HENRY REGINALD ARNULPH MALLOCK—1851–1933.

Arnulph Mallock, the youngest son of the Reverend William Mallock, was born at Cheriton Bishop, on March 12, 1851. His father, then the Rector, left Cheriton Bishop about a year later and went to Brampford Speke in the Exe Valley.

The Rev. W. Mallock was a younger son of Roger Mallock, Squire and Vicar of Cockington Court, Torquay. His wife, Mary, was a daughter of John Mudge, whose relative, Thomas Mudge, was the famous clockmaker. If heredity goes for anything it would appear that the mechanical instinct of the Mudge family reappeared in the person of Arnulph Mallock.

Mrs. W. Mallock was a daughter of Archdeacon Froude, and her three brothers were all distinguished: Hurrell, the friend of Cardinal Newman; William, the Naval Architect; and James Anthony, the Historian. With such evidence of ability on his mother's side Arnulph Mallock was again able to draw on the gifts of heredity.

After the death of Mrs. Mallock's aunt, Miss Margaret Froude, about 1854, the family lived for some years at Denbury Manor, near Newton Abbot, a dower house of the Froude family, and there the two boys Arnulph and his elder brother W. H. were educated at home. W. H. Mallock's book, "The New Republic," attracted great attention some 50 years ago, and many of his other books are almost equally well known.

From the age of 11 to 16 the brothers were first at Haylebury and then at a small school at Harlow, Essex. From the age of 16 until Arnulph went to St. Edmund's Hall, Oxford, the brothers were with a tutor, the Rev. Philpot, who had been a favourite pupil of Dr. Arnold's.

It will be seen from this bald statement of his education Arnulph Mallock had the very great advantage of an unusually large proportion of individual attention. Presumedly, therefore, he suffered less from the cast-iron school and university system which used to tend towards stamping out individuality.

After leaving Oxford Mallock assisted his uncle, Mr. W. Froude, of Chelston Cross, Torquay, in working out the very beautiful gear of the original ship model tank. I remember years later when Mr. Froude spent half a day showing me all his apparatus then in use at the Admiralty tank at Haslar, being lost in admiration of the perfection of the design of all the parts and the successful way in which the whole machine worked. This was before I knew Mallock, but now looking back I see the hand of Mallock, or it may be Mallock's hand as I afterwards knew it, had been guided and trained by Froude.

In 1876 Mallock went as assistant to the third Baron Rayleigh. He had some doubt whether his mechanical skill would be sufficient to enable him to meet Lord Rayleigh's requirements. It would seem that his misgivings were

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unnecessary for two reasons. He was in fact an accomplished mechanic, capable of the finest instrument construction if he had suitable tools, and Lord Rayleigh was such a genius in devising means, almost absurdly simple, for conducting experiments of the most crucial character. The time spent under Lord Rayleigh must have been, perhaps, the most precious of all in encouraging Mallock, if indeed he needed encouragement, in confidence in first principles where difficult problems were to be met. Neither Lord Rayleigh nor Mallock seem ever to have asked the question—what is the proper way to do this, how have other people done it? Never this, but only, regardless of all prior practice, what are the fundamental principles involved and how can they be applied?

Mallock was fortunate in having lived among a group of brilliant men in the engineering world—Brunel, Froude, Tower, of spherical engine fame, Baker, Metford and others—and with his very great mechanical skill and considerable mathematical ability and ingenuity, was ready to attack and solve problems as they arose. He had no need to go out to seek for these: they were thrust upon him, for his reputation brought our great industrial undertakings, and railways, as well as the War Office, Admiralty, and Air Force to seek his aid and the greater part of his active life was so occupied. It is perhaps unfortunate that so much of this work was essentially confidential but his interests were so wide that he found time to experiment and write papers upon a great variety of subjects, besides those of purely mechanical or of engineering interest.

Perhaps the class of experiment for which he showed especial genius was that in which the smallest movements, tremors, bendings or stretchings had to be determined, and the railway companies constantly approached him for authoritative information. He designed and either made himself or designed and superintended the construction, by the firms of Troughton and Sims or Adie in particular, of the beautiful instruments with which he examined tremors due to the underground railway, disturbances of St. Paul's Cathedral, problems connected with the Forth and Tower Bridges and many more. As a civilian member of the Ordnance Committee he wrestled with many of the problems of ballistics. As a member of the Aeronautical Research Committee he delivered the James Forrest lecture on Aerial Flight, to the Institution of Civil Engineers in 1912, and I find from his papers that he was engaged on many problems for the Admiralty.

Mallock's apparatus was always simple but mechanically perfect, and it had the supreme merit that at least in his own hands it worked accurately.

