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SAMUEL LEWIS PENFIELD.

In the recent death of Samuel Lewis Penfield, the mineralogist, science in America has lost one of its best representatives, his chosen field of work its ablest exponent and investigator and the community in which he lived a man of the highest type of character. His loss is a heavy blow to his profession, to his University and to his friends. Men of his attainments come but rarely, and when they pass, the place they have made can never be exactly filled.

Attacked some three years since by a very serious malady which occasioned great anxiety, his unwearying and patient fidelity to the regimen prescribed for him and the devotion and care of his family enabled him to resist the disease, and it was hoped that his life might be prolonged for years to come. His trouble took, however, a sudden and unfavorable turn, and after a very brief illness he passed peacefully away on Aug. 12th, at the little village of South Woodstock, among the hills of eastern Connecticut, where he was spending the summer.

Penfield was born Jan. 16th, 1856, in the town of Catskill on the Hudson River, where his father, George H. Penfield, who was engaged for many years in a mercantile and shipping business, was a prominent, useful and highly esteemed citizen. His mother, whose maiden name was Ann A. Cheeseman, was of Connecticut stock; she was a notable woman in her community and family, and from both his parents Penfield had a

fine inheritance and thorough training in high principles and ideals. He was one of several children; his father's roof sheltered other members of the family, all united by strong ties of affection, and he thus grew up in an atmosphere which made him feel keenly all his life the ties of kindred and gave him a humanitarianism which strongly marked him.

His early education was received in his home and in the school at Catskill. Ideals of learning and culture were traditional in his family; some of his ancestors had been college-bred men, and it was early determined he should have a college education. To fit himself to enter Yale he attended the academy at Wilbraham, Mass., and in the autumn of 1874 he became a member of the freshman class of the Sheffield Scientific School. Like many other graduates of that institution, who have become well-known in natural science, he took the course laid out in chemistry. Languages he learned with difficulty though he retained them well, but in mathematics and natural science, and especially analytical chemistry, he excelled. He was graduated with honors in 1877, receiving the customary degree of Bachelor of Philosophy. While devoted to his studies, the social side of university life had not been neglected and he was loved and respected in his class, and made many enduring friendships.

After his graduation he became one of the assistants in the laboratory of analytical chemistry, a position held for two years and which, outside of the benefits of the training which its duties conferred, gave him excellent opportunities for continuing his chemical education. At this time Professors Brush and Edward Dana were engaged in their researches on the remarkable mineral locality at Branchville, Conn., which has become classic in the history of mineralogical science for the great number of new mineral species, chiefly phosphates, which it afforded.

The task of ascertaining the chemical composition of these minerals was confided to Penfield and his classmate and fellow assistant, now Professor H. L. Wells. The importance of the work, its great scientific interest, the new problems in analytical chemistry involved, all combined to excite the enthusiasm of the young investigators and to stimulate their powers

to the highest degree, while giving them a training of the greatest value. Penfield, who took to analytical chemistry with the keenest eagerness, no doubt in great part had his future career determined by his work during these two years and the one following, when he was transferred from the chemical to the mineralogical laboratory as assistant.

During this period he analyzed the new minerals eosphorite, triploidite, dickinsonite, fairfieldite and fillowite, and made analyses also of triphylite, childrenite, amblygonite, cymatolite, spodumene, etc. Up to this time his work, though dealing largely with minerals, had been entirely of a chemical nature and it is certain that he expected to make chemistry the subject of his life work, for in the years 1880–1881 he went to Germany to obtain advanced instruction in the organic side of this science. He spent two semesters in the laboratory of Prof. Rudolph Fittig at Strassburg and a part of the work resulted in the publication with him of a joint paper on organic compounds prepared and studied. He heard some lectures under Prof. P. Groth, at that time located at Strassburg, but there can be no doubt that, had he known the work he was to do in the future, his studies would have been almost wholly under the direction of this eminent teacher and crystallographer. He never regretted, however, the time he had thus spent, for it added greatly to his general knowledge of chemistry and to his training in the solution of chemical problems.

It was at the close of this stay in Germany that the opportunity opened which finally determined Penfield's career in science. The constant growth of the Sheffield Scientific School had laid such an increasing burden of executive duties upon its director, Professor Brush, that he was no longer able to give more instruction in mineralogy in the institution than was involved in the course of lectures on the descriptive side of the subject and suggestions and advice in advanced work. The practical work in the subject in the laboratory, the determinative mineralogy, was given by his assistant, who, at that time, was the late Dr. G. W. Hawes. The authorities of the National Museum offered the latter an opportunity to develop a department of Geology, which he accepted, and Penfield was called to fill his place. He entered on his duties with

the beginning of the fall term in 1881, having the title of Instructor in Mineralogy, and from that time until his death he was actively engaged in teaching and in extended researches in this subject. Feeling the need of more advanced training in certain ways, especially in methods of optical and microscopical research, in 1884 he again went to Germany and spent the summer semester at Heidelberg under Professor Rosenbusch and with great benefit to his future work. In 1886 he assumed entire charge of the instruction in mineralogy, he was appointed an assistant professor in 1888 and in 1893 was promoted to a full professorship and became a member of the Governing Board of the Sheffield Scientific School.

