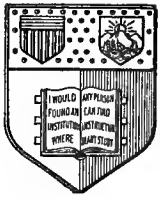

Sir JOHN BENNET LAWES, Bart., 1814—1900.

The manor-house of Rothamsted, situated in the parish of Harpenden, Herts, was the birthplace of John Bennet Lawes, and the Rothamsted farm became, in subsequent years, the scene of the great work of his long life. So far-reaching have been the results which he achieved, that the name of Rothamsted is now a household word wherever the science of Agriculture is studied.

The ancestors of Sir John Lawes had occupied Rothamsted for many generations. Jaques Wittewronge came to England from Flanders in 1564, owing to the religious persecution then prevailing. The manor of Rothamsted was purchased in 1623 for his grandson, John Wittewronge, who was then a minor. John Wittewronge was knighted by Charles I, and afterwards created a baronet by Charles II. In consequence of the failure of male heirs, the manor passed to the Bennet family by the marriage of Elizabeth Wittewronge with Thomas Bennet, and finally to the Lawes family by the marriage of Mary Bennet (great-granddaughter of James Wittewronge) with Thomas Lawes. His son, John Bennet Lawes, was the father of the John Bennet Lawes of whom we have to speak, who was born at Rothamsted on December 28, 1814.

John Bennet Lawes was an only son. He lost his father when eight years old, and owed much to his mother's bringing up. He seems to have led the life of a country boy, and his studies he afterwards described as being "of a most desultory character." Experiments in chemistry, made at home, seem to have been one of his favourite occupations. He was sent successively to Eton, and to Brasenose College, Oxford, which he entered in 1832. While at Oxford he attended some of the lectures of Dr. Daubeny, the professor of chemistry. He left the University without taking a degree.

In 1834 Mr. Lawes entered on the personal management of the home farm at Rothamsted, then of about 250 acres; he at the same time threw himself heartily into chemical investigations. He tells us: "At the age of twenty I gave an order to a London firm to fit up a complete laboratory, and I am afraid it sadly disturbed the peace of mind of my mother to see one of the best bedrooms in the house fitted up with stoves, retorts, and all the apparatus and reagents necessary for chemical research. At the time my attention was very much directed to the composition of drugs; I almost knew the Pharmacopœia by heart, and I was not satisfied until I had made the acquaintance of the author, Dr. A. T. Thomson. The active principle of a

number of substances was being discovered at this time, and, in order to make these substances, I sowed on my farm poppies, hemlock, henbane, colchicum, belladonna, &c. Some of these are still growing about the place. Dr. Thomson had suggested a process for making calomel and corrosive sublimate by burning quicksilver in chlorine gas. I undertook to carry out the process on a large scale, and wasted a good deal of time and money on a process which was, in fact, no improvement on the process then in use."* At this time Dr. Anthony Todd Thomson, Professor of Materia Medica at University College, London, was his chief instructor and adviser. An old barn at Rothamsted was transformed into a laboratory, and here the calomel was afterwards made; this laboratory remained in active use till 1855.

The researches of De Saussure, on the nutrition of plants, seem to have first called Mr. Lawes' attention to the relations between chemistry and agriculture. In 1837 he commenced experiments in pots with agricultural plants, the manures made use of supplying various elements of plant food. These experiments were continued on a larger scale in 1838 and 1839. Spent animal charcoal was then a waste product, and Mr. Lawes was asked by a London friend if it could be turned to any use. He therefore employed it as a manure in his pot experiments, and discovered that if previously treated with sulphuric acid its efficacy as a manure was greatly increased. Apatite and other mineral phosphates were soon treated in a similar manner, and the "superphosphate of lime," thus prepared, was found to be most effective as a manure, especially for turnips. The new superphosphate was employed on a large scale for crops on the Rothamsted farm in 1840 and 1841, and the results were so satisfactory that in 1842 Mr. Lawes took out a patent for the manufacture of superphosphate.

The application of sulphuric acid to bones had been practised before the date of Mr. Lawes' patent; the novelty of his patented invention consisted in the treatment of mineral phosphates in this manner. The supply of bone available for farmers is but small, but the supply of apatite, coprolite, and of the various rock phosphates discovered in recent years, is almost unlimited. These mineral phosphates are usually too insoluble to have any practical value as manure, but by treatment with a limited quantity of sulphuric acid, a mixture of monocalcic phosphate, phosphoric acid, and gypsum is produced. The phosphates in this compound are almost entirely soluble in water, and far more efficacious as manure than the phosphates of raw bone. The enormous influence which the introduction of superphosphate has had on the development of agriculture may be gathered from the quantity now annually employed by farmers. The annual manufacture of

* "Agricultural Gazette," January 2, 1888.

superphosphate in Great Britain amounts at present to about 1,000,000 tons, while the total manufacture in the world is about six times this amount. If Sir John Lawes had done nothing more than introduce the manufacture of artificial manures, he would still rank among the greatest benefactors to agriculture.