He was also interested in many problems in Optics and in particular he was skilled in dissection under the microscope and wrote many papers on the eyes of insects and the eyes of spiders. I am not aware that he made any experiments on the apparent usefulness of their eyes to different kinds of spiders. I mention this point here as there appears to be so great a difference with different

species. *Epeira diadema* and the small garden spider have not made any response to any test I could devise, while *Tegenaria* and the common house spider see in the ordinary sense quite well, and the hunting spider which Mallock also examined seems to see best only straight ahead, or it may be that he can only jump in that direction. In connection with his skill in microscopic dissection Mallock astonished the Zoological Society at one of their meetings with slides showing his dissections of the muscles of a butterfly's wing.

For his microscopical mountings Mallock made use of Styrax, on which he wrote two letters to 'Nature' in 1924. I do not know how well, if at all, this gum was known as a mounting medium of exceptionally high refractive index, but among Mallock's papers there is a large collection of letters from many parts of the world to him in answer to his enquiries and he evidently took much trouble at the time to find out all he could about it and its origin. Now I understand it is a standard microscopical medium.

His optical interests naturally drew him to experiment as so many have done with the brilliant colours of butterflies' wings and the metallic hues of beetles.

As long ago as 1874 Mallock noticed a colour phenomenon not very conspicuous but ready to hand for almost everyone. As is well known, two sheets of wire gauze or perforated zinc laid one over the other give rise to patterns of the watered silk type but without colour. If, however, only one piece of fairly fine gauze be used and the other is the reflection in an ordinary looking-glass on which it is laid the patterns are seen as before, but now they are coloured mainly with the colours of tempered steel. The simple explanation is given in our 'Proceedings,' vol. 94 (1918), and it is followed by a note on the colours of tempered steel. These have generally been supposed to be interference colours like those of soap bubbles without consideration of the opacity of the oxide. Mallock found that on gradually reducing the thickness by polishing, the colour did not change. On the other hand, it was to a certain extent influenced by obliquity and was affected by polarized light.

So far as I can remember the first of Mallock's papers which completely captivated me was one on Young's modulus for topaz, tourmaline, beryl and a number of ordinary materials obtained by bending bars in a minute testing machine. On again looking up this paper which was published in 1891, vol. 49 of our 'Proceedings,' my old admiration with a riper judgment is in no way diminished, and I think if anyone wants an example typical of Mallock's genius no better among many could be found.

Mallock was associated with Mr. Metford in the design of rifle bullets and in ascertaining their trajectories. There are three papers in the 'Proceedings,' vol. 80, on this subject and one on p. 110, that has other interest also. He took up a series of stations down a rifle range and noticed the direction from which the sharp click due to the air wave shown in photographs of bullets

travelling at speeds in excess of that of sound and found that the sense of direction agreed with the normal to the air wave with considerable accuracy, even though the head cannot be shifted to a series of positions as it is when locating the direction of a fog-horn at sea. As the click is made by a single compression wave small in dimension compared with that of the head any idea that the sense of direction is determined by a phase difference is ruled out and it can only depend, so it would seem, on the difference of time that the sound reaches the two ears. In later experiments on the extreme range of rifle bullets Mallock and Lord Cottesloe made use of the long stretch of quiet water at Sir A. Noble's estate at Ardkinglas where they were able to see the splash until at the most extreme range the velocity was so low that the bullet entered the water without much disturbance, but it could still be heard and its position determined by the direction of the sound. The sharp line indicating the position of the compression wave in photographs gives an insufficient indication of the energy carried by the wave which is the chief cause of resistance to a projectile's flight. In order to appreciate better how great this is it is only necessary to go down the line of fire of a heavy gun say, for half a mile when this wave, like that from lightning, is found to give rise to a deafening explosion, and wooden huts seem as if they would be shaken to pieces. Then a moment later the quiet boom of the gun is heard. I have never been able to understand why a strip of gold leaf placed just above a bullet's path so that the compression wave crossed it half way up showed no sign of any disturbance or kink under this violent action as I had expected.

Another interesting example of Mallock's ingenuity and painstaking research is to be found in his apparatus for measuring the growth of trees. For this purpose he adopted an instrument which he had formerly used for observing changes in the dimensions of cracks on St. Paul's and other buildings. In this the movement of interference fringes formed between nearly parallel plates by monochromatic light at perpendicular incidence gave him measurements of very small quantities which were all he had to observe. Such accuracy was of the order of one millionth of an inch but this was far too delicate a piece of apparatus to be suitable for trees. By some instinct he saw that if he replaced one plate by an ordinary reflecting prism and allowed the other to be in contact with the reflecting face of the prism at a very small angle rays of white light just not totally reflected and passing to the plate at almost a grazing incidence would give rise to an interference pattern with these two peculiarities. There is one band nearly achromatic which can at once be distinguished from the others so that it may be used merely as an indicator, a micrometer screw being used to compensate for the growth and to bring back the particular band to its central position. The delicacy of measurement is brought down to less than a tenth of that given before but this is still ample for the purpose. Indeed, with quick growing trees such as the black Italian poplar the bands can be watched moving

