cessors of perhaps a hundred years hence to determine with great accuracy the relative places of stars that form globular clusters. It is only in this way that we shall ever be able to say what the motions within these clusters are; and this in turn will go far toward telling us what these objects themselves are, and what place they occupy in the universe of stars. A third research that we contemplate is the determination of the brightness of faint stars by means of extra-focal images, or otherwise expanded star disks. This method for determining stellar magnitudes is surpassed in accuracy only by the selenium photometer, which is however not applicable to faint stars.

These are the things that we have in mind, but we reserve the right to alter these intentions as soon and as often as circumstances may demand. I should not wish to commit myself, much less any other man, to an unalterable routine of work. But I do wish that it were in my power to commit the present staff and its successors to the policy of doing that thing which is most in need of attention, within the limits set by our resources and equipment, both personal and instrumental. If we do not succeed in contributing our fair share to the progress of our science, I think it will not be because we have not tried; and I believe I can make this promise for those who are to come after us, as well as for ourselves. For it would be a strange thing if the devotion that has been lavished upon the Allegheny Observatory by William Thaw and his sons, by Langley, Keeler, Wadsworth and Brashear—it would be a strange thing, I say, if the example of such devotion should ever cease to be a compelling incentive to any who may have the privilege of working within these walls, and if the tree that these men have planted and nourished should cease to bear fruit for many a season to come.

FRANK SCHLESINGER
ALLEGHENY OBSERVATORY

M. HENRI POINCARÉ

THE city of Paris is commonly regarded as the greatest mathematical center of the world, and Henri Poincaré stood for a number of years at the head of the Paris mathematicians. He was a mathematician in the broadest as well as in the deepest sense of this term. He started as an engineer in 1879, but soon thereafter he entered upon his life work as university instructor, first at Caen in December, 1879, and afterwards at Paris from October, 1881, until his death on July 17, 1912. His positions in the University of Paris were as follows: Maître de conferences d'analyse, chargé du cours de mécanique physique et expérimentale; professeur de physique mathématique et de calcul des probabilités, and professeur d'astronomie mathématique et de mécanique céleste.

He was born at Nancy, April 29, 1854, and was educated successively at the Lycée de Nancy, l'École Polytechnique and at l'Ecole nationale supérieure des mines, receiving his doctor's degree from the University of Paris in 1879. He was a very bright student and received first rank at the entrance examination of l'Ecole Polytechnique. At the early age of 32 he was elected as a member of l'Académie des Sciences, and for this occasion he prepared, in 1884, a statement entitled "Notice sur les travaux scientifiques de M. Henri Poincaré."

Although this "Notice" was written less than five years after Poincaré had begun the publication of his researches, it reviews a large number of his published articles along the following three lines: (1) Differential equations, (2) General theory of functions, (3) Arithmetic or the theory of numbers. He emphasizes the fact that he did not pursue his researches in these three directions independently of each other, but that the results obtained along these various lines threw light on each other, and that his work along each

one of them was greatly aided by the work along the other lines.

The breadth of scholarship exhibited by Poincaré in his early writings and his great ability to observe relations between apparently widely different subjects became still more pronounced as he grew older, but we observe even at this early date a mind of very broad sympathies and of extraordinary ability to generalize. His principal writings may be classed under the following four headings: pure mathematics, analytic and celestial mechanics, mathematical physics, and the philosophy of science.

In 1909 Emile Borel published, in the journal called *La Revue du Mois,* an article on the method of Poincaré. Parts of this were translated for the first article in the *Bulletin of the Calcutta Mathematical Society.* In view of the great importance of the method of work, we quote parts of this translation.