The life of Sir John Lawes divides at this point into two parts. He became from the date of his patent a chemical manufacturer, carrying on an extensive London business, and as prosperity increased he embarked in a variety of enterprises. While, however, obliged to spend two days of every week in London, his devotion to agricultural research continued to increase, and the profits yielded by commerce were employed for the creation and maintenance of a large experiment station at Rothamsted. The experiments in the fields had already, at the date of his patent, reached a stage at which the continuous services of a trained chemist were urgently needed. On the recommendation of Dr. A. T. Thomson, Mr. Lawes engaged a young chemist who had studied under Liebig—Dr. J. H. Gilbert. Dr. Gilbert entered upon his work at Rothamsted in June, 1843, and continued actively occupied in the scientific superintendence of the agricultural experiments during the whole of his long life. For fifty-seven years Lawes and Gilbert worked together on a great variety of agricultural problems; of these labours and their results we shall give a brief account after completing our sketch of the life of each worker.

Mr. Lawes married, in 1842, Caroline Fountaine, daughter of Andrew Fountaine, Esq., of Narford Hall, Norfolk. He enjoyed her society for more than fifty years, and her artistic power was not unfrequently employed in providing illustrations of the investigations in progress. As the commencement of manufacturing operations made great demands on his capital, Mr. Lawes at this period let Rothamsted House, and for some years resided either in London or Devonshire.

His first factory for the manufacture of superphosphate was erected at Deptford Creek in 1843. The business rapidly extended, and in 1857 about 100 acres of land were purchased at Barking Creek, and a larger factory erected, including an extensive plant for the manufacture of sulphuric acid. In 1866 Mr. Lawes purchased the tartaric and citric acid factory at Millwall. The purchase was unwillingly made, but the new work was taken up with his accustomed energy and enterprise, many economies and improvements were introduced, and the factory became the most important of its kind in this country. In 1872 he sold the whole of his manure business for £300,000; he retained the tartaric and citric acid factory till his death. Mr. Lawes had also a large sugar estate in Queensland: the low price of sugar and the lack of cheap labour prevented, in this instance, a commercial success.

The investigations at Rothamsted made rapid progress. In 1843

were commenced the systematic field experiments on turnips and wheat; the wheat field has grown wheat without intermission ever since. In 1847 the field experiments on beans commenced, and in 1848 those on clover, and on a four-course rotation. In 1851 the rotations of wheat and fallow, and wheat and beans were started. In 1852 the field experiments on barley commenced. In 1856 those on grass land. In all about 40 acres were brought under experiment. Of all these crops complete chemical statistics were obtained. Experiments on sheep-feeding with various foods commenced in 1848. The whole bodies of ten animals—oxen, sheep, and pigs—of various ages and conditions as to fatness, were analysed between 1848 and 1850. In 1850 an extensive series of pig-feeding experiments was made.

The extent of the work undertaken, its thoroughness, and the practical value of the results obtained, gained the admiration of both scientific and practical men. At a meeting of Hertfordshire farmers at St. Albans, on December 24, 1853, it was resolved to present Mr. Lawes with a testimonial. The circular issued states: "It was considered that Mr. Lawes has for many years been engaged in a series of scientific and disinterested investigations for the improvement of agriculture generally, which have been carried out to an extent, with an attention to accuracy and detail, and at a cost, never before undertaken by any individual, or even by any public institution." The proposal was soon enlarged, and became national in its character. The subscriptions received amounted to about £1,160. At Mr. Lawes' desire, the greater part of this sum was spent in the erection of a new laboratory, which was opened at a gathering of distinguished agriculturists on July 19, 1855, the Earl of Chichester presiding on the occasion. The speeches made by Mr. Lawes, Dr. Gilbert, and others, have fortunately been preserved.* Mr. Lawes, on this occasion, paid a warm tribute to the work done by Dr. Gilbert. Besides the gift of the laboratory, Mr. Lawes received a handsome silver candelabrum, bearing a suitable inscription. In later years the laboratory was found too small for the preparation and storage of the numerous samples, and additional buildings were erected.

Mr. Lawes was elected a Fellow of the Royal Society in 1854, and in 1867 one of the Royal medals was awarded to him and Dr. Gilbert for their systematic researches upon agricultural chemistry. Seven papers by Lawes and Gilbert have been published in the Society's Philosophical Transactions.

The connection of Mr. Lawes with the Royal Agricultural Society was naturally a close one. He became a member of the

* *Herts Guardian*, July 28, 1855. Also *Gardeners' Chronicle and Agricultural Gazette*, July 15, 1871, p. 918.

Council in 1848, and was afterwards a vice-president and trustee. In 1893 the presidency of the Society was offered to him, but declined on account of his advancing years. In the Journal of the Society the greater number of the reports on the Rothamsted agricultural investigations have been published; forty-six reports had thus appeared before the year 1900. In 1876 he took an active part in arranging for the commencement of the field experiments conducted by the Society at Woburn, in Bedfordshire. These experiments consisted in repetitions of the experiments at Rothamsted upon the continuous growth of wheat and barley with known manures, the experiments, in this case, being made upon a purely sandy soil; they also included rotation experiments designed to test the manurial value of cattle foods. These experiments were conducted on the Duke of Bedford's estate, and at his expense.

The relations of Mr. Lawes with the Chemical Society were also intimate. He became a Fellow in 1850, and was elected to the Council in 1862. The chief part of the chemical work done in the Rothamsted laboratory was communicated to this Society, and about twenty-two lectures and papers by Lawes and Gilbert, and other Rothamsted workers, appear in the Journal and Transactions.