so that the increase of girth in a few minutes may be seen, but if so long a time as an hour or more is concerned then the micrometer screw is used to bring the special band back to its initial position. At the end of the paper (' Proc. Roy. Soc.,' B, vol. 90) there is a note giving the optical theory. In the paper he discusses the results obtained with a number of trees, some in Kew Gardens. With a black Italian poplar which when 20 years old will increase 4½ inches in girth in the few months of the year in which growth takes place no doubt a plain steel tape would give all the information which could be wanted by the practical forester. Even he, however, might be glad to have means of such delicacy if he were watching the growth of a box tree.

I have referred to this instrument not so much for any results on trees which he observed, interesting though they may be, but rather because the design of the instrument and the optical theory are typical of Mallock's genius.

Another of his enterprises was the design and construction with his own hands of a machine for ruling diffraction gratings. I remember a visit to Lord Rayleigh's either about 1891 or about 1895, when Mallock was also a guest, and he had with him his drawings of this machine and several gratings which he had ruled with it, and which to the eye were very perfect. Lord Rayleigh was going to examine them, but I never heard with what result. Those who remember Rowland's account of his perfecting of the screw of his machine would hardly expect any screw as cut in the lathe to be so perfect that under this severe test there would not be periodic or other error which might be smoothed out by grinding. Also Rowland found a very long nut to be essential. How far Mallock had got in this direction I never heard, but I remember being struck by the completeness of the drawings. He told me that he finished these drawings in every particular before he began the construction. I have lately seen about half a dozen of his gratings, but by some evil chance tissue paper had been laid upon each and they had been kept packed together with the result that the paper had entered the lines and ruined the gratings. One only in part retains some of its brilliancy. One feature of these gratings, which from the point of view of their use in the physical laboratory should be followed, was the prolongation of every 100th line for one-hundredth of an inch or so to facilitate counting and measurement. This machine is now at the National Physical Laboratory. I have heard from the Director that they have only recently begun to do anything with it and so far have not made much way.

I have selected a few only of Mallock's contributions to physical science out of a great number. The selection is based mainly on the consideration that they are essentially typical of his special aptitude, and in minor degree because they have interested me so much. To give a list of his papers in our ' Proceedings ' and of his letters to ' Nature ' would require inordinate space, for there were forty-eight in the ' Proceedings ' and eighty-nine in ' Nature,' respectively. While this may be impracticable it may be sufficient to state that they

embraced a very wide range from which curiously electricity and magnetism seem to be excluded. In his later years Mallock made some use of the facilities afforded by the Mond laboratories attached to the Royal Institution.

In 1904 he married Helena Maria Caroline Finlay, of Castle Toward, Argyllshire. In his last years with rapidly increasing blindness her devotion did much to alleviate his distress, for his mind and interests remained acute, but first his beloved microscope and gradually all print ceased to be available to him.

He had some valued relics of instruments which had belonged to those he knew as a child. A Mudge clock which was for some years in the Science Museum, South Kensington, is now in the possession of a friend. Sextants and other instruments having the initials "I. K. B." engraved upon them, which had been the property of Brunel, are going to that wonderful collection made by Dr. Gunther at the Ashmolean Museum, Oxford, and here his tree-measuring machine and some of his gratings may also find a home. The machine for ruling diffraction gratings as already mentioned is now in the care of the National Physical Laboratory. Among the apparatus that remains, there is a spectrometer beautifully designed and made, with large telescope and collimator but without divided circles, evidently used by Mallock for the critical examination of the spectra produced by his diffraction gratings. This is in perfect order and it is desirable that it should go to some physical laboratory where it would be valued.

Mallock did not seek publicity, quite the reverse. He cared nothing about the general public and they in general had never heard of him. He was of the old school of clean-cut, exact mechanics and physics and he took no interest in what appeared to him (and not only to him) the modern more nebular methods. He would not be photographed in the ordinary way and it is only possible to reproduce his portrait as he was when one of a congenial little party of six at one of those very elegant and charming dinners that our Fellow, Campbell Swinton, used to give at his house when Professor R. W. Wood was in London. A photograph was taken after dinner. Those present were R. W. Wood, Lord Rayleigh, A. Mallock, W. Duddell, C. V. Boys and C. Swinton, and the reproduction is taken from my copy of this group.

Arnulph Mallock was elected a Fellow of the Royal Society in 1903, and he served on the Council from 1910-12.

C. V. B.