scientific principle shown in their treatment. It was high time that someone in a position of authority should have been called on to lay down the principles that govern, or should govern, the pruning of trees in public thoroughfares. The outcry periodically made in the daily Press is usually marked by want of knowledge and unfairness. As a matter of fact, there is no work more thankless in nature than the management of street trees. In London and other great urban areas the planter's choice is restricted to a few species (of which the plane is the chief and best) which experience has proved will thrive, but which, as regards size, are quite unsuited to the spaces usually available for them. In the Mall this difficulty does not arise, for the space is ample. The object there is to control the growth of the trees that have been planted so that the foundations of a stately avenue may be laid.

Perhaps the most valuable portion of Prof. Balfour's report is that in which he shows that nature herself is always pruning. That is an aspect of the case which never strikes the lay critic. Yet the smothering out of weakly and overcrowded growths is continually going on. Correct pruning anticipates nature's end, and substitutes the prompt action of the knife for that of slow decay. If one compares the branch-system of a fully grown plane with that of a young specimen, and notes how few of the numerous branches of the latter survive, we see how drastic nature's pruning is. In such a place as the Mall it is essential that the trees should possess a certain uniformity and balanced proportions. The means to secure this end have been admirably chosen, and there the matter may be allowed to remain. But we may recommend Prof. Balfour's report to those who desire to gain some insight into the fundamental laws of tree growth with which the pruner's art should be in unison.

AN EXHIBITION OF BIBLICAL NATURAL HISTORY.

As a supplement to the literary and historical Biblical exhibition which has been arranged at Bloomsbury for the tercentenary of the Authorised Version, an exhibition of the animals, plants, and minerals mentioned in the Bible has been arranged in one of the bays of the Central Hall of the Natural History Museum, South Kensington. The animals and minerals, respectively, have been selected, arranged, and labelled by Mr. R. Lydekker, F.R.S., and Dr. G. F. Herbert Smith, under the general supervision of the keepers of zoology and mineralogy; the plants have been dealt with by Dr. A. B. Rendle, F.R.S., the keeper of botany. The interesting guide-book to the collection is in great part a reprint of the exhibited labels, which were mainly based on the careful work of the late Canon Tristram. The minerals, which Tristram did not consider, are dealt with in a scholarly essay by the director, Dr. L. Fletcher, F.R.S., who explains how modern interpretations of the ancient names of Biblical minerals have been deduced.

The collection, and the guide to it, will be of special interest to those to whom Bible plants and animals are rich in picturesque associations; but it is, of course, part of a liberal education to know that the "unicorn" was probably the extinct wild ox or aurochs, "behemoth" the hippopotamus, the "coney" the hyrax, and the "leviathan" of Job the crocodile. Some of the corrections are curious; thus the "ferret" of Lev. xi. 30 was probably a gecko, and the "mole" of the same verse a chamæleon, and the "chamæleon" of the same verse a monitor, and the "spider in king's palaces" a gecko. An up-to-date suggestion is noticed, though not accepted—that the "badger" of Exod. xxvi. 14 was the okapi. We do not see any reference to the "fiery serpent," though the museum used to have a specimen of *Filaria medinensis*, the guinea-worm, with a label indicating that *it* was probably that reptile.

What must strike the reader most, especially perhaps when he comes to the botanical part, is the large proportion of misses that the translators made. And if we might venture on a criticism of a carefully executed piece of work, we would suggest that a little more might have been said in explanation of this. A paragraph or two on the backward state of natural history when the authorised translation was made three centuries ago would have been interesting. We also wonder why our leading scientific institution has not used this opportunity, which is undoubtedly one of wide popular interest, to tell us—who could do it better?—what is scientifically interesting in the fauna and flora of Palestine.

LIEBIG AND HIS INFLUENCE ON THE PROGRESS OF MODERN CHEMISTRY.[1]

A HUNDRED years ago Europe was still plunged in the misery of war. Almost every country had suffered the bitter experience of seeing the devastation caused by the passage of contending armies, the death and suffering of thousands of fighting men, and the want and desolation spread over still greater numbers of a helpless population. Amid all the wretchedness of the time, insecurity of property, dearness of food, frequent changes of governments, and every condition which would appear to be unfavourable, the study of nature steadily went on. France, still staggering from the fierce shocks of the revolutionary period, had still many distinguished men of science, Laplace, Berthollet, Lamarck, Cuvier, while the memory of Lavoisier was fresh and green, and Gay-Lussac, Dulong, Arago, and Chevreul were among the coming men. England, still engaged in the struggle with Napoleon, possessed Humphry Davy, Rumford, and Dalton, and Herschel among the astronomers. Henry Cavendish was still living, though an old man, and Priestley was but lately dead. In Germany, Goethe might be counted among the votaries of science, and Prussia had sent forth Humboldt to survey the world, while in Italy, Volta was busy in the study of electricity, and Avogadro, little noticed by the world, was meditating on the properties of gases and preparing for the enunciation of the great principle which is now associated with his name, though it took the chemical world half a century to recognise it. One other name must not be forgotten, and that is Berzelius, the Swede, then young, and preparing, by his eager activity in research, for that great position of almost undisputed authority in the chemical world, which he filled for nearly forty years.