Mr. Lawes was a member of the Royal Commission appointed in 1857 "To inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable uses." Two members of this Commission, Lawes and Way, conducted for several years important experiments on sewage irrigation at Rugby. The investigation dealt with the quantity and composition of the grass receiving varying amounts of sewage, and its value as food for fattening oxen and milking cows, including the composition of the milk obtained. The effluent waters from the irrigated fields were also analysed, and the formation of nitrates in large quantities was demonstrated. The final report was published in 1865.

The aid of Rothamsted was again sought by the Government in 1863, the object in this case being to ascertain whether the malting of barley resulted in any increase of its value as a food. A considerable bulk of barley was divided into two lots, one of which was malted, and the loss in dry matter ascertained; feeding experiments were then made, in which the nutritive effect of a given weight of barley was compared with that shown by the quantity of malt which could have been produced from it. The trials with oxen, sheep, and pigs, were made at Rothamsted, and those with milking cows at Rugby. The full report was presented to Parliament in 1866.

While the formal reports on the Rothamsted investigations were to a large extent the work of Dr. Gilbert, Mr. Lawes was himself an active writer on agricultural subjects. In middle life he was a frequent con-

tributor of short papers to agricultural newspapers and periodicals, both English and American; he also lectured from time to time to agricultural associations. His writings were always marked by great originality, they were also very practical in character. When bringing forward the results of recent scientific inquiries, he would avoid as far as possible the use of scientific language, and speak as a farmer to farmers. The fertility of the land and its relation to landlord and tenant, and the manure value of foods, with the compensation due to an outgoing tenant for unexhausted manures, were subjects which he made peculiarly his own. For many years he sent annually to the *Times* newspaper, in the early autumn, an estimate of the quantity of wheat yielded by the preceding harvest in this country. This estimate was based on the produce of the standard plots in the experimental wheat field at Rothamsted; as the produce here was over or under the average, so it was assumed would be the general produce of the country. The estimates thus made proved generally to be near the truth.

For his great services to agriculture Mr. Lawes was created a baronet by the Queen in 1882. The degree of LL.D. was conferred on him by the University of Edinburgh in 1877; D.C.L. by Oxford in 1893; and Sc.D. by Cambridge in 1894. He received the Legion of Honour from Napoleon III.; he was also a Chevalier du Mérite Agricole. He was elected a corresponding member of the Institute of France in 1879. In 1863, he received a Gold Medal from the Russian Government. In 1881, the German Emperor awarded a Gold Medal for Agricultural Merit to Lawes and Gilbert.

Sir John Lawes early conceived the idea of perpetuating the Rothamsted investigations by placing the laboratory and fields in the hands of trustees with a permanent endowment for their maintenance. He first spoke of this in his speech at the opening of the new laboratory in 1855. In 1872 he publicly announced that he had set aside £100,000 for this purpose. By deeds executed by him in February, 1889, the laboratory and experimental fields were leased to Sir John Lubbock, William Wells, Esquire, and Sir John Evans, as trustees, for 99 years at a peppercorn rent. To the same trustees he covenanted to pay the sum of £100,000, the interest on which was to be applied to the maintenance of agricultural investigations under the direction of a Committee of nine persons, of whom four were to be nominated by the Royal Society, two by the Royal Agricultural Society, one by the Linnean Society, and one by the Chemical Society, the owner of Rothamsted being always a member of the Committee. The appointment of new trustees when required was vested in the Royal Society. The Managing Committee were at once appointed. They consisted of Sir John Evans, Dr. Hugo Müller, Sir Michael Foster, and Sir W. T. Thiselton Dyer, nominated by the Royal Society; Sir John H. Thorold,

and Charles Whitehead, Esq., nominated by the Royal Agricultural Society; William Carruthers, Esq., nominated by the Linnean Society; Prof. H. E. Armstrong, nominated by the Chemical Society; with Sir John Bennet Lawes. Under this Committee, with but few alterations in their constitution, the direction of the work at Rothamsted has since proceeded. One provision of the trust deed directs the Committee to send a lecturer from time to time to the United States of America to lecture upon the results of the Rothamsted investigations.

The Jubilee of the Rothamsted Experiments was celebrated on July 29, 1893. The organisation of this celebration originated with the Royal Agricultural Society. At a meeting on March 1, presided over by H.R.H. the Prince of Wales, it was resolved: "That some public recognition should be made of the invaluable services rendered to Agriculture by Sir John Lawes and Dr. Gilbert." A subscription list was opened, and with the contributions received a large boulder of Shap granite was erected in front of the laboratory, bearing the following inscription:—"To commemorate the completion of Fifty Years of continuous experiments (the first of their kind) in agriculture, conducted at Rothamsted by Sir John Bennet Lawes and Joseph Henry Gilbert. A.D. MDCCCXCIII." A large and distinguished gathering was held in front of the laboratory on the afternoon of July 29, the Rt. Hon. Herbert Gardner, M.P., President of the Board of Agriculture, presided. The Duke of Westminster, as President of the Royal Agricultural Society, presented to Sir John Lawes his portrait, painted by H. Herkomer, R.A., and to Dr. J. H. Gilbert, a silver salver. He also presented congratulatory addresses to both Lawes and Gilbert from the subscribers to the fund, each address being signed by H.R.H. the Prince of Wales. The presentation of a large number of addresses from English and Foreign Societies then followed, including one from the Royal Society. Sir John Lawes and Dr. Gilbert then replied.* A few of the words spoken by Sir John Lawes must be quoted. "That afternoon he had to return thanks to that distinguished and brilliant assembly for their kind congratulations to himself and Dr. Gilbert upon the work that they had been carrying on for the last 50 years. When two people were joined together in marriage they could not part, because they were bound together by very solemn ties. But with regard to himself and Dr. Gilbert the case was quite different, Dr. Gilbert could have left him, or he could have left Dr. Gilbert. Their connection, however, had lasted for more than 50 years. What was the cause? Nothing less than mutual love of the work they had been engaged in. He (Sir John) had delighted in the work from the

