SECTION III.

PHYSICS, CHEMISTRY, AND BIOLOGY.

ADDRESS.

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PRESIDENT OF THE SECTION.

I HAVE been honoured by the selection of your Council to preside over this Section, which, though greatly occupied with theory, may be looked upon as dealing with the very foundation of practical sanitary work. It is therefore my duty, nay, should I not say my privilege, to give a cursory review of some, at any rate of the more important, advances that have been made in sanitary science in recent years.

I wish I had the power to put before you in the form of brilliant epigram or pointed aphorism some of the truths that we have daily to study, to deliver an address that might be destined to become classical, not only because of the patient display of accumulated facts and observations, the logical accuracy of the deductions and the brilliance of the theories put forward, but also because of the concise description and beauty of diction. I can lay claim to little of all this. My one merit must be that I desire to lay before you a plain unvarnished tale, leaving you to draw your own deductions, and fill in the framework of a very incomplete and skeletal structure.

The history of sanitary science might, if we allow our fancy some rein for a few moments, be compared to the history of geology as put forward by its modern exponents. We may at one time have been somewhat inclined to adhere too strictly to the old cataclysmic theories, and to consider that unless some new thing or startling development was announced at every Sanitary Congress, or at every meeting of the British Association, the progress of the preceding year or years had been but little of which to be proud; the slower processes, corresponding to the mighty but not easily observed workings of Nature, were, and even now too frequently are, passed over as having little significance, and the year is written down as almost barren, though in many ways it may have been one of extreme fertility.

It may appear to be paradoxical perhaps, that it is sometimes necessary to recall the fact that we are not contemporary with all progress, and with all that makes for a healthy and active people. It may be, and no doubt is, true that we are in many ways favoured beyond any of our predecessors, but just as we now regard the luxuriant verdure flanking the river that flows down the broad-based valley as the temporary but ever-recurring product of a soil which is the outcome of multitudinous geological epochs and changes, so we must remember that the sanitary science of to-day is but the logical outcome of the work of many great minds applied to problems under conditions very multitudinous and constantly changing, until in our own time we have the systems of which we are so proud, but many of which in turn must give way, some in details only, some in principle, to those better suited to the conditions of the future, founded not only on what has gone before us, but also upon the experience of the work done to-day.

It should be an encouragement to all of us that we are not working for the present alone, but that each one who makes his contribution to the science of the present is adding his quota to the advancement of the welfare of his successors, and that although our theories may afterwards be overturned or set aside to give place to others founded on a broader basis, no demonstrated fact, no scrap of honest work of any kind done to-day can ever be entirely lost; it must exert some influence on the work and knowledge of to-morrow.

Had there been no Jenner, there could have been no Pasteur, no Lister, no Koch. The same may be said of every man who is working at sanitary science—we should all have been in a sorry plight had it not been for those who have gone before us. Indeed, in this connection I am often reminded of a saying attributed—with what truth I know not—to Professor Tait, that "our greatest plagiarists are our predecessors."

In the short time at my disposal I should like to say something on three subjects. I select three because they are those of somewhat general interest on which I have had some opportunity of forming an opinion, based on personal observation. On certain points we may differ, but I would have you believe that whether my views are the same as yours or not, I hold to them only after being at some trouble to determine what basis there was for my belief. Each one of us feels that he can speak more authoratively and effectively of that on which he has been personally engaged, and of which, therefore, unless he be very careless and superficial, he has gained some special knowledge, than he can of the work of others however carefully he may follow published details and arguments.

Tuberculosis.

It will suit my purpose best to deal first with a couple of typical examples of the kind of effort that is now being made by those who have charge over the health of the community.

Recently many rapid changes have taken place as regards the light in which we view certain of the infective diseases, but in no two diseases have the changes been so startling, so kaleidoscopic as in tuberculosis and diphtheria.

