From observations upon the far-reaching consequences of undue exposure to the action of X-rays, radiologists were led to explore their possibilities for therapeutic purposes.

It is well known that the first workers in the field of radiology were destined to pay a heavy price for their devotion. The repeated exposure of the skin to the action of the new rays set up a disease in skin known as X-ray dermatitis. Gradually the skin and even the deeper tissues of the hands and other parts that had been exposed to the action of the rays were destroyed. Extensive and painful sores appeared which penetrated deeply and resisted all attempts to induce healing, and in some cases cancerous change set in, necessitating the loss of a limb, and unfortunately, in a few cases, leading to a fatal termination. It was natural to surmise that an agent with such terrible powers for evil as X-rays possess might, in suitable small doses, be converted into a means of salvation, in the same way as many deadly poisons—strychnine, opium, digitalis, and mercury—have become the physician's most potent and useful remedies when rightly administered.

It was found that certain diseases of the skin yielded very readily to carefully administered applications of X-rays; and to-day ringworm, so difficult to eradicate by ordinary methods of treatment, is almost universally treated by X-rays. Prior to this treatment primary schools were deprived of numbers of their pupils for long periods, averaging two years for each child, but now the disease is usually eradicated in three months.

Other diseases which have been treated with a large degree of success by irradiation are: Tuberculous glands; other gland enlargements, such as occur in lymphadenoma (Hodgkin's disease); uterine fibroids; exophthalmic goitre (Graves's disease); blood diseases, such as leukæmia; and some forms of gout, rheumatism, and neuritis: in these painful disorders X-ray treatment relieves pain even when it cannot achieve a cure.

In view of the successful application of X-rays in dispelling enlarged glands, the question naturally arose: Have we here a therapeutic agent which can cure that most dreaded of all diseases—cancer? The answer to this important question was sought with diligence, and at first with much promise. But its limitations soon became apparent, and to this day the results of X-ray treatment of cancer have not fulfilled our greatest hopes. True, many cancerous masses can be destroyed and made to disappear by this treatment, yet a genuine cure does not always follow. Other growths may appear in inaccessible places, or general dissemination of cancer may set in. Early removal by operation is still the safest method of dealing with a cancerous growth. The removal may, however, be advantageously followed by the systematic irradiation of the operation area, so as to destroy any cancerous cells that may have been left behind. We must not (nay, we dare not) despair of the successful treatment of cancer. Recent researches, however, lead to the conclusion that the road to salvation is in the prevention rather than in the cure of the disease. In these researches X-ray observations of the digestive system occupy a prominent place. They have taught us that particular sections or points in the gastro-intestinal tract become so altered from their healthy state as to be specially liable to take on a cancerous change. We have learnt that toxic products, absorbed from the intestinal canal into the general circulation, give rise to deterioration of the tissues and render them liable to become cancerous as the result of some slight source of continued irritation such as would do no harm to healthy tissues.

The effects of X-ray exposures on white blood corpuscles are receiving increased attention, and to-day results are being obtained which are of great interest. We know, for instance, that the white cells of the blood play a leading part in the struggle with invading microbes. If particular kinds of white cells can be increased in numbers and in activity, we shall have gained a notable step in treatment. Already there are reports from more than one part of the world of promising results from treatment on these lines in cases of pulmonary consumption.

It will be seen from the foregoing brief account that important developments in the functions of X-rays in the direction both of diagnosis and of therapeutic application can be hopefully awaited.

Every day we are learning more of the nature and properties of the various kinds of X-rays, the soft and hard primary rays, the homogeneous and other secondary rays; and knowledge is increasing regarding their action on the surface and within the body tissues.

It is safe to predict that in the coming years X-rays will play an increasingly important part in attaining the end and aim of all medical study—the prevention of disease and the maintenance of a high standard of health and efficiency in the community.

PROGRESS OF ELECTRICAL INVENTION.

By Prof. J. A. Fleming, F.R.S.

