There are, nevertheless, many great leaders, notably Bohr, who believe that we are still merely approaching the problem and that in due course the reasons for the correctness of the quantum theory and wave mechanics will be made clear. This further step, if it is ever achieved, will not detract from the fame of the present pioneers. At least it has been made certain that novel ideas, due to many great men of science, often revolutionary in type, have first been scorned and later accepted, but there has certainly never been any necessity for what has been called 'advertising'. Let us name Copernicus, Galileo, Newton, Fourier, Maxwell, Planck, Rutherford, Bohr, Einstein. Other names might be added of men whose just fame is not yet so firmly established, men belonging, too, to various nationalities—a matter of no real importance in science.

Rutherford, indeed, frequently lectured on his discoveries to a variety of audiences in many countries all over the world. He believed that it was one of his duties to interpret and spread the good news of scientific discovery and progress. He would be a rash man who dared to use the word 'advertising' in this connexion, and no fair-minded man will connect the word with Einstein, for his views quickly and naturally caught and held the attention both of the well-informed and the general public.

Although Rutherford made no incursions into wave-mechanics and held fast, wherever and as long as he could, to classical views, yet he was honest enough to admit when the latter failed, and

he was eager to adopt anything, however modern or revolutionary its source, which might assist him in his research work, such as the use of resonance to secure low-voltage transmutation, an idea due to Gamow, and to Condon and Gurney (1928), derived from wave-mechanical theory and impossible from a classical viewpoint. We must also admire that abstruse analysis of Dirac, involving negative energy, which led him to the conception of a positive electron before its discovery in cosmic rays by Anderson and its confirmation by Blackett. Here, as in so many cases, ideas which might be termed 'dogmatic' by some have led directly to the pragmatic. In fact, theory based on experiment or observation (and who bases it on anything else?) will often yield results at first unexpected, just as Faraday's experiment led through Maxwell's theory to wireless telegraphy, telephony and broadcasting on one hand and to our gigantic power houses and electrical supply on the other.

That is the gist of the whole matter and there is nothing more to be said. The search for truth or 'reality' is common to all, but there may be different avenues of approach. Let us throw these open without hindrance and give full credit to all who extend by any means our natural knowledge, setting aside all prejudices and determined that the rule of reason and the law of liberty shall prevail throughout the realms of science.

¹ See also Prof. C. G. Darwin's presidential address to Section A (Mathematics and Physical Science) of the British Association, delivered at Cambridge ("The Advancement of Science, 1938." London: Burlington House.)

Sir William Herschel, 1738-1822

By Sir Frank Dyson, K.B.E., F.R.S.

AT the age of thirty-five years, William Herschel, a distinguished and prosperous musician, was impelled to explore the heavens. He found a small telescope which he had hired insufficient for his needs, and with great skill and patience constructed larger and larger instruments. After his day's work, he spent a great part of the night observing the stars. The conclusions he drew from his observations were characterized by an originality, boldness and splendour of outlook which have placed him among the greatest astronomers. "We ought", he writes, "to avoid two opposite extremes. If we indulge in a fanciful imagination and build worlds of our own we must not wonder at going wide from the path of truth and nature. . . . On the other hand, if we add observation to observation, without attempting to draw not only certain conclusions, but also con-

jectural views from them, we offend against the very end for which observations ought to be made. I will endeavour to keep a proper medium; but if I should deviate from that, I could wish not to fall into the latter error."

Frederick William Herschel was born at Hanover on November 15, 1738. His father was a hautboy player in the Hanoverian Guards, and at the age of fourteen William was engaged as a musician in that regiment. He left in 1757, as he had taken no oath binding him to military service. He received a formal discharge in 1762. The legend that he deserted from the army, and received a pardon from George III in 1782, is a fiction.

Towards the end of 1757, Herschel came to England and for some time had hard work to earn a living by copying music and giving occasional performances. His musical abilities were gradually

recognized, and in 1760 he was appointed instructor of the band of the Yorkshire Militia stationed at Richmond. In 1762 he resigned this post; he composed symphonies, conducted concerts at Leeds, was for a short time organist of the Halifax parish church, until in 1766 he became organist at the Octagon Chapel at Bath. He was soon the centre of musical activity in this fashionable watering place and had a busy life, composing, conducting concerts and taking pupils.