To understand the influence which any one man appears to have had in his day and generation, it is necessary to bear in mind the condition of the world into which he was born, as well as the quality of his genius. The one reacts on the other. In endeavouring, therefore, to estimate the nature and extent of the services rendered to science, and to the world in general by Liebig, it is necessary to get a clear view of the state of knowledge in chemistry at the time when he appeared on the scene.

Born in Darmstadt, on May 12, 1803, where his father was a colour manufacturer, he passed through an unsuccessful school career at the local gymnasium, and, at the age of sixteen, was apprenticed to an apothecary. It soon became evident, however, that he was as little fitted to become a pill-maker as he was to be a Greek scholar, and he ultimately persuaded his father to allow him to go to the then newly-founded University of Bonn, whence he followed Kastner, the professor of chemistry, to Erlangen. But Liebig soon became convinced that he could not study chemistry effectively in Germany, and after taking his degree at Erlangen, at the age of nineteen, he proceeded to Paris. There, after many difficulties, he ultimately obtained the privilege of working in Gay-Lussac's laboratory, where he remained about two years. In 1824, on the recommendation of Humboldt, he was appointed extraordinary professor of chemistry at Giessen, being then only twenty-one years of age. He became ordinary professor two years later, and remained at Giessen until called to Munich, in 1852. There he died on April 18, 1873.

Such was the main course of Liebig's career; but to draw a picture of the man from descriptions of his personal characteristics is not easy. In early youth he became familiar with the poet Platen, who noted in his diary "the friendly earnestness in his regular features, great brown eyes, with dark shady eyebrows, which attracted one instantly." Those brown eyes, shining with earnestness, remain in the portraits which have come down to us, and as a

[1] Lecture delivered at Oxford on August 23, at the Fifteenth Summer Meeting, by Sir William A. Tilden, F.R.S.

family feature, reappear in the faces of some of his children. Ardent, eager, enthusiastic in the pursuit of experiment, his remarkable power of exact observation stood him in good stead. Kindly and tender with children, there were times when eagerness in research or controversy led to exhibitions of impatience, but the steadfast character of the man is illustrated by the persistence of his lifelong intimacy with Friedrich Wöhler. This intimacy resulted in a correspondence which extended over more than forty years, and had consequences in the lives of both men, which were full of importance for the progress of chemical science. To this reference must be made further on.

We may now endeavour to sketch, in outline, the state of knowledge and theory when Liebig entered on his career.

The modern use of the term element, which had been introduced by Robert Boyle in the seventeenth century, was by this time universally adopted, and to the metals on the list had been added such important substances as oxygen, hydrogen, nitrogen, and chlorine. To use the words of Davy, in one of his researches on chlorine, "Neither oxygen, chlorine nor fluorine are asserted to be elements; it is only asserted that they have not been decomposed." And that is the sense in which the term has, in modern times, always been used. The process of burning or combustion was, of course, now always explained by Lavoisier's doctrine, according to which a body in burning combines with the oxygen of the air, and forms one or more chemical compounds with it. At the time that Liebig went to Giessen, in 1824, Sir Humphry Davy was still living, but his scientific career was practically closed, and Berzelius was the predominant authority in matters of theory. Gay-Lussac, in Paris, had made important discoveries relating to the proportions in which gases enter into combination. Dalton's atomic theory, propounded in 1808, though not generally accepted, was gaining ground. Broadly, the position was this: elements were clearly distinguished from compounds, chemical combination was explained by the supposition that it was due to the close approximation of atoms of opposite kinds, and the union of atoms to form a chemical compound was attributed to the attraction caused by charges of electricity of opposite nature, which were supposed to be resident on the atoms.

But the composition and nature of "organic" compounds were practically unknown. A few such substances had been isolated, *e.g.* milk sugar and grape sugar were known as distinct substances, and were differentiated from common sugar. Alcohol, nearly pure, had been known, in the form of spirit of wine, from early times. Acetic acid was known, as well as several acids found in vegetable tissues, such as oxalic, formic, malic, tartaric, and benzoic acids. There were, however, no means of determining their composition, and although Lavoisier had devised an apparatus in which organic compounds could be burned in oxygen, and the water and carbon dioxide thus formed could be collected, the process was both cumbrous and incapable of yielding exact results.