> The method of Poincaré is essentially active and constructive. He approaches a question, acquaints himself with its present condition without being much concerned about its history, finds out immediately the new analytical formulas by which the question can be advanced, deduces hastily the essential results, and then passes to another question. After having finished the writing of a memoir, he is sure to pause for a while, and to think out how the exposition could be improved; but he would not, for a single instance, indulge in the idea of devoting several days to didactic work. Those days could be better utilized in exploring new regions.
>
> All this is not specially applicable to mathematics. Let us examine more closely the mechanism made use of for discovery. The essential feature of that mechanism is, as we have already pointed out, the construction of new formulas. It is not useless that some stress is laid on this point, for this constructive power is the essential trait of the genius of Poincaré. The non-mathematical readers can be made to understand all this by means of a comparison. They know what arithmetical calculation is, and are often led to believe that mathematicians are in the habit of making interminable additions, multiplications, etc., and also extractions of cube roots.
>
> In reality, arithmetical operations are unique combinations of integral numbers formed of units which are all equal to one another. These operations can be compared to the construction of regular walls by means of bricks of uniform sizes. The work requires only some patience and a little care. On the contrary, analytical operations make use of extremely numerous materials and their variety is comparable to those of structures, where stone, marble, wood, iron, etc., are used. These operations are as different from each other as cuirassé is from a Gothic church. They have also with the architectural constructions this in common, that an impression of beauty is produced by the simplicity and elegance of the essential lines, without exhibiting any of the effort by means of which the result has been obtained.

Poincaré was a great pioneer, boldly entering into unexplored regions and noting some of the most important objective points and then leaving to others the details of organization. In the words of Borel he was more of a conqueror than a colonizer, and he attached little importance to conceptions which can not be realized in a concrete form. In this respect he may be compared with men of action; his method of work was too active to leave much room for such reflections as do not lead to concrete results.

On January 28, 1909, Poincaré was received as member of l'Académie Française, and on this occasion M. Masson, Directeur de l'Académie, delivered an address in which he entered into many details in Poincaré's career. A translation of a part of this address appeared in the *Popular Science Monthly,* September, 1909, page 267. A sketch of Poincaré's career may also be found in the *Independent,* October 5, 1911, under the general title of "Twelve Major Prophets of To-day." An elementary article by Poincaré on the foundations of geometry appeared in the *Monist,* October, 1898, and a number of his other articles have been translated into English from foreign journals.

In 1909 Ernest Lebon published, in his series entitled "Savants du Jour," a little volume on Henri Poincaré. This volume contains a list of his 436 different publications. The largest number of articles classed under one heading is 98, under the general

heading of Pure Analysis. The number of his other articles in pure mathematics at this time was 46, 23 being classed under each of the two headings, analysis applied to arithmetic and analysis applied to geometry. From this it appears that only about one third of Poincaré's writings were devoted to pure mathematics.

Poincaré won great fame in connection with his prize memoir relating to the problem of three bodies. In 1885 King Oscar II. of Sweden offered a prize for the solution of a question in reference to this general problem, and one half of this prize was awarded to Poincaré for his article entitled, "Sur le problème des trois corps et les équations de la dynamique," published in the *Acta Mathematica* in 1890. In the *Bibliotheca Mathematica* for 1904, page 198, Enestrom calls attention to the interesting fact that the copy of this memoir for which the prize had been actually awarded contained a serious error, and that the given published article was really prepared for the press after the prize had been awarded.

Among the other prizes received by Poincaré we mention the gold medal of the Royal Astronomical Society of London, the Sylvester medal of the Royal Society of London, the Bolyai prize of the Hungarian Academy of Sciences, and the Lobatchefsky gold medal of the Kasan Mathematical Physics Society. In addition to these foreign prizes Poincaré received two prizes from the Paris Academy and a gold medal from the French Association for the Advancement of Science. He received an honorary doctor's degree from each of the following universities: Cambridge, Christiania, Oxford, Glasgow, Brussels and Stockholm.

To those who would like to establish a connection between the university athlete and intellectual greatness, between physical powers and the intellectual giant, Poincaré was a decided disappointment. He was only about 5 feet 5 inches in height, was somewhat stooped, at least in the latter part of his life, and his weight was about 154 pounds. Even as a child he was rather weak and did not generally engage in the rougher sports of the boys of his age. He cared little for politics and achieved his greatness solely through his scholarly services. When he entered the French Academy he was told that he was born a mathematician and would die a mathematician. He had, however, the good fortune to live in a country where mathematical attainments are held in high esteem even by the general public.

