period, it will be seen that a similar connection seems to exist between the latitudes of the centres of action of the prominences and the three types of coronas.

The investigation seems to indicate that it is the *sum total of prominence action* in the different zones which produces the largest coronal streamers, and not any particular prominence at any particular moment; it is for this reason that the form of the corona is not a fleeting phenomenon changing every minute or hour, but one lasting over several months, and sometimes as much as a year or more. That the general form of the corona does undergo comparatively slow changes is borne out, to a great extent, by the similarity of coronas which are observed at eclipses which occur close together, such as those in 1900, 1901, the two eclipses in 1889, &c.

It is of great interest briefly to note the connection between the centres of prominence action when either two or one of them exist in each hemisphere. In the first place a well-defined large coronal streamer apparently originates, as many photographs indicate, not from disturbance at the *centre* of its base, but near the two ends. Such a streamer is generally made up of groups of incurving structure, termed previously "synclinal" groups, and this structure is, in many cases, very distinct. When there are *two* centres of prominence action in one hemisphere, the coronal disturbances resulting from each trend towards each other, and constitute a large streamer with an apparent "arch" formation. If the two centres of prominence action exist in comparatively mid-latitudes, one large streamer is formed in each quadrant, and the form of the corona is of the "intermediate" or "square" type.

When one of the centres is near the region of the poles and the other in comparatively low latitudes, the tendency is still for the two disturbed coronal regions to trend towards each other, but they constitute either a large streamer of an "arch" formation nearer the solar poles with a very extended base, or two separate streamers which combined have a fish-tail appearance.

With *one* centre of action of prominences in each hemisphere, the resulting coronal disturbances in both hemispheres curve towards the solar equator, and form apparently a large equatorial streamer; the "equatorial" type of corona is here formed.

The accompanying sketches (Fig. 2) illustrate in diagrammatic form the general relationships between the latitudes of the spot zones, the latitudes of the centres of action of the prominences, and the suggested resulting positions and origin of structure of the coronal streamers for each of the three types of coronas here discussed. It will be noticed that in the case of the "polar" and "intermediate" types, when the sun-spots are numerous, the zones in which they occur have apparently little connection with the coronal streamers. When the latitudes of the spot zones do approximate more nearly to the bases of the coronal streamers, as in the "equatorial" type, and might be considered as being the origin of their existence, the spots at these epochs are near a minimum, that is, are very few and small in size, and have the least power of action.

WILLIAM J. S. LOCKYER.

SOME PRESENT AIMS AND PROSPECTS OF MATHEMATICAL RESEARCH.[1]

IT may be doubted on the whole whether any completely scientific and permanent dividing lines for the classification of modern original work of pure and applied mathematics can be drawn.

The nearest approach is perhaps an arrangement according to motive. Thus a first class may be constituted of those investigations which aim at discovering and establishing the foundations of the subject, and obtaining rigorous proofs of theorems already known; such work as that which Peano and Russell are doing in their symbolic notation for the general principles of mathematics, or Pieri and Veronese for the axioms of geometry, or Picard for the existence theorems of differential equations, or Vallée-Poussin for the differentiation of definite integrals.

[1] From an address by Mr. E. T. Whittaker on "Some Present Aims and Prospects of Mathematical Research," delivered before the University College Mathematical Society on June 25.

Although the primary aim of such papers is that of imparting a strict logical rigour to the theory discussed, yet the most surprising and unexpected new results are constantly arising in them; as an instance, I may mention Fano's discovery of a space which consists only of 15 points, and which satisfies all the conditions for an ordinary projective space except the condition that each part is to be distinct from its harmonic conjugate; or the remarkable result that a projective geometry of two dimensions cannot be obtained without the supposition that the two-dimensional space is contained in a three-dimensional space; or the well-known theory of Fourier series and integrals which can represent different analytic functions in different parts of their domain of existence. It is a notable fact that this type of research seems peculiarly congenial to the mind of the Latin races. Undoubtedly much work of the kind has been done in Germany during the nineteenth century, but the honour of its foundation must be assigned to Cauchy, and its home has always been in France and Italy. In this country it has never thoroughly taken root, perhaps because, as someone said, the Englishman cannot distinguish between a proof and an appeal to the jury. In America, however, a considerable amount of attention is now given to the subject by such writers as Moore, Osgood, Bôcher, and Huntington.