A most interesting autobiographical sketch was discovered among Liebig's papers many years after his death, and from this we learn that in his early life "at most of the universities there was no special chair for chemistry. It was generally handed over to the professor of medicine, who taught as much as he knew of it, and that was little enough, along with toxicology, materia medica, &c." But the total neglect of experiment was the source of much mischief, and the persistence of the degenerate deductive method led to neglect of the careful observation of nature. The lectures of Prof. Kastner Liebig describes as without order, illogical, and they resembled the jumble of knowledge which he carried about in his own head. When he got to Paris all was different, and the lectures of Gay-Lussac, Thénard, and Dulong had for the young student an indescribable charm. The lecture consisted of a judicious series of demonstrations—experiments of which the connection with each other was pointed out and explained; and soon the consciousness dawned on him that all chemical phenomena, whether exhibited by the animal, vegetable, or mineral kingdoms, are connected together by fixed laws.

Liebig therefore returned from Paris to his own country with the intention of founding an institution in which students could be instructed in the art and practice of chemistry, the use of apparatus, and the methods of chemical analysis. In view of the total absence of such provision elsewhere, it is not surprising to learn that, so soon as its existence became known, students streamed into the Giessen laboratory from every civilised country. It is interesting to learn from Liebig's own words what was the method he adopted. Obviously, in order to teach a large number at one time, it is necessary to have a systematic plan, and in his case this had first to be thought out and then put to the proof, as no course existed which could be used as a model. He says, however, that "actual teaching in the laboratory, of which practised assistants took charge, was only for the beginners; the progress of my special students depended on themselves. I gave the task and supervised its carrying out. There was no actual instruction. Every morning I received from each individual a report on what he had done the previous day, as well as his views about what he was engaged on. I approved or criticised. Everyone was obliged to follow his own course. In the association and constant intercourse with each other, and by each participating in the work of all, everyone learned from the others. Twice a week in winter I gave a sort of review of the more important questions of the day. We worked from break of day till nightfall. Dissipation and amusements were not to be had at Giessen. The only complaint which was continually repeated was that of the attendant, who could not get the workers out of the laboratory in the evening when he wanted to clean it."

Such was the spirit and such the method by which a great school was created! Nor was this the only result. To the influence and example of the school at Giessen may be attributed the rapid spread of the new method of teaching chemistry. In 1824 there were no laboratories devoted to the purposes of instruction. A few of the most eminent professors of chemistry—Berzelius in Stockholm, Gay-Lussac in Paris, for example—admitted one or two students already advanced in the subject to practise in their private laboratories, but only as a great favour. In this way Mitscherlich, Rose, Wöhler, and Magnus had repaired to Berzelius in Stockholm as Liebig had gone to Paris. But in a few years the fame of what Liebig was doing in Giessen penetrated to other countries of Europe, and many of the men who had studied under his direction became teachers in other lands. Here in England no chemical laboratory for general instruction existed, and only in the medical schools were a few tests described and shown. In London the Society of Apothecaries had a laboratory which had existed since 1671; but this was not used for teaching, but as a place of manufacture of drugs for use in medicine. At Cambridge the professor of chemistry was a country clergyman, who came up once a year to give a course of lectures. At Oxford the professor of chemistry was also, later, professor of botany, and in neither university was there a laboratory for instruction, nor was chemistry a subject recognised in the curriculum for a degree. Twenty years later things began to improve. In this country the first laboratory for instruction in practical chemistry was provided by the then newly instituted Pharmaceutical Society of Great Britain at their premises in Bloomsbury Square. This was in 1844, and in the following year a new and enlarged laboratory was fitted with places for twenty-one students.[1] About this time the College of Chemistry was established in temporary quarters in George Street, Hanover Square, and soon afterwards the Birkbeck Laboratory, modelled on that of the Pharmaceutical Society, was built at University College. Many other laboratories were opened about this time. In 1848 Pélouze founded in Paris a laboratory to which some English chemists resorted. But the Giessen laboratory under Liebig's direction continued to supply the majority of the teachers who in the succeeding generation founded schools, not only in Germany, but in other countries—Hofmann, for example, at the Royal College of Chemistry, and Williamson, who was appointed at University College in 1849.