* The whole of the addresses and speeches will be found in the Report of the Jubilee Commemoration, published by the Royal Agricultural Society.

beginning. All the time he could spare in the midst of many other responsibilities and duties he had given to the work. But with Dr. Gilbert it had been the work of his life. If it had not been for Dr. Gilbert's collaboration their investigations would have been in a very different state to what they were then."

Shortly after the Jubilee celebration Dr. Gilbert received the honour of Knighthood. In September of the same year the Liebig Silver Medal was awarded to Sir John Lawes and Sir Henry Gilbert by the curators of the Liebig Foundation of the Royal Bavarian Academy of Sciences. In the following year, 1894, the Albert Gold Medal of the Society of Arts was presented to Lawes and Gilbert by H.R.H. the Prince of Wales, "for their joint services to scientific agriculture, and notably for the researches which, throughout a period of fifty years, have been carried on by them at the Experimental Farm, Rothamsted."

Something must now be said as to the personality of the remarkable man whose life's work we have attempted to describe. He possessed an extremely vigorous constitution, and when past 85, exhibited but few of the infirmities of old age. His holiday was always spent in Scotland, and deer stalking and salmon fishing were then his chief occupations. At home, all his leisure time was spent on the farm. He was a keen observer, and knew the experimental fields better than anyone else. His interest in agricultural problems never tired, he was continually finding fresh subjects for inquiry. While gifted with a full share of the scientific imagination, he was thoroughly practical in his conclusions. His long experience as a farmer, and the careful attention to economy learnt in business, were of great use to him when he brought the results of scientific investigation before the agricultural world. He took a broad, statesman-like view of all agricultural questions, and was looked up to by the English farmer as his safest guide and his highest authority.

Sir John Lawes seldom took part in public functions, he was not seen at meetings of scientific societies, and took no active part in politics; excepting the hours unavoidably spent on his London business, he lived as far as possible a country life. It was, however, in no sense a secluded life; his correspondence was very large, and the visitors to the Rothamsted experiments were extremely numerous and of all nationalities. They found at Rothamsted a genial host and a ready guide to the fields, where the lessons taught by the experimental crops were described in brief and pithy sentences by one who knew thoroughly the whole history of each plot.

Sir John Lawes by no means confined his attention to science, agriculture, and business; he was a man of active benevolence. The agricultural labourers of Harpenden found in him their best friend. He began to provide allotment gardens in 1852, and before his death the

number had reached 334. In 1857 he built a club room in the gardens. Various co-operative schemes were started for the labourers' benefit; one of these has been immortalised by Charles Dickens, who visited the club room in April, 1859, and afterwards gave an account of what he saw in the first number of "All the Year Round." The welfare of his workmen at his various factories was equally considered. He exercised a wide private benevolence, and in his own parish was never appealed to in vain for any good work.

Sir John Lawes' life was prolonged to an unusual period; he lived and worked and taught through two successive generations. His health remained very good till within about a week of his death. He died at Rothamsted on August 31, 1900, in his 86th year, and was buried at Harpenden. His only son, Sir Charles Bennet Lawes, who has assumed the additional name of Wittewronge, succeeds to the Rothamsted estate.*

R. W.

Sir JOSEPH HENRY GILBERT. 1817–1901.

Joseph Henry Gilbert was born at Hull on August 1, 1817. He was the second son of the Rev. Joseph Gilbert, a Congregational Minister, who had previously held the position of Professor of Classics at the Divinity College, Rotherham. His mother belonged to a well-known literary family, and under her maiden name of Ann Taylor, was a popular authoress of poems for children. The family removed in 1825 to Nottingham, and it was here that the boyhood of Joseph Henry Gilbert was spent. He was first sent to an elementary school taught by a blind lady of great intelligence, and afterwards to a school kept by Mr. Long at Mansfield. In 1832, while at Scarborough, he met with a serious gunshot accident, which permanently deprived him of the sight of one eye, and considerably damaged the other; his general health suffered much from the shock, and it was some years before he was able to resume his studies. During this interval he in 1838 paid a visit to St. Petersburg. In the autumn of 1838 he became a student at the University of Glasgow; here he devoted nearly a year to the study of analytical chemistry in the laboratory

