and Le Play. In more recent years the tradition has been carried on by Le Châtelier, Moissan, Pourcel, Osmond, Dumas, and Guillaume, whose work on the special alloys of iron resulted in the discovery of "Invar," an iron-nickel alloy the coefficient of expansion of which at ordinary temperatures is negligible. Such a list shows how keen has been the interest taken by French scientific workers in metallurgical problems. The debt due to them is not readily appreciated, that due to Le Châtelier being even greater than Sir Robert acknowledges, since, in addition to the credit already

from so many countries to attend this Congress, I venture to point out that this very gathering itself affords an obvious testimony to the truth of the saying that 'Science knows no boundaries.'

We are met, here in Paris, the renowned capital of France, and, it may with truth be said, the city wherein, perhaps more than in any other throughout the whole world, science receives most help and most encouragement.

In a memoir which I communicated to the University of Oxford, towards the beginning of this year, I showed an engraving in which was represented one of the greatest scientists of medieval England, Roger Bacon, in the act of presenting a book, the record of his work, to the University of Paris, about the year 1250. During the fourteenth and fifteenth centuries Paris was, indeed, the centre of science.

The University of your city was, even then, exercising considerable influence on the universities at that time established in England. I might cite, as an example, Jean Buridan, Rector of the University of Paris, who was one of the founders of modern dynamical science. M. Picard, chief secretary of the Academy of Sciences, has already written, on this subject, a memoir most carefully and interestingly drawn up, with reference to the facts I have mentioned.

That which was true of the past centuries is still true of the present day. Paris has not lost her ancient renown in the sciences; she still preserves it, and it may very frequently be observed that the great ideas which spread through the world of science are ideas the origin of which may often be traced to distinguished Frenchmen.

I venture to believe that in uttering these sentiments I am expressing, not my own views alone, but those of my colleagues here present, and those, indeed, of the whole world. I trust that France will maintain, in the future, the position which the wisdom of her great men has won for her in the past."

FIG. 1.—Photomicrograph of a specimen from the Delhi iron pillar.

given, there must be added that due to his researches on the transformations of silica at elevated temperatures, which in no inconsiderable manner paved the way for the recent advances in our knowledge of the refractory materials in general.

Sir Robert's concluding remarks are of wide interest and may well be quoted in full:

"In offering my contribution to this distinguished gathering of prominent scientists, who have come

One cannot but be impressed throughout the address by the intimate connexion of the work of French men of science with industrial problems, a liaison which has proved of the greatest importance. A quotation by Percy, in the preface to his classical work on the "Metallurgy of Iron and Steel," from Réaumur, remains as true to-day as it was two hundred years ago: "... L'utile bien considéré a toujours de curieux, et il est rare que le curieux bien suivi ne mène pas à l'utile. ..."

F. C. T.

The Cierva Auto-Gyro.

By Prof. L. BAIRSTOW, F.R.S.

A NEW flying machine, quite unlike the normal aeroplane and bearing a strong resemblance to a helicopter, has flown very successfully and excited general interest. It is yet too early to see the full consequences of this notable achievement, but perhaps not too soon to attempt a preliminary statement of what appears to be its general principles, in order to prevent undue expectations.

The auto-gyro has the normal parts of an aeroplane except its wings; the latter are replaced by a screw

rotating freely about an axis which is nearly vertical in flight. Except when starting, this screw or auto-gyro, is not mechanically driven, but is maintained in rapid rotation by the play of aerodynamic reactions. The forward motion of the craft is produced by the normal airscrew and engine of an Avro biplane, the body, controls, and under-carriage of which are retained, except that a very large movement is given to the elevators. Ailerons have been fitted to the craft, but are said to be unnecessary.

In flight the body of the auto-gyro appears to be supported by a flat shuttlecock, and when flying slowly its performance is astonishing. The inventor claims the possibility of flight at ten miles an hour, and exhibition flights at Farnborough in the last fortnight have shown that, when flying in a light wind, the device can hover over the ground. Furthermore, after shutting off the engine, safe descent can be accomplished at an angle of 60° to the horizontal, the craft coming to rest with a forward run of a few yards only. As at present arranged, starting from the ground is primitive; a rope is passed round projections on the auto-gyro screw and rotation up to about 60 rev. per min. produced by hauling on this rope. Taxi-ing over the ground in the normal way then brings the speed to 120-150 rev. per min., when the machine may safely leave the ground. The run is rather long.