As evidence of the high popular regard for Poincaré we may mention the fact that the French Ambassador occupied the chair last May when Poincaré gave the first lecture of a series of four at the University of London. The account of Poincaré's funeral which appeared in SCIENCE, August 9, 1912, furnishes further evidence along this line. On this occasion M. Jules Clarétie spoke as follows, according to *Nature* of July 25:

> In the name of the French Academy, I have the honor of saluting Henri Poincaré on behalf of a company of which he was justly one of the most illustrious members. When his colleagues called him, not yet thirty-two years of age, to take his place amongst us, it was a poet that this mathematician, this geometer, this philosopher, this poet of the universe, succeeded. And, from the first day, we were conquered by the simple and limpid eloquence of this master writer, who, knowing everything, verifying everything, illuminated with his definitions, animated with his observations and guided with his counsels our researches, the study of our language.
>
> It is not to-day, nor is it here, that one must study the work of this great man, who, scarcely full-grown, had already at one bound mounted to the summits. One might say, in many and eloquent tones, how much the country owes to this son of the borders of Lorraine, to this child of Nancy, who has shed luster upon the whole of France. Before his grave the French Academy can only express its sorrow, and deplore the loss of a great seeker after truth, that stopped all too soon in the midst of his work. He would be a bold man who would assess the worth of a scholar. In celebrating his fame, we can only do homage to a philosopher whose thoughts will have so fertile, so profound an action on the new generations.
>
> Passion for scientific truth did not suffice for him, he loved literary beauty, and this incom-

parable mathematician was a strong supporter of good writing, of those humanities which for so long have guided the French genius along a right and safe road. One might hear him, when the dictionary was under discussion, ask about the origin, and, as it were, the titles of nobility of words. This modern, who stimulated contemporary life by his discoveries and his calculations, defended with boldness the heritage of our ancestors. He knew that the French language is itself a country, and, against every perilous invasion, this soldier of sound speech stood firmly at the frontier.

While it would be futile to try to give an account of the mathematical work of Poincaré in such a hasty sketch, yet it seems hardly appropriate to omit entirely the things which were dearest to him. One of the earliest problems which he attacked was the study of linear differential equations with rational or algebraic coefficients. This study led him to the discovery of new functions which may be regarded as generalizations of elliptic and of modular functions. These functions were characterized by the property that they are invariant under certain linear transformations. He was thus led to the study of various groups of transformations, and in his "Notice," to which we referred above, he remarks that there is a theory which has been equally useful to him in all his researches, namely, that of the groups formed by linear substitutions. In fact, these substitutions play a preponderant rôle in the study of linear equations and in that of arithmetic forms. It is to this circumstance that one ought to attribute the interrelations, often unexpected, between the theory of numbers and the theory of Fuchsian functions, theories which, moreover, do not at first appear to have any point of contact.

He pointed out relations between the theory of complex numbers and the theory of continuous groups, and thus he threw new light on these far-reaching subjects. The theory of the solution of systems of an infinite number of linear equations with an infinite number of unknowns is largely due to Poincaré. He was the first to establish definite criteria of convergence in reference to the infinite determinants employed by the American astronomer, G. W. Hill, with so much success. It should, however, be observed that infinite determinants had been studied earlier by E. Fürstenau and T. Kötteritzsch, and that these determinants should not be accredited to G. W. Hill, as is sometimes done.

Poincaré wrote a number of books especially on mathematical physics, but the three books which are perhaps the most commonly known deal with philosophical questions and bear the following titles, respectively: "La Science et l'Hypothèse," "La Valeur de la Science," and "Science et Method." In regard to the first of these, the Director of the French Academy said at the time when Poincaré entered this academy: "By the sale of 16,000 copies of 'La Science et l'Hypothèse' you have increased your personality (personnel) ten-fold."

He was fond of traveling and many Americans recall his visit to the St. Louis Exposition, in 1904, where he delivered an address entitled, "The Present and the Future of Mathematical Physics." This address was translated for the *Bulletin of the American Mathematical Society* by J. W. Young, and published in the February, 1906, number of this journal. Poincaré visited all the countries of Europe and also some of the countries of Africa. He was married and had four children—three daughters and a son.