* Some further facts relating to Sir John Lawes, and views of his career, will be found in *Nature*, September 13, 1900, p. 467; *Jour. Roy. Agri. Soc.*, 1900, p. 511; *Trans. Chem. Soc.*, 1901, p. 890; *Agricultural Gazette*, lii., 1900, p. 228; *Agricultural Students' Gazette*, x., p. 37.

of Prof. Thomas Thomson. Materia-Medica was studied under Dr. J. Couper, and botany under Sir W. J. Hooker. He came to London in the autumn of 1839, and continued his studies at University College, where he attended the chemical lectures and practical classes of Prof. T. Graham, and worked for a short time in the laboratory of Prof. Anthony Todd Thomson. He also studied natural philosophy under J. Sylvester, anatomy under Dr. Grant, and botany under Lindley at Chiswick, and made some progress in the German language. In 1840 he went to Germany, and spent a summer session at Giessen, in the laboratory of Prof. Liebig. Here he took the degree of Ph.D.; two other English students, J. Stenhouse and L. Playfair, afterwards to become celebrated as chemists, took their degrees at the same time. On returning to England, Dr. Gilbert renewed his studies at University College, and became class and laboratory assistant to Prof. A. T. Thomson during the winter and summer sessions of 1840–41. In 1842 he left London and became consulting chemist to Mr. Burd, a calico-printer in the neighbourhood of Manchester. The turning point of his life soon arrived. Mr. Lawes had already made his acquaintance in the laboratory of Prof. A. T. Thomson, and being in want of a trained chemist to assist in the agricultural investigations he had commenced at Rothamsted, he, on the recommendation of Prof. Thomson, engaged the services of Dr. Gilbert. On June 1, 1843, Dr. Gilbert entered on his work at Rothamsted. The connection between Lawes and Gilbert thus commenced continued till the death of Sir John Lawes in 1900, a period of 57 years.

The rapid development of the agricultural investigations at Rothamsted after the year 1843 has been already noticed in the preceding account of the life of Sir John Lawes. The value of the work done was largely due to the unremitted labours of Dr. Gilbert. At the opening of the new laboratory in 1855, Mr. Lawes said, "I should be most ungrateful were I to omit this opportunity of stating how greatly I am indebted to those gentlemen whose lives are devoted to the conduct and management of my experiments. To Dr. Gilbert more especially, I consider a debt of gratitude is due from myself and from every agriculturist in Great Britain. It is not every gentleman of his attainments who would subject himself to the caprice of an individual, or risk his reputation by following the pursuits of a science which has hardly a recognised existence. For twelve years our acquaintance has existed, and I hope twelve years more will find it continuing." The testimony borne by Sir John Lawes to his colleague at the end of fifty years of their joint work has been already quoted in the preceding account of Sir John Lawes.

We must now attempt to give some idea of the special part taken

by Sir Henry Gilbert in the Rothamsted investigations. The two leaders of the work were in almost daily consultation, Sir H. Gilbert spending, as a rule, an hour at Rothamsted every day that Sir John Lawes was at home. The plans for new experiments, the results obtained from day to day, and the drafts of the reports in preparation, were thus all discussed by them together. Sir John Lawes directed the agricultural operations in the experimental fields; the execution of the remainder of the work was in the hands of Sir Henry Gilbert. Sir John Lawes contributed to the joint work a thorough knowledge of practical agriculture. His original mind was stored with facts learnt by keen observation and study in the field. A born investigator, he seemed to be continually occupied in the study of agricultural problems. His enterprising and practical spirit impressed its character on the whole of the Rothamsted work. Sir Henry Gilbert supplemented in a remarkable manner the qualities of his chief. His training as an analytical chemist, and his acquaintance with foreign languages and literature, were naturally of great value in research work. His knowledge of colloquial German enabled him in after years to describe the results of the Rothamsted investigations to many foreign visitors. His special mental characteristics also eminently fitted him for the work subsequently carried out. He was both cautious and painstaking to a remarkable extent, desiring to accumulate a great mass of facts before coming to any certain conclusion upon them. His mode of work was also extremely methodical, and the method once adopted, after full consideration, was continued through many subsequent years, thus giving rise to long series of results obtained in a perfectly similar manner. The continuation of the same field experiments for more than fifty years, and the important results which subsequently followed from an examination of the soils so long under definite cultivation, may be cited as examples of Gilbert's method. Under his care, samples of the grain and straw from each experimental plot, in each year, were preserved in the laboratory, and also samples of the ash yielded by each. In later years, when samples of the soils and subsoils of each plot were repeatedly taken, large portions of each sample were also preserved. At his death the number of samples stored for future reference in the laboratory and in the adjoining building exceeded 50,000. The bulk of tabulated records prepared by the clerks at the laboratory was correspondingly large. He thus laid the foundation of much solid work. The same characteristics appeared in his reports. These usually contained a great bulk of numerical statements, set forth in an orderly manner, with not unfrequently only a small proportion of illuminating theory. The recording of observed facts seemed often to satisfy his object as an investigator. When, however, a definite conclusion had been arrived

at it was tenaciously held, and if attacked was vigorously defended. Sir Henry Gilbert was an antagonist who never tired. His controversies with Liebig, on the subject of his mineral theory, and, in later years, with other German investigators, on the source of fat in the animal body, will be well remembered by his contemporaries.