That which Penfield accomplished during his life divides naturally into two parts, the results of his investigations and his work as a teacher of mineralogy. In regard to the first the bibliography appended to this notice speaks far more eloquently to those acquainted with the history of mineralogical science during the last quarter of a century than could the efforts of any pen. Yet out of this great volume of important results of work which issued from his laboratory during the twenty-five active years of his life—results which have been equalled in scope and value by but few men during a much longer working period—certain salient facts may well be mentioned to indicate his achievements. He published over 80 papers relating to Mineralogy and Crystallography, either under his own name or in collaboration with others, besides the large number which came from the assistants and students in his laboratory and which were directly due to his inspiration and oversight. Moreover this does not include a great number of notes, representing crystallographic and chemical work, scattered through the literature as published in the papers of other workers, for Penfield was ever most generous of his time and skill in helping others and he had long come to be regarded in America as an ever present aid and final source of appeal in problems relating to mineralogy by workers in the geological sciences.

The mere statement of the volume of his work would, however, mean little unless it were taken in connection with its

quality. Both in the importance of the problems treated and in the ability and technical skill with which they are handled his work is of the very highest scientific character, and the greater part of it, together with his methods and ideas, has already become classic in the history of his science. In regard to this the following facts are of interest and may be mentioned. Fourteen new mineral species were established and described by him,—sometimes in combination with others. These are: *Bixbyite*, *Canfieldite*, *Clinohedrite*, *Gerhardtite*, *Glaucochroite*, *Graftonite*, *Hamlinite*, *Hancockite*, *Leucophoenicite*, *Nasonite*, *Nesquehonite*, *Pearceite*, *Roeblingite*, *Spangolite*.

What in reality was of even greater importance was the large number of already described minerals, many of them well known and prominent species, which he studied and whose true chemical composition and mineralogical affinities he established. These include *Alurgite*, *Amblygonite*, *Argyrodite*, *Aurichalcite*, *Childrenite*, *Chondrodite*, *Clinohumite*, *Connellite*, *Cookeite*, *Ganomalite*, *Hanksite*, *Herderite*, *Howlite*, *Humite*, *Monazite*, *Ralstonite*, *Staurolite*, *Sulphohalite*, *Topaz*, *Tourmaline* and *Turquois*.

Among the more important facts which he brought out as the result of his chemical work was the discovery of germanium in silver ores from Bolivia and the determination of the correct formula and crystallization of argyrodite, the Freiberg mineral in which germanium was originally discovered. Another contribution of the highest value was his recognition that fluorine and hydroxyl are isomorphous in chemical structures, and that they play a significant function in the composition of many minerals whose correct formulas may be derived by the application of this principle. He showed also that the variations in the physical properties of certain prominent minerals were dependent upon the variations in the relative amounts of these radicals. This was shown very strikingly to be the case with topaz, and applying these ideas to the chondrodite group of minerals, whose relations until then had proved an unsolved problem, he derived their correct compositions and showed that they formed a definite series with related physical properties. He was, moreover, able to indi-

cate the probable existence of another member of the series and to predict its composition and properties, a forecast whose correctness has since been established by Sjögren in the discovery of prolectite.

The idea of the isomorphism between hydroxyl and fluorine was suggested in the first Branchville paper by Brush and Dana from Penfield's analysis of triploidite. At first it was not accepted by prominent chemists and mineralogists, but Penfield by steady work in his laboratory again and again demonstrated its validity and importance, until now it has gained general acceptance and it has become recognized that the existence of these isomorphous radicals not only explains the structure of many minerals, but that their presence is of the greatest importance in understanding the mode of formation, especially in magmatic processes.

Another contribution of the first order, in the field of chemical crystallography, was his announcement of the mass action of complicated inorganic acids in determining crystal form. Thus while the bases in combination with such acids may be of the most diverse kinds, the system of crystallization is not affected. This was brought out in his important paper with Foote on the chemical composition of tourmaline, but has since been shown to be of wide application.

