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, to which the term "dynamo" was later on applied. In 1870 Z. Gramme, a French electrician, re-invented a special form of armature construction, first suggested by Pacinotti, which enabled a dynamo to give a very uniform direct electric current; and Hefner Alteneck, in Germany in 1873, had patented another type of armature winding, now called the drum winding. The way was then opened for the production of electric currents by mechanical power on a large scale and for the solution of the problem of public electric lighting.

Paul Jablochkov invented in 1876 his "electric candle" and initiated public street electric lighting in Paris. C. F. Brush, in America, invented a simple form of arc lamp adapted for working in series with others and a type of series arc-lamp dynamo. This Brush system soon after 1878 was largely in operation for street lighting.

In the following year Edison, in America, and Swan, in England, solved the problem of the production of a practical carbon filament incandescent electric lamp and thus rendered domestic electric lighting possible on a large scale.

In the same year the writer of this article exhibited some of Edison's early carbon filament lamps in operation in Queen Victoria Street, London, though it was not until the Crystal Palace Electrical Exhibition of 1882 that the public saw the new illuminant used on a large scale. The invention of the metallic filament lamp about 1904 made an immense improvement in economy in electric illumination, and more recently the "half watt" gas-filled lamp threatens to displace arc lighting entirely from streets and buildings.

The utilisation of this lamp, however, required a public electric supply, and Edison was one of the first to work out all the practical details and provide a complete system. This was put into operation in New York and in London in 1882. Improvements in the dynamo rapidly followed, and in the hands of J. Hopkinson, Crompton, Siemens, and others it became a highly efficient machine. About 1883 attention began to be directed to alternating currents, and alternators and transformers were designed by Ferranti, Mordey, and Parker.

In or before 1890 or 1891 polyphase alternators were first produced by Ferraris, Tesla, and C. E. L. Brown. Large electric supply stations were then built, and a lively contest took place on the relative merits of direct and alternating currents. The polyphase alternating system has, however, enabled electric power transmission to be conducted over great distances, and in the last twenty-five years an immense utilisation of natural water-power has taken place by this means, beginning with the Niagara Falls Power Station in 1893. Electrification of urban tram lines and short-distance inter-urban railways has made enormous progress in the last quarter of a century.

Meanwhile, between 1876 and 1879 Graham Bell, Edison, and Elisha Gray, in the United States, had given us the speaking telephone, and D. E. Hughes, in England, had produced the microphone, which is the basis of all modern telephone transmitters. In 1876 Lord Kelvin astonished the British Association at Glasgow by the information that he had heard articulate speech transmitted over a wire by one of Bell's early telephones. In 1879 the first rudimentary telephone exchange was established in London.

When once the commercial possibilities of telephone exchanges and of domestic electric lighting had been realised, progress was assured, although that of the latter was retarded by the unwise Electric Lighting Act of 1882, not repealed until 1888, and telephonic improvements were hindered by the Government control of it established by the legal interpretation of the term "telegraph" to include "telephone," under the Telegraph Purchase Acts.

Limiting consideration, then, to improvements in telegraphy and telephony, we note very briefly the following stages of invention. In 1869 the British Government passed an Act for the acquirement of the electric telegraph companies, and made the transmission of paid messages a public service. This "nationalisation" has, however, put a burden on the taxpayer, although it resulted in great extension of the facilities. Improved methods of transmission, such as the Wheatstone automatic system, capable of sending 400 words a minute, were soon introduced for Press purposes.

So far back as 1855 D. E. Hughes had invented an ingenious printing telegraph, but immense improvements afterwards introduced by Baudot, Creed, and Murray now enable twelve messages to be sent simultaneously on a single wire, each being printed down on paper at the receiving end, the sending being done by a typist on a special typewriter at the rate of thirty to forty words a minute.

Most long telegraph lines are now worked multiplex, meaning that several messages can be sent in the same or opposite directions on the same wire simultaneously.