The life work of Sir Henry Gilbert will chiefly be found in the published reports of the Rothamsted investigations, which, at the time of his death, had reached ten volumes; the subjects of these investigations will be briefly noticed at the close of this biography. His work, however, frequently extended beyond the sphere of the Rothamsted experiments. He was Mr. Lawes' scientific adviser, and as such he played an active part in the trials which took place in the Law Courts respecting the alleged infringment of Mr. Lawes' patent. He made reports on deposits of phosphates at home and abroad. He superintended the experiments relating to the disposal of sewage at the time when Mr. Lawes was a member of the Royal Commission of 1857. Other important undertakings will be mentioned presently.

Dr. Gilbert was married in 1850 to Eliza Laurie, daughter of the Rev. G. Laurie. His wife died in 1853. He married a second time, in 1855, Maria Smith, who survives him. Sir Henry Gilbert owed much to his second wife's untiring assistance. The feeble condition of his eyesight obliged him to rely a good deal on clerical help. Both foreign and English papers were read to him by Lady Gilbert, while the greater part of his own work was dictated to an amanuensis. His great pluck and determination, with the assistance thus rendered, enabled him to accomplish a very large amount of work notwithstanding the serious difficulties under which he laboured.

Sir Henry Gilbert was an active member of many scientific societies, a regular attendant at their meetings, and a member of many scientific committees. The Rothamsted investigations undoubtedly gained by the intercourse thus obtained with other investigators, though the time occupied by visits to London was often considerable. Sir Henry Gilbert was elected a Fellow of the Royal Society in 1860. He was the author, with Sir John Lawes, of seven papers in the Philosophical Transactions. In 1867 he received, with Sir John Lawes, one of the Royal medals for the work done at Rothamsted. He served on the Council in 1886–8. Sir Henry Gilbert joined the Chemical Society in 1841, a few weeks after its formation, became a member of the Council in 1856, and a Vice-President in 1868. In 1882 he was elected President of the Society. Sir Henry Gilbert delivered four lectures before the Society, and was the part author of several other papers. In 1898 a memorable dinner was given by the Society to six Past-Presidents, all of whom had been members of the Society for more than fifty years; of these Past-Presidents Gilbert was

the eldest. The President concluded his address to him by saying: "The Rothamsted results will be for ever memorable; they are unique, and characteristic of the indomitable perseverance and energy of our venerated President, Sir Henry Gilbert."

Of the Linnean and Meteorological Societies Sir Henry Gilbert was also a Fellow, and occasionally read papers at their meetings. He was also a member of the Society of Arts. He became a member of the Scientific Committee of the Horticultural Society in 1868, and for many years regularly attended its meetings.

In his summer holidays the meeting of the British Association for the Advancement of Science was generally attended; his attendance commenced in 1842, and during many years he scarcely missed a meeting, and frequently read a paper describing some of the Rothamsted results. In 1880 he was President of the Chemical Section, and gave as his address: "A Sketch of the Progress of Agricultural Chemistry." A tour on the Continent generally formed part of the summer holiday; agricultural laboratories and experimental stations were then visited, and the Naturforscher Versammlung, and other scientific gatherings, were often attended and papers read before them. In 1871, and the following year, the details of sugar beet culture were studied in Germany, Austria, and France, preparatory to the commencement of experiments on this subject at Rothamsted.

Three visits were paid to the United States and Canada. In 1882 he attended the meeting of the American Association for the Advancement of Science, at Montreal, and brought before them the recent determinations of nitrogen in the experimental soils at Rothamsted. A tour of nearly three months was afterwards made in the United States. In 1884 he was again at Montreal, at the meeting of the British Association, and afterwards made a second extensive tour through North America. The last visit was paid in 1893, after the celebration of the Rothamsted jubilee, for the purpose of delivering a course of lectures on the Rothamsted experiments, in accordance with a provision of Sir John Lawes' trust deed. Sir Henry Gilbert first attended the Agricultural Congress held in connection with the World's Fair at Chicago; here he had a splendid reception, all present rising and cheering for some time. To this Exhibition at Chicago a large collection of diagrams had been sent from Rothamsted, and for these a medal was afterwards awarded. Sir Henry Gilbert then gave a course of seven lectures at the State Agricultural College at Amherst, Mass., taking as his subject the chief results relating to the crops ordinarily grown in rotation, with those relating to the feeding of animals, obtained at Rothamsted during the previous fifty years. These lectures, in an enlarged form, were afterwards published by the United States Department of Agriculture, and were reprinted, with an intro-

ductory account of the Rothamsted experiments, in the Transactions of the Highland and Agricultural Society of Scotland for 1895.

In 1884 Dr. Gilbert was elected Sibthorpian Professor of Rural Economy in the University of Oxford, and held this office for six years, the full term allowed by the statute. He delivered during this time over seventy lectures on the results of the Rothamsted investigations; these lectures he hoped to publish, but the intention has remained unfulfilled.

In 1885 Dr. Gilbert became an Honorary Professor of the Royal Agricultural College at Cirencester, and delivered an annual lecture during six years; the lectures were published in the *Agricultural Students' Gazette*. They treat in a condensed form of some of the subjects previously discussed at Oxford.