As music was not sufficient for his boundless energy, Herschel studied Italian, Greek, harmonics, mathematics, optics and astronomy. In 1773, he hired a small telescope and commenced to search the heavens. He soon wanted a larger telescope, and after many experiments and failures succeeded in making a Newtonian reflector of six and a half inches diameter and seven feet focal length. The parabolic mirror was of speculum metal in the proportion of 5 lb. of tin to 9 lb. of copper. He cast the disk himself, ground it and polished it with his own hands. With this instrument, he repeated and extended a previous survey of the heavens. His intention was to find bright stars with faint stars near them, on the supposition that the difference of magnitude was the effect of distance and might thus serve to determine stellar distances.

On March 13, 1781, Herschel made this entry in his note-book: "In the quartile near ζ Tauri, the lowest of the two is a curious either nebulous star or perhaps a comet". After several cloudy nights, he found on March 17 that the star had moved and was presumably a comet. He communicated his discovery to Maskelyne, the Astronomer Royal, who wrote to him on April 23: "It is as likely to be a regular planet moving in an orbit nearly circular round the Sun as a comet moving a very eccentric ellipsis. I have not seen any coma or tails to it". The evidence of its great distance and uniform movement soon showed that the body was, in fact, a new planet. This was an astounding discovery, as no one had ever imagined there could be more than the five planets Mercury, Venus, Mars, Jupiter and Saturn, which had been known for ages. Herschel was awarded the Copley Medal of the Royal Society in November 1781 and was elected a fellow of the Society in December.

The attention of George III was directed to the fame of the Hanoverian astronomer, with the result that Herschel was appointed King's Astronomer with a salary of £200 a year. He was now relieved of the necessity of snatching astronomical observations in the intervals of concerts or sitting up all night after a hard day's work. He had at this time a 7-foot telescope of 6 inches aperture and a 20-foot telescope of 12 inches aperture. He now proceeded to make a 20-foot telescope with an 18-inch speculum, and com-

menced his famous 'sweeps' to find what was in the sky and to gauge the depths of the heavens. Some years later, he constructed the great 40-foot telescope with a 40-inch speculum. Before he had made the flat mirror so as to use the telescope in the Newtonian form, he looked down the tube directly with his eyepiece and found the definition good, and the brilliancy greater owing to the absence of a second reflection. He accordingly adopted what is known as the "Herschelian" type of reflecting telescope in later work.

Herschel continued his observing with, if possible, increased vigour, finding in his 'sweeps' objects which enrich the natural history of the sky and classifying them according to their species, hundreds of double stars, thousands of clusters and nebulae. Double stars attracted him because he hoped to find a parallactic displacement between a bright star and its faint neighbour, and thus obtain an idea of stellar distances. He published a list of 269 double stars in 1782, giving their position angles and their angular distances apart inferred roughly from the size of the disks. In 1784 he published a further list of 484 stars, with their distances apart now measured by a micrometer. He seems to have suspected that some of them might be real binary systems. By 1802 he was satisfied from the changes in position angle that a considerable number of these stars were binary systems moving in elliptic orbits under their mutual gravitation. Newton's law thus held in these distant regions in space.

In 1760 Mayer had indicated the perspective effect which would be shown in the proper motions of stars by the movement of the sun in space, but had failed to find it. In 1783, from the proper motions of seven bright stars given by Lalande, Herschel determined that the sun was moving in the direction of λ Herculis. From a larger number of stars he obtained a slightly different and not quite so good a direction, as that found by later researches from thousands of stars arranged in all manner of ways according to magnitude, size of proper motion, and type of spectrum.

Herschel's ideas about the physical nature of the sun now seem to us very extraordinary. He regarded it as a dark, cool, solid globe, possibly inhabited, protected by a layer of cloud from the light and heat of the upper luminous region. This solid part of the sun is revealed in the openings of the luminous region shown in sun-spots. This theory held the field for many years. Erroneous facts are harmful, but erroneous theories are better than none at all and act as incentives to better ones.

With his large telescopes, Herschel examined the planets. He discovered two satellites revolving

around 'Georgium Sidus' or Uranus, and thus encouraged found two additional satellites of Saturn. He found that Venus was covered with clouds, noticed the changes in the white spots at the poles of Mars, and concluded that Mars was most like the earth as regards habitability. He determined the direction of the axes, periods of revolution and oblateness of the planets. He found that a spot in the atmosphere of Jupiter had a different period of revolution from the rest of the planet.