Liebig's career as a chemist and investigator was influenced in no small degree by his friendship with Wöhler. Born three years before Liebig, Friedrich Wöhler

[1] I saw this laboratory about 1857. It had the aspect which one usually associates with ideas of the alchemists. Many of the operations were connected with the use of furnaces, such as fusion, sublimation, &c., and the place was full of smoke and fumes.

studied medicine at Marburg, but subsequently pursued chemistry at Heidelberg under Leopold Gmelin. Having relinquished medicine on taking his degree, he obtained the privilege of working with Berzelius in his laboratory at Stockholm. On his return from Sweden in 1824 he was appointed teacher of chemistry in the Trade School in Berlin. Some years later he became professor in the University of Göttingen. Soon after his return from Sweden he met Liebig in Frankfort, and a close intimacy at once sprang up, which continued for more than forty years to the end of Liebig's life. Two volumes of their correspondence have been compiled by Hofmann, and the perusal of these letters, extending from 1829 to 1873, affords a view of the subjects which occupied the minds of both, as well as many of the incidents of their lives. One only we have time to notice here. Liebig paid several visits to England, and in a letter to Wöhler dated from Giessen, November 23, 1837, he tells him that he has travelled through England, Ireland, and Scotland in every direction, and has seen many surprising things, but has learned little. The absence of scientific knowledge in England he attributes to the badness of the teaching. In another letter, addressed to Berzelius nearly at the same time (November 26), he says:—"England ist nicht das Land der Wissenschaft," only there is a widespread "dilettantismus," and he complains that "die Chemiker schämen sich Chemiker zu heissen, weil die Apotheker, welche verachtet sind, diesen Namen an sich gezogen haben."

Liebig's contributions to pure chemistry, though so numerous and important, can be recalled only briefly. They may be placed under three heads, namely, first, the invention and perfecting of a method for analysing organic compounds, which in all essential features is still practised everywhere.

Secondly, the discovery of a large number of new compounds, of which even the names cannot now be mentioned for want of time, but which include chloroform and chloral and many cyanides. He also established the formula of uric acid and the nature of aldehyde.

Thirdly, we owe to Liebig the conception of the theory of compound radicals, which arose out of his researches jointly with Wöhler (1832) into the products from essential oil of bitter almonds.

In a letter to Wöhler (May 26, 1839), Liebig writes that he is occupied with the study of the phenomena of fermentation and putrefaction, and having sent an account of his views to Wöhler, another letter, dated June 3, discusses the criticism which he has received from him. In the postscript to this long and interesting letter, we find a concise statement of Liebig's hypothesis concerning the action of ferments.

Before proceeding further, it will be well to understand what is meant by fermentation. If we take a solution of sugar, and add to it a very small quantity of brewers' yeast, or, if we take grape juice without any addition, in a short time, especially in warm weather, a frothing, due to the escape of minute bubbles of gas, soon sets in, and this continues until the liquid has lost its sweet taste, and has become more or less alcoholic and intoxicating. The escaping gas is carbon dioxide, vulgarly called carbonic acid, and the liquid retains, beside alcohol as the chief product, small quantities of other things. Somewhat similar changes go on in the leavening of bread, the souring of milk, the putrefaction of meat, and apparently also in the animal body in the course of many feverish diseases. One peculiarity of the process consists in the fact that the ferment, the yeast for example, serves to bring about chemical decomposition in a relatively large, almost indefinitely large, quantity of the sugar or other substance in solution.

Liebig's explanation of these changes was based on purely mechanical ideas as to the motions of the hypothetical particles or atoms. He imagined the atoms of a substance which causes fermentation or putrefaction to be in a state of unceasing vibratory motion, and that this state of agitation was communicated to the molecules of the sugar, causing them to undergo an internal rearrangement, and to break down into simpler structures of a more stable nature, in the case of alcoholic fermentation of sugar, in fact, into alcohol and carbon dioxide.

Liebig made the mistake of ignoring, as nearly all chemists and biologists of that time ignored, the constitution of the ferment. In 1859 and following years, Pasteur, the great French chemist, demonstrated the essentially vitalistic character of the phenomenon, and showed that the destruction of the sugar was an effect concomitant with the growth and multiplication of the cells of a minute organism, visible under the microscope. A special form and character of organism is concerned in each type of fermentation.

The organised character of yeast had been proved many years before by the observations of Kützing, Cagniard Latour, and Schwann. Nevertheless, the views of Liebig prevailed for some time. In the English version of his famous letters on chemistry, in the fourth edition, which appeared in 1859, there is a chapter headed "Theory which ascribes fermentation to fungi refuted." As a matter of fact, it was about this time established.

Liebig was ultimately convinced of the organic nature of yeast, but he still contended for his theory of molecular destruction by communicated agitation, as furnishing the explanation of the physiological act which comes about within the cells of the yeast. An important step was taken much later, when, in 1897, it was shown by Buchner that something can be dissolved out of yeast which, independently of the cells, is capable of resolving sugar into alcohol and carbon dioxide. Thereupon, it seemed to some that Liebig's views might be resuscitated. But the changes which occur are now known to be very complicated, involving, in the first place, a process, not of destruction, but of building up molecules of a more complex nature, before they are broken down into the final products of fermentation. Liebig's theory, therefore, disappears from the scene.