In submarine cable work Great Britain has always been pre-eminent. The first submarine cable was laid in 1851 by the Brothers Brett across the English Channel, and the first permanently successful Atlantic cable by Sir Charles Bright and Sir James Anderson in 1866 from the s.s. *Great Eastern*. Lord Kelvin, who had previously given to the world his mirror galvanometer, invented also in 1867 the syphon recorder which receives and records the feeble arrival currents, and later improvements have given to it its present form. Very sensitive relays and repeaters have been invented by Muirhead, Heurtley, S. G. Brown, and Axel Orling, which have vastly increased the speed of transmission. Lord Kelvin laid the firm foundations for the theory of the telegraph cable so far back as 1855. There are at present about 300,000 miles of working submarine cable in the world, most of which has been made and laid by British electricians. In connection with telephony, enormous inventive thought has been given since 1880 to perfecting the mechanism of telephone exchanges, and the difficulties of automatic exchanges, which require no telephone girls or operators to effect the connection between subscribers, have now been finally overcome. Another very great advance has been in the "loading" of telephone lines. In 1887 Oliver Heaviside first showed the importance of inductance in the line as a remedy for "distortion" in the wave form of the speech currents, but it was not until Pupin, in the United States in 1899, suggested the insertion of inductance or "loading" coils at certain proper intervals in the line that practical success was obtained. A Danish engineer, Krarup, introduced a system of uniform loading for submarine telephone lines. The Pupin type of loading has made telephony possible over very great distances, such as New York to San Francisco, and Berlin to Rome. The difficulties of loading submarine cables up to 100 miles or so in length have been overcome. The theory of the subject has been treated by Heaviside, Kennelly, and Fleming.

Wireless telegraphy has attracted the attention of electricians since 1842, but no important invention was made until Marconi in 1896 first showed how to employ electromagnetic waves for this purpose, generated by a special form of Hertzian oscillator, and detected by an improved form of Branly metallic filings coherer. Lodge then demonstrated the importance of syntony in connection with the subject, and it soon took very practical shape. Inventors all over the world were attracted to this new field, with the result that in a few years, chiefly by the work of Marconi and his co-workers, electric wave telegraphy between ships and shore became established as an indispensable aid to navigation. The construction of long-distance wireless stations, the first of which was erected at Poldhu, in Cornwall, in 1901, brought to notice many remarkable facts in connection with the propagation of long electric waves round the earth and through the atmosphere.

A very important factor in the recent developments of wireless telegraphy and telephony has been the invention of the thermionic detector and oscillator. The pioneer invention, according to judicial decisions, was made by the writer of this article in 1904 in applying for the first time an incandescent electric lamp with a metal plate sealed into the bulb as a detector of high-frequency electric oscillations. The "Fleming valve" led to the invention of the three-electrode amplifier and thermionic generator of oscillations. This has given us an instrument of marvellous sensibility for detecting electric waves, and made wireless telephony a success and wireless telegraphy half round the world an achievement. The importance of wireless telegraphy and telephony in the European War of 1914–18 has been the cause of wonderful developments of the subject owing to the number of able minds brought to bear upon it.

Turning, then, from the present and the past and directing our gaze upon the future, we can certainly see many achievements looming before us. The world will be covered with long-distance wireless stations which will effect instantaneous communication over thousands of miles. Long-distance wireless telephony will enable speech to be transmitted over great distances, and it is quite within the bounds of possibility that the business man of the near future in London may hold a five-minutes' conversation with a friend in New York or even South Africa with as much ease as we now telephone to Glasgow or Liverpool. Directional wireless telegraphy will be used to steer passenger-carrying aeroplanes through cloud or fog. The steam locomotive and engine will gradually be replaced by the electric motor, and the water-power of the world will be utilised by its means. There are large possibilities still latent in connection with electro-chemistry and electro-metallurgy, and one great problem of the future is to tap the illimitable stores of energy latent in every chemical atom for the use and benefit of man. As coal becomes exhausted or coal power is made too expensive by labour difficulties, the question of new sources of energy becomes pressing. The engine of the future may be an improved form of internal-combustion engine in which the combustible is not coal gas or oil vapour, but some form of explosive compound in which atomic energy is suddenly released and expended in heating air or other gas in a cylinder.

Of one thing we may be perfectly certain, namely, that it is only through the avenue of pure scientific research sedulously and disinterestedly pursued that we shall reach the solution of these technical problems of supreme importance to mankind. The last fifty years has been a period of extraordinary technical applications of ever-increasing electrical knowledge, and no one can see reason to think that we have yet reached finality in the possible utilisation of this physical agent for ameliorating the conditions of human life.

DEVELOPMENTS OF MECHANICAL SCIENCE.

BY DR. W. C. UNWIN, F.R.S.

THE attempt here made to give a sketch of the mechanical side of progress in the last fifty years is necessarily slight. The year 1869 was the centenary of that in which Boulton and Watt took out their first patent for the steam engine. It is due to the application of steam-power to industrial operations, more than to anything else, that there has been so great an increase of population, of wealth, and of social prosperity, and indirectly also of scientific knowledge, during