Herschel's name is inseparably associated with great telescopes, but for the years 1795-97 he interrupted his work to arrange the stars in different constellations, according to their magnitudes. This was largely done with the naked eye. The work was not estimated at its full value until Prof. E. C. Pickering reduced and discussed the observations. "Herschel furnished observations of nearly 3,000 stars from which their magnitudes a hundred years ago can be determined with an accuracy approaching that of the best modern catalogues".

Herschel was attracted by Messier's short list of nebulae and clusters published in the *Connaissance des Temps* for 1783. In the belief that all nebulae could be resolved into stars, he commenced a survey of the whole sky with his new 20-foot reflector of 18 inches aperture. At the same time, by counting the number of stars in equal areas in different parts of the sky, he purposed to 'gauge' the depth of the sidereal universe. He began these famous 'sweeps' of the heavens on October 28, 1783. He first placed his telescope in the meridian, and standing in a gallery at the end of the telescope could give it a motion in azimuth of 10° or 12° either way. He moved the telescope slowly backwards or forwards and noted what he saw. He then changed the telescope 8' or 10' in altitude. Twenty or thirty of such operations he called a 'sweep'. They were very fatiguing and spoiled the sensitiveness of his eye for faint objects. After the forty-first sweep he discarded this method and had recourse to vertical sweeps, employing a workman to move the telescope, and calling out his observations to his sister Caroline, who noted them down. In 1789 he published a catalogue of 1,000 clusters and nebulae. "As a mere explorer of the heavens," wrote Agnes Clerke, "his labours were prodigious. He discovered no less than 2,500 Nebulae, 806 double stars, and passed the whole firmament in review four several times, and counted the stars in 3,400 gauge fields."

In these 'gauges', Herschel counted the number of stars in the field of view of his eyepiece, which had a diameter of 15'. His telescope revealed all the stars to about the fourteenth magnitude, at

least a thousand times as faint as the faintest star visible to the naked eye. He found that the number of stars diminished with increasing distance from the Milky Way until they were only one thirtieth of the number at its pole. He was thus led to the 'grindstone' theory of the 'Construction of the Universe'. His views were modified in his later papers in 1811 and 1814 and he realized that the Milky Way is more complex, and that nebulae are not always irresolvable clusters. "We may have surmized nebulae to be no other than clusters of stars disguised by their very great distance, but a longer experience and better acquaintance of their nature will not allow of such a principle." He gave the name "planetary nebulae" to bodies "which, notwithstanding their planetary aspect, retain a haziness by which they are surrounded and evinces their nebulous origin." He regarded the Orion nebula as true nebulosity and typical of other extended nebulae, but retained his belief that some nebulae were resolvable into stars and were comparable in size with our own Galaxy.

Only the briefest reference can be made to an important paper published in 1800, when he discovered that "the heat derived immediately from the sun or from candescent terrestrial substances, is occasioned by rays emanating from them; and that such heat-making rays are subject to reflexion and refraction". He gives in a diagram the intensity of the heat in what we should now call all wave-lengths extending from the infra-red to the violet.

We must on no account overlook the help Herschel received all his life from his devoted sister Caroline. From 1772 she was his constant companion, housekeeper and assistant in his music and astronomy. She accompanied him to Slough and would sit up whole nights taking down his observations and copying them out the following day. When William married she took lodgings in Slough and still continued as his assistant. At her brother's suggestion, she searched for comets and discovered no fewer than eight. After Herschel's death she returned to Hanover and prepared a catalogue of 2,500 nebulae and clusters discovered by him. For this she was awarded the Gold Medal of the Astronomical Society. She died in 1848 after a prolonged and cheery old age.

On May 8, 1788, Herschel married Mary, daughter of Mr. Adeel Baldwin, a merchant of the City of London, and widow of John Pitt, Esq. Their son John was born on March 7, 1792. Mrs. Herschel was of an amiable and gentle character and lived on friendly terms with Caroline, whom she had displaced. In 1791, Herschel visited Glasgow and was given the freedom of the City and a doctorate of laws by the University, and

on his return called on Michell, an astronomer of distinction and originality. In 1802 he went to Paris and met Messier, Delambre, Laplace, Count Rumford and Napoleon. In 1816 he was knighted by the Prince Regent. In 1820, when the Astronomical Society was founded, he was made its first president. He was too feeble to attend the

meetings, but allowed his last paper to be published in the *Memoirs of the Society*. He died at Slough on August 25, 1822, and was buried in the Church of St. Lawrence at Upton.*

* In the preparation of this article, I have used to a great extent the admirable introduction to "The Scientific papers of Sir William Herschel" written by Dr. Dreyer, and am also indebted to a conversation with Dr. W. H. Steavenson.—F. W. D.