Before 1840 it may be stated as almost literally true that physiology in the modern sense of the term did not exist, and certainly there was but a small basis for chemical physiology. The chemical production of urea independently of animal life, by Wöhler, in 1828, was a fact of which the deep significance appeared only much later. The studies in organic chemistry, into which Liebig had plunged alone, or in conjunction with his friend, necessarily attracted his attention to problems connected with the phenomena of animal and vegetable life. His visit to England, in 1837, was largely occupied with observation of the methods of agriculture then prevalent, and during the succeeding years we find in the catalogue of his scientific papers, many signs of his activity in pursuit of questions connected with the application of chemistry to agriculture, the growth and nutrition of plants, the formation of fat in the animal body, the composition and classification of foods, the source of animal heat, and the chemical processes connected with respiration and digestion. It is not possible for us to enter freely into the discussion of all these great subjects, but we must glance at Liebig's views in regard to two of them, not because those views have retained their predominance, but because of the stimulus they gave to inquiry and the encouragement he gave by precept and example to the fundamental principle on which the greater part of modern science is built, namely, the constant appeal to nature, not only by observation, but by systematic experiment.

In Liebig's time all biological processes were supposed to be controlled by what was called "vital force," that is, something which is not mechanical force, nor heat, light, electricity, nor chemical affinity. We are still a long way from knowing what life is, but to show how far some physiologists have travelled in the opposite direction, I will make a very short quotation from a recent book. Concerning the use of the word "metabolism," which is a comprehensive word covering all chemical changes which go on in the body during life, the writer directs attention to its implication "that all the phenomena of life are, at bottom, chemical reactions. When a muscle twitches no less than when a gland secretes, it is not too much to say that when we are moved to tears or laughter, it is chemical reactions that are the underlying causes to which ultimate analysis must lead us." I quote this as an extreme view.

Let us turn first to Liebig's classification of foodstuffs. It is necessary to account for the maintenance of the animal functions, the growth and repair of the body, the maintenance of its temperature.

Liebig attributed, as we believe correctly, the heat produced in the body to the process of burning, which goes on in the tissues in consequence of the absorption of atmospheric oxygen. Liebig was also right in his assertion that animals do not necessarily derive fat from their food, but the animal body is a laboratory, in which fat may be manufactured from carbohydrates, such as sugar and starch. The substance burned in the body is material derived from the food, but it has long been known that the substance thus burned does not consist exclusively of sugar, starch, and fat, which Liebig called *respiratory* foods.

The other constituents of food, now included under the general term protein, which contain nitrogen, and are more or less like white of egg in properties, he called *plastic* foods. These were supposed to produce new tissue, or repair waste, and to be the source of muscular energy or power to do work.

It is now known that the case is by no means so simple, and, in fact, this classification now possesses only historical interest. The whole question when considered in the light of modern knowledge is, in fact, a mass of difficulties, and very far from being clear of serious controversy. Liebig's name is associated in the public mind almost exclusively with the extract of meat, which he prepared for the first time in connection with his studies of food. This is to do him less than justice. Liebig never proposed it for use as a substitute for meat, because it contains only a part of the constituents of flesh. It appears that his idea, in the first instance, was to turn to account the flesh, which would otherwise be wasted, of animals which in Australia and South America were then bred solely for the sake of their wool and fat. Extract of meat is to be regarded as a valuable stimulant to be consumed together with bread or other vegetable food.

Let us now turn to the investigations into the operations and theories of agriculture with which Liebig's name should be for ever associated. Whence do plants get their carbon and nitrogen, which, together with hydrogen and oxygen and water, form the material of their tissues? What is the use of the mineral substances found in the ash left on burning vegetable matter? Why are different soils adapted to different crops, and what is it that gives fertility to a soil?

The state of knowledge on such subjects is indicated roughly by the summary which had been provided by the lectures of Sir Humphry Davy in 1813. During the subsequent twenty-five years very little had been done in the way of experiment, but it would be only fair to mention the name of the great French agricultural chemist Boussingault as one of the pioneers a little in advance of Liebig in the study of such questions. Briefly, the position was somewhat as follows: it was known that plants decompose the carbonic acid of the air, using the carbon and letting the oxygen go free, but it was commonly supposed that the brown or black substance in the soil, which is usually called *humus*, and is the result of the decay of preceding vegetable growth, was the chief source of the carbon in growing vegetables. Liebig pointed out that this was impossible, because it failed to show from what source the original plants from the decay of which humus was formed derived their carbon. Liebig was the first to study carefully the mineral constituents of plants and to recognise the importance of certain substances, especially potash and phosphates. The services which Liebig rendered to the world in connection with plant physiology and agriculture are, however, less to be recognised in the shape of positive contributions to knowledge than in the example set and in the influence of that example in stimulating systematic investigation of agricultural questions. By 1840 Liebig was one of the most famous chemists in the world, and the effect of his inquiries is shown in the activity which became manifest almost immediately after the communication of his first report to the British Association at the Glasgow meeting in 1840. In Germany the Government instituted a large number of Versuchs Stationen in different parts of the country, and in 1843 the systematic experiments were started at Rothamsted which must for ever place the names of Lawes and Gilbert among the benefactors of the world.