As an analytical chemist Penfield must be ranked as one of the great masters of this art. He had a broad and comprehensive grasp of its principles, was very fertile in their application, suggestive in combinations and in details and joined to this a technical skill and dexterity in manipulation that was really marvelous. In consequence of this the ease and speed with which he turned out complicated analyses of remarkable accuracy have always been a source of admiration among his friends and fellow-workers. His analysis of the rare mineral connellite and derivation of its formula was performed upon less than a tenth of a gram of material. Many similar feats of his skill might be cited. He rarely took up any new analytical method that he did not suggest excellent improvements in it, and he devised new methods, many of which are now in general use; his mineralogical papers in fact are full of contributions to analytical chemistry and he published several useful papers directly upon analytical methods.

Penfield's work as a crystallographer is scarcely of less importance than that which he performed on the chemical side of mineralogy. He handled mathematical relations with ease and clearness and his work was both rapid and accurate. His perception of crystal forms and symmetry seemed almost intuitive and in practical operations he was greatly aided by the same manual dexterity that he showed in chemical manipulation; thus he made measurements on the goniometer of crystals of such a degree of minuteness, as in the case of sperrylite, that it seemed almost impossible that they could be handled.

Besides establishing the crystallization of the new minerals already mentioned, Penfield determined that of the following species: *Amarantite*, *Argyrodite*, *Bertrandite*, *Herderite*, *Lansfordite*, *Metacinnabarite*, *Penfieldite*, *Polybasite*, *Sperrylite*, *Tiemannite*, *Willemite*.

In addition to his contributions to the crystallography of minerals we also owe to Penfield the determination of the other physical properties of many species, especially the optical; a work which he first took up in Rosenbush's laboratory and afterwards accurately and skillfully carried out whenever possible upon all of the species which he investigated.

His labors as a crystallographer were not, however, confined to minerals. For a number of years he spent much time in the determination of the crystallization and optical properties of compounds prepared in the chemical laboratory of the Sheffield Scientific School. As may be seen by reference to the appended bibliography, this work was done either directly by himself or under his care and supervision by the assistants and advanced students in the laboratory whom he had trained. Among these compounds studied there may be mentioned as of special importance the large series of new double salts, particularly the double halides, prepared by his colleague Professor Wells or under his direction. During the later years of his life Penfield gave much time and thought to the perfecting of practical methods for the solution of problems in crystallography. He was led to a study of the stereographic projection as a means of expression and in 1901 published an important paper on this subject, showing how it could be used for solving problems, not only in crystallog-

raphy, but also in astronomy, geodesy, navigation, etc. He prepared also an ingenious set of instruments for use in connection with this method of projection by means of which laborious calculations could be avoided and the problems quickly and accurately solved by graphic methods. He extended these practical methods and applied them to the drawing of crystals, devising special plates of axes to be used in connection with his instruments by which the solving of the form of a crystal and the drawing of its figure could be easily and rapidly carried out. These methods have since come into very general use.

In reviewing Penfield's work in mineralogical science one is struck, not more by its quantity than by its quality and varied aspects. He was a thoroughly trained man and had a firm grasp on every phase of his subject. He had a wide and accurate knowledge of minerals and the correctness with which he often identified them at sight seemed almost like intuition. While he clearly apprehended principles and, as has been shown, produced generalizations of wide importance, the great majority of his contributions to science are not of a theoretical nature but consist of direct and positive additions to knowledge. He had a highly analytical mind, and this combined with his inventive faculty and the great manual skill with which he was gifted made him a born investigator, one of the greatest who has yet appeared in his field of science. It is safe to say that with his gifts he would have had a successful career in whichever of the physical sciences he might have entered. The thoroughness of Penfield's work, its high quality and the completeness with which he covered every side of his subject, is well illustrated in his last paper on stibiotantalite, published in the current July number of this Journal, in conjunction with his junior associate and former pupil Professor Ford.

His services to science have been worthily recognized at home and abroad : in 1893 he was made an associate Fellow of the American Academy of Arts and Sciences in Boston : in 1896 he became a Foreign Correspondent of the Geological Society of London and his university conferred on him the degree of Master of Arts : in 1900 he was elected a member of the National Academy of Sciences : in 1902 he was chosen as a Fellow of the American Association for the Advancement of Sci-

ence, a Corresponding Member of the Royal Society of Sciences at Göttingen, Germany, and member of the Scientific Society of Christiania, Norway: in 1903 he was elected Corresponding Member of the Geological Society of Stockholm and Foreign Member of the Mineralogical Society of Great Britain: in 1904 the University of Wisconsin conferred upon him the degree of Doctor of Laws. He was also a member of the Connecticut Academy of Arts and Sciences and a Fellow of the Geological Society of America.