A second class of research can be formed from those which are directly provoked by some observed phenomenon of nature, researches of which the immortal type is Newton's discovery that if the planets move in ellipses with the sun in one focus, it must be because they are attracted to the sun with a force which varies as the inverse square of the distance.

In work of this kind our country has always borne a distinguished share; the greatest achievements of the English school of mathematical physicists must all be included in it, and even at the present time no paper excites so much interest among us as one which gives a mathematical explanation of the Zeeman effect or the second law of thermodynamics.

A third class of investigations may be made to consist of those in which the motive is not in some external phenomenon, but in what may be called the internal expansive force of the subject itself, the inherent capability of extension, which is latent in every theorem of mathematics, the desire of the mathematician who has solved the quadratic equation to solve the cubic and quartic, and then either to solve the quintic or to show that it cannot be solved by radicals.

This, which is by far the largest of the three classes, admits of several subdivisions, according as the successful issue of the work is due mainly to the author's geometrical imagination, as in the writings of Cremona and Chasles, or to his power of algebraical analysis, as in much of the work of Jacobi and Cayley, or to his having brought to bear on the subject a novel set of ideas, as, for instance, in Fuchs's papers on linear differential equations, or to what may be called pure constructive intuition, which does not depend on the extension and generalisation of preceding results, as for instance, Euler's expression for the gamma-function as an infinite product, or his solution of the many types of differential equations.

The second of these subclasses, namely, that in which the successful management of highly complicated symbolic work is the most prominent feature, has flourished perhaps more than any other branch of non-physical mathematics in our own country.

It may be questioned whether this is not in part a consequence of the traditional English mode of training, which includes far more working of hard examples than is customary abroad, and thereby gives the mathematician that algebraical power which comes of much practice: but no one can see such work as that of Cayley or Forsyth without feeling that it is largely due to an inherent algebraic power with which our distinguished fellow-countrymen have been endowed. The introduction of new algorithms and new concepts is, on the other hand, a German characteristic; a notable instance is furnished by the invariant-theory, which, after its first development by Cayley and Salmon on purely algebraical lines, was transformed by Aronhold's introduction of the symbolic notation. The *Mengenlehre* of Cantor, the Ausdehnungslehre of Grassmann, numerative geometry and the theory of algebraic numbers, are instances of subjects the inception of which we owe to the Germany of the nineteenth century.

While, as we have already remarked, the English have shown a considerable interest in some branches of research, it is often said, and I think with truth, that our record in the history of modern mathematics is not worthy of our place among the nations. It is, at any rate, a fact that a considerable number of men spend the greater part of their student life in the special study of mathematics, and after a successful college career are appointed to teaching posts which leave them a fair amount of leisure for the pursuit of their chosen subject, and that, nevertheless, their life is barren of contributions to learning. This state of things, which we must admit to be much more general in this country than on the Continent, is, perhaps, the gravest feature in the situation at present, and it becomes deeply interesting to attempt to trace its course.

The explanation which I personally favour places the origin of the evil back in student days, and in our methods of instruction. The most casual reader of text-books cannot fail to be struck by the fact that English text-books treat their subjects in much greater detail than is customary on the Continent; innumerable side-issues are raised, trifles are elaborated, and examples are multiplied a hundredfold. Moreover, topics which have now become comparatively unimportant, or even positively obsolete, are always retained, and each text-book differs from its predecessor only in a further increase of prolixity.

The result is that even the best men cannot, in a student course of many years, wade through this mass of material to the frontier of existing knowledge, and the unfortunate student finds his college career over and his teaching life begun before he has gone anything like far enough to begin independent research.

I can scarcely conceive a greater benefit to the study of mathematics in this country than a series of short text-books holding closely to the main lines, casting away the rubbish and the trifles, and carrying a student to the furthest boundary of learning in a three years' university course.

Although the evil relates chiefly to college text-books, it would not be difficult to mention branches of higher learning the progress of which has been arrested for a long period simply by the publication of unreadable accounts of them.

In order that our research may be the worthy centre of a life-work, it is needful to have not merely the equipment of a full knowledge of the past, but also a clear and well-defined idea as to which are to be considered the chief and which the minor objects of investigation. For the next worse thing to doing no research at all is to spend one's time on matters that are of very little consequence.