But here I must pause to remind myself and my hearers that the subject of my lecture is Liebig and his influence on the progress of modern chemistry. He died in 1873; but the period of his greatest activity in science lies further back by thirty years. Since either period vast changes have been brought about by chemical discovery, which, be it always remembered, is based on experimental work in the laboratory. That is the reflection which supplies the explanation of Liebig's great influence on the progress of science. That influence was fully recognised by the generation of chemists now passing away, or almost gone, and it seems to be a duty to preserve as long as possible a memory so rich in past benefits and so full of suggestion for future use.

Liebig made many discoveries in chemistry; but his great and permanent service to the world was not in the isolation and study of individual compounds or series of compounds, nor in the conception of theories of chemical action, nor even in views which he promulgated concerning the operations of agriculture, the composition of food, the processes of digestion, or the source of animal heat. His great service consisted in showing how chemistry should be studied and how it should be taught, in setting the example of submitting all questions to the light obtained by direct experimental study of nature, and in thus affirming and illustrating the principle that what is called pure science is of greater permanent value than what is called applied science; a knowledge of the laws of nature is more useful than many inventions.

In the Giessen laboratory were trained a considerable number of chemists, many of whom became the teachers of the next generation. From these teachers and their pupils, guided by the same principles as those of the Giessen school, came discoveries of first-rate importance. If Hofmann, a student of Liebig's, had not been attracted to the study of aniline, an inconsiderable constituent of coal tar, if his pupil, Perkin, had not been led to a further study of its transformations, we should have had to wait a long time for the coal-tar dyes and the industries connected therewith. If a host of workers trained in Liebig's laboratory, and others emulating their example, had not cultivated the study of all sorts of carbon compounds, often unimportant in themselves, we should not have seen the numerous applications of chemistry to medicine—the saccharin, aspirin, antipyrin, sulphonal, &c.—nor the artificial perfumes, such as those of violet and lilac, which are now made independently of the original source in the flowers. Without the foundation work I have mentioned we could not now have the beginnings of the true physiology based on the study of chemical and physical processes and reactions, nor the possibility of following the changes brought about by all sorts of ferments, on the combined results of which we may hope to have a complete development of a scientific system of medicine and the treatment of disease.

But there is one other direction of Liebig's activity to which I have not alluded. Discoveries in the study of nature are of little value unless they can be communicated to that part of the world which can and will make use of them. Up to the end of the eighteenth century there were no means of publication except, on one hand, through the transactions of the half-dozen academies, and these were the only scientific periodicals, or, on the other, by the special treatises prepared by investigators for the purpose of making known their own discoveries or opinions. Thus we have the famous works of Robert Boyle on the Spring of the Air, and the Sceptical Chemist, Scheele's works on Air and Fire, Priestley's Experiments and Observations on different kinds of Air, Dalton's New Chemical Philosophy, and many others. The publication of such books was often accomplished only after years of preparation. In 1832 Liebig founded the *Annalen* which have ever since borne his name. Out of Trommsdorff's old *Annalen der Pharmacie* Liebig created a journal which has been for eighty years one of the chief repositories of the best products of the laboratories of the German Empire. Into this journal were poured the results of Liebig's and Wöhler's several or joint researches. At the time of Liebig's death, in 1873, 165 volumes of the *Annalen* had appeared, and there has been an equal number since that date.

I need do no more than mention the titles of the "Handwörterbuch" which Liebig, with the cooperation of his friends Poggendorff and Wöhler, produced between 1836 and 1856, the "Handbuch der Chemie" in 1843, and the famous "Letters on Chemistry," which were originally published as newspaper articles in the *Augsburger Allgemeine Zeitung* with the object of bringing within the ken of the general public some of the more important consequences of the advance of knowledge in connection with the affairs of everyday life.

Again, up to 1847, Berzelius had for many years prepared annually a "Jahresbericht über die Fortschritte der physischen Wissenschaften," but near the end of his life this laborious undertaking was no longer possible for him, and Liebig, in association with Hermann Kopp, the physical chemist, commenced the "Jahresbericht," which, so far as chemistry and the allied sciences is concerned, continues to this day. It is no longer so important as formerly, having fallen behind in date, but for certainly forty years it was indispensable to every practising chemist who was directly or indirectly interested in the progress of the science.

Since the days of seventy or eighty years ago, when Liebig set these enterprises in motion, the number of periodical publications devoted to recording advances in chemistry has greatly increased, and a number of journals now appear at regular intervals of a month, a fortnight, or even a week, which have become necessary in consequence of the specialisation which is characteristic of our time. We have therefore journals of inorganic chemistry, physical chemistry, applied chemistry, and some limited even to one topic, such as electrolysis or radium. Liebig's *Annalen*, however, continues to hold an honoured place in every chemical library.