Obituary Notices

Sir Robert Mond, F.R.S.

ROBERT LUDWIG MOND, the elder son of the late Dr. Ludwig Mond, F.R.S., was born at Farnworth, near Widnes, Lancashire, on September 9, 1867, and was brother of Alfred Moritz Mond, the late Lord Melchett. He was educated at Cheltenham and at Peterhouse, Cambridge. Later he worked at the Polytechnicum, Zurich, and at the Universities of Edinburgh and Glasgow, and had the privilege of being private assistant to Sir William Thomson (Lord Kelvin). His first wife, the mother of his two daughters, died tragically in Egypt in 1905; and he married in 1922 Marie Louise Le Manach, of Belle Isle en Terre, Brittany.

In consequence of his varied training in the physical sciences and the atmosphere of his home, Robert Mond had an extraordinary wide outlook on scientific problems; so that, while never becoming a specialist in any one branch, he was able to contribute materially to the solution of problems in these subjects. On proceeding to Winnington, he had the privilege of working not only with his father but also with such distinguished collaborators as Carl Langer and Friedrich Quincke. He assisted in the investigations leading to improvements in the production of zinc by the electrolysis of zinc chloride, and to the discovery of nickel carbonyl, the basis of the process for the production of pure nickel. In the course of time, Robert Mond was called upon to assume positions of responsibility in various organizations arising from the exploitation of scientific investigations at Winnington. He joined the board of directors of Brunner, Mond and Company and the Mond Nickel Company, of which he subsequently became chairman.

In connexion with the exploitation of the nickel mines at Sudbury, Ontario, Robert Mond identified himself with the Royal Ontario Museum, Toronto, of which he became trustee and to which he gave considerable sums of money and also enriched by valuable contributions arising from his archaeological investigations in Egypt. His absorbing interest in archaeology dates from about 1898, when, shortly after his marriage, he had to spend winters out of England for health reasons. In his earlier days, Robert Mond was a keen mountaineer, and later, although never of sound physique, his unusual vitality made it possible for him to undergo physical

strain which always surprised those who knew him intimately.

In 1910, Robert Mond went to live at Combe Bank, Sevenoaks—one of the first houses to have electric lighting installed—with its model farm and laboratories originally intended for his father's use. Characteristically and with his usual vigour, Robert Mond took up, for him, new investigations in agriculture, including stock-breeding, and it was from here that he supplied with milk the Infants Hospital in Vincent Square founded as a memorial to his late wife. The late Prof. H. E. Armstrong used to maintain that Robert Mond was the first to appreciate the meaning of 'pure' milk and to conduct his experiments on a satisfactory scale.

It is difficult to give an adequate account of Robert Mond's scientific and industrial interests. His scientific greatness lay not so much in what he himself discovered or achieved but in what he did to make it possible for those to achieve who were less fortunately placed. Especially after his father's death, he regarded his wealth and position as a trust to be used in the advancement of knowledge and appreciation of beauty, and through that of international peace and fellowship, and he worked incessantly to achieve this ideal.

The large number and extent of Robert Mond's benefactions will probably never be known to the outside world, and if by chance he happened to mention any one of them to an intimate friend one felt that he had been guided by his ideals rather than by the mere amelioration of a difficult financial situation. Some of them in Great Britain are known. There is his large benefaction to the University of Liverpool, of which he held the honorary LL.D. degree. Another typical example of what he has done for the advancement of scientific knowledge is his work for the Royal Institution. Sir Robert Robertson, the honorary treasurer, has written:

"By the same deed of trust (1896) of Ludwig Mond in which he conveyed the Davy-Faraday Research Laboratory and its endowment to the Royal Institution, Robert Ludwig Mond was named Honorary Secretary of the Laboratory Committee for life. When in London he came occasionally to the meetings of the Committee and read the minutes. To the equipment and furnishing of the Davy-Faraday Laboratory, he gave much thought and travelled over the Continent and in America studying arrange-