The transfer of the laboratory and experimental fields to the management of a committee appointed under Sir John Lawes' trust deed of 1889 has been already mentioned. After this date the virtual direction of the experiments continued to remain in the hands of Lawes and Gilbert during their joint lives. For the information of the new committee Sir Henry Gilbert drew up a brief report on the investigations hitherto conducted, showing to what extent the results obtained had been already published, and making suggestions as to future work. This report was printed in 1891 for the use of the committee.

The celebration of the jubilee of the Rothamsted experiments in 1893 has been already described in the notice of Sir John Lawes, with the numerous honours subsequently conferred on both Lawes and Gilbert. Dr. Gilbert received knighthood from the Queen on August 11 of that year.

Sir Henry Gilbert was a member of the committee appointed by the Government in 1896 to take evidence and report on the materials used in the manufacture of beer. The committee presented their report to the Treasury in 1899.

He received many honorary degrees. The University of Glasgow made him LL.D. in 1883; Oxford, M.A. in 1884; Edinburgh, LL.D. in 1890; Cambridge, Sc.D. in 1894. He was a life governor of University College, London; a Corresponding Member of the Institute of France; a Chevalier du Mérite Agricole; and an honorary member of many agricultural societies at home and abroad.

With a life so filled with many labours it need hardly be said that Sir Henry Gilbert was possessed of a robust constitution. He, however, suffered at times from over-brainwork, and his frequent excursions abroad were really needed to maintain a healthy tone. In later years he suffered much at times from internal pain, the precursor, probably, of his last illness. The death of Sir John Lawes in 1900 was naturally a great shock to him. He was fairly vigorous, however, during the

next summer, but was taken seriously ill during a visit to Scotland, and returned home with difficulty. He died at Harpenden on December 23, 1901, in his 85th year.* R. W.

The Investigations of Lawes and Gilbert.

The Rothamsted Agricultural Station was the *first* of the many Agricultural Research Stations now in existence; the only earlier work of the same kind was that carried out for some years by Boussingault on his farm at Bechelbronn, commencing in 1834.

An extensive and long-continued series of field experiments upon the principal agricultural crops is the most striking feature of the Rothamsted work. The trials commenced with turnips and wheat, and soon extended to many other crops, till nearly 40 acres were occupied by these experiments. In each case the same crop was grown year after year on the same land. Thus, at the death of Sir John Lawes, the fifty-seventh successive crop of wheat had been harvested in Broadbalk field. From the commencement of each field experiment one plot was left entirely unmanured and one received farmyard manure each year. The remaining plots received at first various manures, but in a few years the earliest experimental fields were brought under a continuous system of manuring, and the fields afterwards taken for crop experiments received from the first a uniform treatment. The plan in each case was to supply certain plots every year with the various ash constituents of the crop—called by Lawes and Gilbert "mineral manures"—while other plots received nitrogenous manure in various forms, and others various mixtures of the mineral and nitrogenous manures used separately on the other plots. The plan of manuring adopted in these field experiments was originally intended as a practical test of the "mineral theory" of Baron Liebig; no better scheme could, however, have been chosen for the elucidation of the general problems of the relation of crop, soil, and manure to each other. Experimenting in this way many important facts were brought to light—the capacity of the crop to supply itself with nitrogen from the natural sources of the soil and atmosphere; its capacity to supply itself with ash constituents from the soil; the particular ash constituents most necessary to be applied as manure, and those of which the soil soonest became exhausted; the relative value of various nitrogenous manures, and the effect produced by varying amounts of nitrogen. A comparison of the crops produced by chemical manures with the crop yielded by ordinary farmyard manure was also obtained every year. In some instances the special application of manure was stopped on certain plots after a number of

* For some further information upon Sir Henry Gilbert's life and work see *Nature*, January 2, 1902, p. 205; *Jour. Roy Agric. Soc.*, 1901, p. 347; *Trans. Chem. Soc.*, 1902, p. 625.

years, and the land left unmanured; the effect of the residue of the former manuring was thus made apparent. The produce of each plot was carefully weighed, and at the laboratory the proportion of dry matter and ash was determined, while in selected instances the percentage of nitrogen was ascertained, and the plant ash was submitted to analysist. The great variety of seasons met with in so long a series of field experiments enabled the effect of season upon the weight and composition of the crops to be studied, as well as the effect produced by manures.

In later years samples of the soils and subsoils of the various experimental plots were repeatedly taken and analysed; the accumulation or loss of nitrogen, carbon, phosphoric acid and potash resulting from the particular treatment of each plot was thus ascertained. In the case of the wheat field each plot was provided with a drain-pipe, and the water percolating through the soil was regularly collected and some of its constituents determined by chemical analysis; information was thus gained as to the losses which manured land suffers by drainage.

In order to make the chemical statistics of the experimental crops more complete, the rain was collected in a large rain-gauge, and some of its constituents determined. Three drain-gauges, consisting of three masses of bare soil of various depth, were also constructed to ascertain what proportion of the rainfall passed through the soil; the drainage waters from these bare and unmanured soils were also analysed for comparison with the drainage waters furnished by the soils cropped and manured in Broadbalk field.

Besides the field experiments with individual crops, there was a rotation field in which four systems of cropping were carried out, representing ordinary farm practice. A part of this field was permanently unmanured, another portion received only the important ash constituents of crops, and a third portion the ash constituents together with nitrogenous manures. Here, too, both crops and soil have been submitted to analysis in order to complete the chemical statistics of the experiment. In other fields the simple rotations of wheat and beans, and wheat and fallow have been studied.