This point is all the more important because there is every indication that we are now at a critical point in the history of mathematics, and that the twentieth century will see progress in somewhat different directions from those which characterised the last half of the nineteenth.

Let me recall the fact that, from the time of Newton to the death of Cauchy in 1857, the main progress of mathematics was in the realm of analysis—the science which is based on Newton's infinitesimal calculus, and which was enriched by all the greatest masters, Euler, Lagrange, Laplace, D'Alembert, the Bernouillis, Taylor, Legendre, Fourier, Gauss, Abel, Jacobi, and Cauchy.

The latter half of the nineteenth century saw, however, a notable change. As in the hands of these giants even the inexhaustible mine of analysis seemed to be worked out, new subjects came into prominence, such as invariants, the theory of groups, the Mengenlehre, analysis situs, quaternions, and non-Euclidean geometry; the theory of functions developed itself on lines quite foreign to the older analysts, and the demand for rigorous proofs led many even of those who remained in the domain of analysis, as Du Bois Reymond and Pringsheim, to devote themselves rather to a careful investigation of the foundations than to an extension of the superstructure. Now, however, we seem to be on the threshold of a change. The branches of mathematics the introduction of which we owe to the last generations of German mathematicians are already beginning to show signs of exhaustion—by which I mean that further work in such a subject as the invariant-theorem along the present lines does not promise to yield any great increase of mathematical power; the process of underpinning the edifice has now been, to a great extent, accomplished, and the work of upbuilding can be recommenced, while the interest of the theory of functions has largely passed over into topics of a distinctly analytical character, such as the theory of automorphic functions, the theory of expansions convergent within a given region, and the theory of summable series.

All the indications seem to point to the conclusion that pure mathematics is in the process of its natural evolution returning to the old path, and that a new phase of advance in the analysis of differential equations and functions is about to come upon us.

But though the same, it will be changed; the work of the last fifty years has given rise to ideas and methods the application of which must necessarily extend the older subjects in altogether new directions, and perhaps lead to an era worthy to be compared with that of Euler and Lagrange.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE Joule studentship, founded "to assist research, especially among younger men, in those branches of physical science more immediately connected with Joule's work," will shortly become vacant through the termination of the tenure of Dr. Ulrich Behn, who was nominated by the K. Akademie der Wissenschaften of Berlin in 1901. On this occasion the nomination of a student rests with the president and council of the Royal Society, who will make their selection in October next. The studentship is of the value of 100*l.* in all. Information may be obtained from the assistant secretary of the Royal Society.

WE regret to see the announcement of the death of Sir Joshua Fitch at the age of seventy-nine. The country has thus lost one of its foremost authorities on educational theory and practice. Sir Joshua Fitch was for thirty-one years connected with the Education Department, and the wide and varied experience which he acquired give exceptional weight to his views on educational subjects, expressed in many articles, books and addresses. Since his retirement from official life in 1894, he has taken an active part in the formation of sound public opinion upon educational questions. He recognised that the important point to bring before the people was "that education ought to be a national concern, that it should not be left entirely to local, or private, or irresponsible initiative." This principle must be accepted before any substantial provision will be made for educational progress. Sir Joshua took an active part in the reorganisation of the University of London as a teaching university, and throughout his career identified himself with movements which had for their object the coordination and development of the educational forces of the country.

OF the Education Vote of 11,249,806*l.* agreed to by Committee of the House of Commons last Thursday, only half a million belongs to secondary education. In the course of a speech made in introducing the vote, Sir William Anson expressed the fear that the traditional educational work was being destroyed, and was not being replaced with anything of a really substantial character. He was especially alarmed at the condition of the smaller grammar schools. "In these schools much attention is now being given to science, with results that are not altogether satisfactory. The classical languages are almost disregarded, and history and geography are neglected." Mr. Balfour spoke to much the same effect in the speech at the Allied Colonial Universities dinner which appears in another part of this issue. The suggestion is that science is not such a good educational instrument as the study of dead languages. It does not need much consideration to see that these conclusions are unsound. For centuries our grammar schools have been training grounds for teachers of Greek and Latin, and it would be strange if efficient methods had not been evolved. Every encouragement has been given to the humanities both in school and university, and the masters who have controlled the curriculum or guided the studies have been, with rare exceptions, men distinguished for