From remarks made by the inventor, it appears that the use of the engine for starting the screw has been contemplated, so as to make it possible to rise from a confined space. The auto-gyro screw as it exists at present is unsuited for driving whilst in the air, and it is not clear that such driving would be advantageous.

From some approximate data given publicly by the inventor, it appears that the complete craft weighs about 2400 lb. and has a highest speed of flight of 68 miles per hour. The Avro biplane with the same engine weighs 1800 lb. and flies at about 90 miles per hour near the ground. So far as I know, the height to which the new machine can climb has yet to be determined.

The auto-gyro screw has four blades, the total area of which is about half that of the wings of the standard Avro aeroplane, and this makes the average loading some 30 lb. per sq. ft. as against the 6 lb. per sq. ft. of the aeroplane. In flight the device seems to be very stable and easy to control, and in this respect the invention gives a solution of one of the very difficult problems connected with the production of a successful helicopter.

The stresses due to rapid rotation are dealt with by ingenious but not novel means, and one can only marvel that in reducing the stresses the inventor has also got a stable aerodynamic system with other good qualities. The auto-gyro screw is mounted on a fixed shaft almost in the plane of symmetry of the fuselage and some 6 or 8 feet above its centre line. The four wings of the screw are hinged to a sleeve which rotates freely on ball bearings on this fixed shaft. The axes of the hinges are close to the shaft and nearly normal to it.

On the ground the weight of the blades is taken by rubber springs and guy wires, but these cease to operate in flight. The lift of the blades produces a moment tending to fold the blades upwards, and this is balanced by a moment due to centrifugal forces. By suitably curving the blades, bending stresses are almost eliminated, and as the centrifugal forces are large, a balance of moments is obtained with an upward tilt of less than 10 degrees. The same agency—centrifugal force—is left to deal with stability, gyroscopic couples, and gusts.

Due to the hinging and the varying lift on the

separate blades in the course of a revolution, a certain amount of flapping occurs. It is claimed—without great emphasis—that the flapping is beneficial to the operation of the screw, although other experiments by the inventor have shown that rotation may be maintained with a fixed screw. It is remarkable to find that forces inclined ahead of the axis of rotation exist over a wide range of speed of flight. Even when the forward speed is only 20 miles per hour, these forces urge the advancing blades to speeds upwards of 150 miles per hour at the tips. As yet there is little knowledge of the effect of forward speed on the rotational speed of the auto-gyro, possibly because the pilot has so manoeuvred his craft as to maintain a specified minimum. One of the suspicions voiced is that rotation would tend to stop at high speeds. Further, it is possible that vertical descent would be too rapid for safety; descent at an angle of 60° appears to cover most requirements when landing, and vertical descent may not be required in any case of importance.

The existence of tip speeds of 150 miles per hour readily accounts for the high average loading of the blades, since, other things being unchanged, the force per square foot of wing varies as the square of the speed. An element of wing moving at 150 miles per hour has then more than fifty times the pressure of the same wing at 20 miles per hour. There is, in fact, no need to look for new types of air flow to account for the phenomena observed. No difficulties are anticipated in analysing the performance of the auto-gyro by existing methods of calculation and knowledge of aerodynamics. From the details which this analysis will give, new developments may perhaps follow, but one general conclusion may already be drawn with some confidence. It may be expected that the auto-gyro will be a less efficient organ of transport than the aeroplane.

The arguments for such conclusion have already appeared in *NATURE* in a discussion of the possibilities of the helicopter (August 18, 1923, vol. 112, p. 229). So long as wings are used in producing lift, there will be a consequential resistance which cannot fall below a certain minimum proportion of the lift. The least amount of work expended in producing a given lift and moving a wing through a prescribed distance is then determined by conditions of airflow beyond the control of a designer. Obviously the path taken by the wings of an aeroplane between two points is the shortest possible, and the longer coiled path of the wings of a screw requires a larger expenditure of work.

This summary leads to conclusions typical of most engineering problems, no single solution containing in itself the whole of the desired qualities at their maxima. Combination of aeroplane and auto-gyro is not yet suggested, and much research lies ahead before the benefits of the new invention can be translated into terms applicable to commercial aircraft. Should uses be found for a new type of craft in which high speed and high efficiency are not essential, the new invention gives valuable help at once. No combination remotely approaching the performance of the auto-gyro at low speeds has yet appeared in the history of heavier-than-air craft.