In the experiments with meadow land mown for hay, the same conditions of manuring were adopted as with other crops. In this case the continued application of different manures produced a great alteration in the botanical character of the herbage, which became extremely different on different plots. This result led to a systematic botanical analysis of the hay produced by each experimental manure. The aid of Dr. Maxwell Masters, F.R.S., was obtained in this part of the inquiry, which has been continued for many years.

The question whether plants assimilated the free nitrogen of the atmosphere was a subject much debated in the early years of the Rothamsted experiments. Dr. Evan Pugh came to England early in 1857,

and devoted more than two years to the investigation of this subject in the Rothamsted laboratory. The results obtained in experiments with a considerable variety of plants, showed no assimilation of free nitrogen. The chemical statistics of the leguminous crops at Rothamsted, and elsewhere, showed, however, that they contained an extraordinary large amount of nitrogen, the source of which was difficult to explain. In 1886, Hellriegel and Wilfarth proved that leguminous plants assimilated the free nitrogen of the air in considerable quantities if the soil in which they grew contained certain microbes forming nodules on their roots. The experiments giving rise to this conclusion were repeated at Rothamsted with a similar result. The very different results obtained in the earlier and later experiments at Rothamsted were due to the fact that the plants in the earlier experiments were all grown in burnt soil, and the microbes were thus excluded.

Among the miscellaneous investigations conducted at Rothamsted, may be named those on the relation between the amount of water transpired by plants and their increase in dry matter; the investigation on the composition of the milling products of wheat grain; the investigations conducted for the Government, on the manurial value of sewage; also the chemical study of the "fairy-rings" in meadow land.

The experiments relating to animals were very numerous in the earlier years of Rothamsted work. Trials were made on a large scale of the comparative fattening capacity of different breeds of sheep. The sheep were kept under ordinary agricultural conditions, and the relation between food and increase was carefully ascertained. The trials extended over several years. Numerous feeding experiments of a more scientific character were made on fattening pigs; these received diets containing very varied proportions of albuminoids and carbohydrates. It was found that the supply of a larger proportion of albuminoids than that contained in cereal grains was not attended by a greater increase in live weight. This conclusion was contrary to the scientific opinion then prevalent, which regarded the amount of albuminoids in a diet as a measure of its nutritive value. Feeding experiments on oxen were conducted by Lawes and Gilbert at Woburn.

A very important and laborious piece of work was the determination of the percentage composition of the whole bodies of animals, oxen, sheep, and pigs, of various ages, and in various conditions as to fatness. The proportion of all the organs, and of the butcher's carcase, in the live weight, was ascertained in the case of a large number of animals; and in the case of ten animals, the proportion of water, fat, nitrogenous matter, and ash was determined in every part, and by calculation in the whole animal. The ash was afterwards analysed and its composition determined. The facts thus ascertained still form our chief source of information as to the com-

position of the animals produced on the farm, and the composition of the increase produced during fattening. The experiments on pigs threw much light on the source of fat in the animal body. One young pig was killed and its body analysed. Another pig, from the same litter, was fattened with food of known composition, and then killed and analysed. The composition of the increase obtained whilst fattening was thus ascertained. It was found that when pigs were fed on barley meal, maize, or diets containing pure starch and sugar, the quantity of fat produced was far greater than could be accounted for by the ready-formed fat and the albuminoids of the food, and that large quantities of fat must have been formed from carbo-hydrates. At that time most German physiologists believed that fat was only formed from albuminoids; the conclusion arrived at by Lawes and Gilbert is now, however, universally admitted to be correct. As a result of their experiments with animals they were able to teach the farmer what amount of fattening increase he might expect from the use of ordinary foods, what proportion of the constituents of the food would be stored up in the animal, and what proportion would appear as manure. Tables were also published showing the weight of butcher's carcase in cattle of any given live weight, in various conditions as to fatness.

In later years, opportunity was taken of the presence of a large herd of dairy cows at Rothamsted to prepare statistics of the food consumed and the milk produced by these animals.

Careful experiments on the relative feeding value of barley, and of the malt made from it, were carried out for the Board of Trade. The process of ensilage was also studied, the losses in the silo determined, and the feeding value of silage compared with that of the original green food preserved as hay, and with other foods. The manure value of cattle foods was repeatedly calculated for the information of the farmer, and tables on the subject were published.

A considerable part of the results obtained at Rothamsted still remains unpublished. The number of papers and reports amounted to 132 in 1901. This is exclusive of very many shorter papers by Sir John Lawes, and of the "Memoranda," published annually. The dates of publication extend from 1847 to 1900. The earliest published paper appeared in the *Gardeners' Chronicle and Agricultural Gazette* of June 14, 1845. Separate copies of the Rothamsted papers have been from the first freely distributed. In later years, complete sets of the reports were prepared by reprinting some of the older publications, and bound copies of the whole were presented to the libraries of Agricultural Colleges and Experiment Stations in various parts of the world. About 200 complete sets were thus prepared, of these 50 were purchased by the English Board of Agriculture.

R. W.