THE progress of electrical discovery and invention, and especially of electric lighting, telegraphy, and telephony, in the last fifty years is the theme on which the Editor of NATURE has asked me to make a short contribution to this jubilee issue. The chief difficulty, however, is in selecting from the enormous stores of accumulated knowledge the topics most worthy of notice in a space all too brief for any adequate treatment.

Casting our glances backward to 1869, we can, however, say that on the theoretical side electrical science was then beginning to emerge from the stage of a chiefly qualitative study of phenomena into an era of quantitative measurement, on which progress so much depends. The initial attempts to lay deep-sea submarine cables and the engineering aspects of land telegraphy had compelled attention to the exact measurement of electrical quantities. Advanced physicists had already appreciated the advantages of an absolute system of measurement based on the fundamental units of space, time, and mass; but practical electricians still employed vague phrases such as "quantity currents" and "intensity currents," and precise ideas on the subjects of potential, capacity, inductance, electric energy, and power were not widely diffused. Lord Kelvin (then Prof. W. Thomson) had, indeed, started into existence some years previously (in 1861) the famous British Association Committee on Electrical Units, and Maxwell, Balfour Stewart, and Fleeming Jenkin had commenced experiments on the practical determination of the ohm, or British Association unit of electric resistance, for which work Faraday, W. Thomson, and Maxwell in Great Britain, and Gauss, Weber, and Helmholtz in Germany had laid the foundations.

A new era began in 1873 with the publication of Maxwell's stimulating work on electricity and magnetism. Up to that time students of the subject for the most part obtained their knowledge from such descriptive non-mathematical works as de la Rive's great treatise on electricity and magnetism. When Maxwell was appointed professor of experimental physics at Cambridge in 1871, and the Cavendish Laboratory was opened for work about 1873, quantitative researches at once commenced with Hicks, Gordon, Chrystal, Fleming, Schuster, Glazebrook, and Shaw as early workers. After Maxwell's lamented death in 1879, the late Lord Rayleigh accepted the position as his successor and directed his attention and great abilities at once to the exact determination of practical electric units, in which he did magnificent service, a work very ably continued by Glazebrook, J. J. Thomson, Searle, and others. After the introduction of public electric lighting, the measurement of electric quantities became a commercial matter. In 1885 the writer of this article read a paper to the Institution of Electrical Engineers in London advocating "the necessity for a standardising laboratory for electrical testing instruments." Soon after, the Board of Trade established such a laboratory, later on the Germans started their "Reichsanstalt," and at a still later stage the National Physical Laboratory in England was organised and equipped.

The Cambridge physicists have always maintained the high standard of research which marked that of Kelvin, Maxwell, and Rayleigh, and much valuable quantitative electrical work has been done there, too extensive for detailed reference. When Sir J. J. Thomson succeeded Lord Rayleigh at the Cavendish Laboratory he began the epoch-making researches on the nature of electricity and matter which have revolutionised scientific concepts. His identification of the cathode-ray particle with the electron of Larmor and Johnstone Stoney, and his measurement of its charge and mass, are amongst the most brilliant achievements of experimental science, and opened up an entirely new era in electrical research. J. J. Thomson gathered round him a band of experimental investigators whose researches, coupled with his own, threw light on innumerable obscure phenomena. The discovery of X-rays by Röntgen in 1895 and of the Becquerel rays, and the discovery of radium by Mme. and Prof. Curie, stimulated the work of Rutherford, C. T. R. Wilson, Townsend, and others, which has resulted in immense accessions to our knowledge of the nature of electricity and atoms.

Side by side with this progress in pure scientific knowledge fruitful advances were made in electrotechnics. Faraday's great discovery of magneto-electric induction had been long before applied in the construction of machines with permanent magnets for generating, by rotation of coils of wire, an electric current. Henry Wilde had suggested the use of electromagnets for producing the magnetic field, and he, as well as Werner, Siemens, and Wheatstone, had discovered the self-exciting principle and applied it in machines,