As a teacher Penfield was a striking example of what may be accomplished by an intelligent and painstaking devotion of one's effort toward a given end. He was not naturally gifted as a teacher—as a lecturer and speaker—as some men are. Of an extremely modest, quiet and retiring disposition and somewhat reserved except among his intimate friends, he always found it difficult, and naturally disliked, to express himself in public. Thus at the outset the management and instruction of students in numbers was for him not an easy matter. But he so entirely overcame this and perfected to so great a degree his methods of teaching, that the many students who came under his instruction regarded him as one of the best teachers in the University. In laboratory work, where the contact with the student is personal, he always had great success from the beginning of his career, because, in his kindliness of disposition, great patience and persistency, and in his interest in the student and his work, he had natural aptitudes which specially fitted him for this kind of instruction, and he took morever distinct pleasure in it. He always insisted upon great thoroughness and completeness in allotted work, and the mental discipline and training in method which students received under him were not less valuable than the knowledge of mineralogy which they acquired.

With those who came under him for advanced instruction he was particularly fortunate. The untiring care and oversight which he gave to their work and the thoroughness and accuracy upon which he insisted gave almost invariably successful results, and thus, especially in research, he communicated his own energy and enthusiasm to his pupils and stimulated their interest. This is clearly shown in the large number of important pieces

of work executed by him in conjunction with his students or by them under his direction. The writer, who was greatly aided by Penfield's instruction at the beginning of his own scientific work in mineralogy, can abundantly testify to his generous helpfulness and sympathetic interest in others and their work.

Penfield gave unlimited pains and thought to perfecting his material equipment for teaching and to this much of his success was due. In his laboratory he had many carefully chosen collections of models, of crystals and of minerals, each designed for particular purposes, and the arrangement of these and of the apparatus was carried out with a system and a completeness for uses of instruction that always excited the admiration of those qualified to judge of their character. In the same way with great skill and ingenuity he constructed models and apparatus for use in teaching crystallography and the optical properties of minerals to his classes and advanced students. Nor should there be forgotten in this connection the care and labor he expended in preparing the new edition of Brush's Manual of Determinative Mineralogy, the additions to which, dictated by his experience in teaching, are of the greatest value to students.

It was in fact a question which Penfield ever had upon his mind—how he could improve his methods and equipment for instruction, and as a result they attained to so high a degree of completeness and practice that many teachers of mineralogy who were not his pupils found a visit to his laboratories a source of help and inspiration.

It is a matter of satisfaction to his friends that, after the first attack of illness, his life was spared long enough for him to realize his cherished ambition in the completing of the new laboratories he had planned in Kirtland Hall and in the arrangement and perfecting of their equipment. In his new quarters he passed, in spite of illness, two very happy years of busy work, with his students and in investigations.

Penfield's activities were not confined to his laboratory. In the middle eighties he spent two summers as assistant in geological work to Professor Iddings in the survey of the Yellowstone Park, and later a number of summers were spent by him in northern New York, in North Carolina and Colo-

rado, collecting minerals and studying their modes of occurrence and field relations. The inspiration to a number of important pieces of work was given by these experiences. He also spent two summers in Europe, in 1894 and again in 1897, visiting other workers in his science and seeing collections and well known mineral localities. In these travels he was everywhere cordially received and made a large number of friends.

For many years Penfield, with several of his colleagues, one of whom was the late Prof. C. E. Beecher, lived in apartments in the top of one of the buildings of the Sheffield School. In this little coterie of young scientists were knitted enduring bonds of intimacy and friendship which had the most happy effect upon his life and work and in it he both gave and received.

As previously remarked, Penfield was distinguished by a broad humanitarianism, by a warm heart and ready sympathy which responded quickly to every call. He was always interested in charitable work and for many years was a weekly visitor to the children's ward in the City Hospital, where he cheered and helped the little patients.

In January 1897 he married Miss Grace Chapman of Albany, N. Y., who survives him. His great happiness in his married life and in the home circle he drew around him and in its generous hospitality was evident and a matter of sincere pleasure to all his friends.

The dominant notes of Penfield's character as a man were his benevolence, his simplicity, earnestness and downright honesty and sincerity in word and deed. These traits, together with a certain sweetness of disposition and a wonderful patience, never more strikingly shown than during his illness, greatly endeared him to his friends. To know him well was to love him.

Great as is the loss, that a man of Penfield's type should be cut off in the midst of his active career, and sincere and deep as our sorrow must be thereat, there is a satisfaction, which helps somewhat to console, in the thought that all there is to such a man can never die. The work that he achieved still remains, and better yet, the influence and memory of the high

principles he inculcated, not only in science but in daily life, as a man and a citizen, still mould the thoughts and feelings of his friends and students. His science is better today, not only by what he did, but still more by the influence he exerted and the high ideal of character he left behind him. This is a precious heritage which can never be lost.

The portrait accompanying this notice has been reproduced from a photograph taken some four years ago.

L. V. Pirsson.

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