The great mainspring of Poincaré's activity was seeking the truth. This made his life both simple and beautiful. Seeking the truth implies an open acknowledgment of ignorance. In fact, one of the strongest mathematical methods consists of putting an x for the unknown; but how could we put an x for the unknown unless we were willing to admit that we are ignorant in regard to this fact. Every one who has worked in elementary algebra knows that much is frequently gained by admitting our ignorance and by calling some particular ignorance x and another particular ignorance y, etc. Even in his mature years Poincaré could honestly ask the question "La terre tourne-t-elle?" Things that are commonly accepted as true but have not been fully established, frequently offer the most

important fields of research, and the great investigator does not always accept the views of the masses as evidence of truth.

At the funeral of Poincaré the French Minister of Public Instruction remarked that all his work, all his life, was animated by a prepossession, which he expressed in this thought: "The search for truth must be the goal of our activity; it is the only end that would be worthy of it."

An open confession of some of the hidden ignorance of the mathematical scholars has furnished the starting point of many of the most important advances in recent years. In this way Weierstrass started some of the fundamental work relating to continuous functions, and in this way Poincaré clarified a number of questions relating to foundations, especially to the foundation of geometry. The mathematical refinements resulting from such new viewpoints have already taken root in the minds of leaders in other sciences. For instance, Boltzmann said: "The fact that the actual behavior of gases is represented by a curve which can not be differentiated and hence can not be represented graphically leads to great difficulties."[1]

In closing this brief appreciation we may perhaps fittingly quote the words of Sir G. H. Darwin, President of the Fifth International Congress, which met recently at Cambridge, England. At the opening meeting of this congress, held August 22, 1912, Sir Darwin said: "Up to a few weeks ago there was one man who alone of all mathematicians might have occupied the place which I hold, without misgivings as to his fitness. I mean Henri Poincaré."

G. A. MILLER

UNIVERSITY OF ILLINOIS

[1] Klein und Hoefler, "Grenzfragen der Mathematik," 1906, p. 8.

SCIENTIFIC NOTES AND NEWS

THE New York State Education building will be dedicated with elaborate exercises on October 15, 16 and 17. The dedicatory address will be made by Dr. Andrew S. Draper, Bureau of Education, and in the course of the exercises a number of addresses will be made, including one on museums by Dr. Henry Fairfield Osborn, president of the American Museum of Natural History, and one on Educational Extension by Dr. C. R. Van Hise, president of the University of Wisconsin.

PROFESSOR STIMPSON J. BROWN, head of the department of mathematics and mechanics at the Naval Academy at Annapolis, and Professor H. M. Paul, the second ranking officer of the department, have been relieved from duty at the academy and Professor Harry E. Smith has been named as head of the department.

PROFESSOR THEODORE FUCHS, director of the geological department of the Royal Natural History Museum at Vienna, has celebrated his seventieth birthday.

R. O. E. DAVIS, Ph.D., lately physicist in the Bureau of Soils, U. S. Department of Agriculture, has been appointed head of the Division of Soils Water Investigation, in the same bureau, to fill the vacancy in that office occasioned by the death of Dr. W J McGee.

DR. F. D. HEALD, professor of botany in the University of Texas, has resigned to become pathologist to the Pennsylvania Chestnut Tree Blight Commission, Philadelphia, Pa.

DR. S. R. KLEIN, formerly professor of histology and embryology at the Fordham University School of Medicine, New York, has been placed in charge of the new research laboratories of the Hahnemann Medical College, Chicago.

MR. OWEN M. JONES, who has been carrying on investigations during the last year for the Michigan-Lake Superior Power Co. at Sault Ste. Marie, Michigan, has resigned his position at the Tulane University of Louisiana, where he was in charge of the department of civil engineering, to accept a permanent position with the Power Co.

PROFESSOR HUGO DE VRIES, on his present trip to Alabama to visit the original locality for *Œnothera grandiflora* (see SCIENCE for