Since Liebig's day we have advanced in many directions very far. Not only has the atomic theory given us by Dalton long since become the mainstay of the chemist, but we confidently assume, on good evidence, that we know the order in which these small bodies stand in a molecule of sugar, for example, and the relation of this order to the visible forms of the crystals in which such substances are often presented. We know, too, the relative masses of these minute bodies—the atomic weights, so called—and it is certain that these weights are directly connected with the properties of the bodies the atoms compose. There is also a relation among the atomic weights, which is broadly summed up in what is known as the periodic law, from the study of which most chemists are convinced that the so-called elements were evolved out of something of a simpler order, possibly one or two primal matters to which the term element would more properly belong. Nor is this all. Everyone has heard of radium, but few of the public, I suppose, know its history. Henri Becquerel, so late as 1897, observed that compounds of the metal uranium emit something which passes through many bodies opaque to ordinary light, and which renders the air around it conductive of electricity. Following up this observation, Madame Curie discovered radium. Radium is a metal in many respects like others previously known, but differing from them in the extraordinary power of throwing off electrically charged particles with enormous velocity, together with a remarkable gaseous emanation. According to the generally received view, which we owe to Prof. Rutherford, we are face to face with a process which is the reverse of that by which we may suppose the ordinary elements, or some of them, to have been formed. The decay of matter is thus indicated, and, though the process affects only minute quantities of stuff in the earth, it is sufficient to provide food for reflection to the geologist who wants to account for the rate of cooling of the earth and to the cosmogonist who can imagine the operation proceeding elsewhere on a far larger scale. There is temptation enough here to the speculative mind. Everything is now supposed to be expressible in terms of electricity, concerning the nature of which no one knows anything. Chemical action is attributed to exchanges of electric units, and matter of all kinds is supposed to be made up of the same. In the midst of all this confusion the clear duty of the chemist, at any rate, is to follow the practice inculcated by Liebig and stick to experiment, observation, and careful inductive reasoning.

One word in conclusion. The creation of a school of thought, such as that of which the chemical school at Giessen was the centre, requires originality as well as learning in the teacher, intelligence in the taught, and a sympathetic relation between professors and students. These are more important than buildings and appliances. But much influence is exercised by the environment; that is, by the attitude of the public. Appreciation of learning and interest in the results of research have long been provided more freely in Germany than in England. Though we cannot now admit, without qualification, the reproach of Liebig, already quoted, it is still true to some extent that what the public in England wants is invention rather than discovery; the applications of knowledge before the knowledge itself.

Some people will doubt, perhaps, whether we are so much behind Germany, "learned, indefatigable, deep-thinking Germany," as Carlyle called her. We have an immense amount of popularisation of the results of science, but it is to be feared that much of this is too easy, shallow, and misleading.

I think the difference between the two peoples is to be partly acounted for by the attitude of the Governments in the two countries. In England it is the custom to leave the investigation of many important subjects, like agriculture, to the chance of private benefaction or voluntary effort. In England, again, it is only in comparatively recent times that assistance out of public funds has been given to the universities. This attitude of the Government has an immense influence in directing popular views of institutions, of things, of men. That which the masses find placed in positions of advantage by the powers set over them are naturally held in higher esteem than those which are always kept in the background or in a position of evident inferiority. In Germany the university chairs are occupied by the greatest specialists in every department, and these are men who are honoured at Court, consulted by Ministers, and trusted by manufacturers. But, after all, when we have exhausted the enumeration of all the adventitious influences at work in both countries, it seems as though there were some elements in the mental constitution of the different peoples which leads them to handle the same subject of inquiry in different ways. It has been so in the study of chemistry.

At the beginning of the nineteenth century, with the aid of the principles bequeathed by Lavoisier, the facts which had been established by Priestley and Cavendish, the discoveries of Humphry Davy, and the atomic theory of Dalton, France and England were engaged in laying the foundations of the new science. At that time Germany had no chemists. Liebig himself bears witness, in his autobiography, that in his youth "it was a very wretched time for chemistry in Germany." During the latter half of the century there arose in nearly every German university a famous school of chemistry, and in practically all cases it has been a school for the cultivation of so-called "organic chemistry," in which department German chemists have achieved the most brilliant successes. Nothing can be more important than Kekulé's theory of the aromatic compounds. Nothing can be finer than the synthetical work of von Baeyer and Emil Fischer in connection with indigo, the sugars, and the proteins, or albuminoid substances, the chief basis of the animal tissues. But it cannot be maintained that they have been equally distinguished for the discovery of broad general principles. German triumphs have been more frequently the result of that patient attention to detail which seems characteristic of the German mind.

Take, by way of illustration, the problems which at the present time loom largest before the chemical world. There are first the relations among the atomic weights, discovered by Newlands, an Englishman, and worked out by Mendeléeff, a Russian; next, the arrangement of atoms in space, or stereo-chemistry, to which the clue was furnished by Le Bel, a Frenchman, and van 't Hoff, a Dutchman; next, the process of electrolysis and the constitution of salts in solution, of which by far the most important theory, the theory of free ions, was supplied by Arrhenius, a Swede. Again, there is radio-activity with all its consequences, the isolation of radium by Madame Curie, and the greater part of its wonderful history, worked out by Rutherford and Ramsay, both British chemists. To those great fields of inquiry Germany has, doubtless, made contributions, but she did not discover them.

My own impressions are strengthened by a passage which I will venture to quote from a modern work, "The History of European Thought in the Nineteenth Century," by Dr. Theodore Merz, himself a German, though domiciled in England. He says (vol. i., p. 300): "The largest number of works, perfect in form and substance, classical for all time, belongs probably to France; the greatest bulk of scientific work probably to Germany; but of the new ideas which during this century have fructified science, the larger share belongs probably to England."

After all, German chemistry can always point with just pride to the great teacher of us all, Justus von Liebig.

EXCAVATIONS AT MEROË IN ETHIOPIA.[1]

THE ruins of the Meroë were noticed so long ago as 1772 by the famous traveller James Bruce; but his identification was not generally accepted, and it was not until three years ago that Prof. Sayce, in the course of an official inspection on behalf of the Sudan Government, recognised that unquestionably they were the remains of Meroë, and invited Prof. Garstang, then at work in Egypt, to undertake the excavation.

The Government of the Sudan encouraged the work by facilities and assistance, including the construction of a railway siding, the provision of water tanks, and materials. In this way the wants of 500 or 600 workmen were provided for. The camp became a stopping place for certain trains, which brought provisions, and it marks the site of a new station which will shortly be available to visitors. Practically nothing of the ancient city was visible above the soil when the party arrived upon the scene—no ruined buildings or connected walls, only mounds of débris and a few carved stones here and there—for the well-known pyramids of Meroë that mark the spot lie back several miles in the solitude of the desert.

The gates of the city opened, as it were, one by one before the ordered and methodical attack of the excavator's trained Arab workmen. Great temples, royal palaces, and public buildings emerged gradually from the sands; the city walls and gates and quays stood once more in their places; colossal statues, altars, and public monuments disclosed their whereabouts; the tombs yielded up their secrets; and numbers of small, artistic remains were trapped in the busy sieves.

[1] From the Guide to the tenth annual exhibition of antiquities discovered at Meroë, and the second interim report upon the excavations, by Prof. J. Garstang.

In addition to the visible results, archæology has received some new and important contributions, for, until this work was undertaken, nothing was known of the subject of the Ethiopian civilisation from the specialist's point of view, and this fact naturally doubled the difficulties of an excavation of this kind. For this reason, primarily, the first experiments (season 1909–10) were made in the tombs and isolated knolls, as being the most accessible sources of information as to the character of ordinary Meroitic objects.

The tombs, being of unknown type and securely cemented down, for some time baffled the workmen, but at last there came to light some thousands of vases—found, in some instances, as many as thirty or forty in a single tomb chamber. They were all of a style new and peculiar, without any noticeable trace of Egyptian influence. In the tombs furthest to the north vases of a special and rare kind were recovered made of thin pottery, decorated with paintings in colours (the subjects being animals, trees, or natural features), or with designs stamped upon the clay. Similar vases in more perfect state were found in 1911 among some ruined buildings in the west of the city area.

FIG. 1.—View in the Temple of Amon. Place of sacrifice in the foreground, the high altar beyond.

In addition to pottery vessels there were in the tombs a variety of objects not merely funerary in character.

In obedience to primitive instinct, the dead was laid to sleep on his bed in his subterranean chamber surrounded by the things which would be to him the most useful upon his awakening. The soldier had his weapons (sword, lance, dagger, &c., all of iron); the huntsman his bow and arrows—even his hounds were sometimes sacrificed with him. The women had equally their beads and their jewels. In a few cases the frame of a decayed wooden bed might be traced; and in every tomb the vases and dishes seemed to have contained drinks and food. It is probable that originally one of the doors was left so that it might be opened for the regular renewal of the offerings.

While this experiment was in progress, the position of the great temple of Amon was determined, and the task of uncovering it was begun. The entrance proved to be a pylon in the Egyptian style, and the central aisle leads through a series of columned halls to the sanctuaries, at a distance of 130 yards, beyond which the temple abuts on the great wall of the city. Towards this end, in the main axis, there still stood the high altar, carved in a single