Twenty years ago the former of these diseases was looked upon as one with which it was almost hopeless to contend with any great prospect of ultimate success, a conviction which is only now being gradually eradicated from the "lay" mind. In regard to diphtheria the outlook was almost equally gloomy up to five years ago. The spread of the knowledge of the laws of health amongst medical men, amongst corporate bodies, public societies and individual laymen had during the last few decades done something to illumine a very great darkness, and tuberculosis and diphtheria were being systematically sapped and mined by most earnest workers, but advance was slow, and many were becoming discouraged.

With Koch's, Loeffler's and Behring's discoveries, however, a new epoch was commenced, the full development of which is even now awaited with the keenest anxiety.

What we know of tuberculosis already has brought home to us the fact that here we have a shield which has two very different aspects. On the one, the dark side, we have the fact that tuberculosis is a parasitic, infective disease, which readily attacks groups of animals of widely different species as soon as these animals are, under certain well-defined conditions, brought into contact with man. Until the *fons et origo* of this disease had been traced by Koch our knowledge of the infective nature of the disease, and of the widespread distribution amongst animals other than man, rendered the outlook still more grave than it now is. Another "quarter" in this dark side of the shield is that after the disease has reached a certain stage there appears to be no possibility of checking its course, whilst we have very strong evidence that, although the specific cause of the disease, the tubercle bacillus, is a markedly pathogenitic organism, and can multiply outside the body and on dead matter only with difficulty, it can nevertheless remain alive and capable of doing harm for a considerable length of time, and under conditions which are only now coming to be fairly well understood.

On the other side of the shield, however, we have a somewhat brighter picture, a picture which gives us encouragement in carrying on our warfare against this scourge of the human species inhabiting the temperate zone.

In the first place, as in so many of the other specific infective diseases, we now know that there can be no tuberculosis without the presence of a specific micro-organism, in this case, the tubercle bacillus. Only those who have had to fight against shadows and to contend with ghostly and unsubstantial causes of disease can thoroughly appreciate the comfort of having a distinctly concrete if not very massive foe to combat. Even those who are engaged in purifying our rooms, our water supplies and our drains can enter upon their task with greater gusto and therefore with infinitely better prospects of success than was formerly theirs, because they feel that most of the specific infective fevers have for their causal agents fairly well-defined and moderately easily recognisable micro-organisms. How much more must this be the case with the physician or surgeon who is constantly called upon not only to treat diseased conditions but also to advise as to the best methods of guarding and fortifying his patients against the attacks of these very real, though very insidious, foes.

No tubercle without the tubercle bacillus is a statement which might in recent years have given much needed comfort to members of nearly every family in the kingdom, whilst it opens up a vista to farmers and cattle breeders that only those who know that nearly 50% of our dairy, and therefore our breeding cattle, tested with tuberculin react to the test, can appreciate in the slightest degree. This statement means that no member of a tuberculous family need despair of evading the dread enemy of his race. The children of tuberculous parents may be placed under such conditions that they will never contract the disease. They do not inherit tuberculosis from their parents though they may inherit those weaknesses of tissue and constitution which render them peculiarly liable to succumb to the attacks of the parasites that in their parents are doing such damage. Strengthen the tissues, build up the constitution by good food, fresh air and exercise, and whilst you are doing this, place the child under such conditions that the tubercle bacillus can gain no access to it, and by-and-bye there will come a time at which the attacks of the bacillus are as futile as they are against the child who inherits from his parents all those protective agencies with which healthy individuals are endowed for the warding off of the onslaught of pathogenetic micro-organisms.

Let us take a concrete example—many valuable herds of cattle in this country are so tuberculous and suffer so from "glands," that when the tubercle bacillus was first described and the hereditary theory of tuberculosis still maintained, it was feared that it would be necessary to sacrifice most valuable cattle in order to eradicate the disease, or at any rate to get rid of tuberculous dams. Naturally there was great reluctance on the part of owners to adopt such a drastic measure as the wholesale slaughter of valuable, though tuberculous breeding stock. That such a course was not necessary was maintained by many who did not believe in the hereditary transmission of tuberculosis, and now Bang of Copenhagen has proved by actual experiment that it is possible to obtain a perfectly healthy progeny from tuberculous herds, if care be taken to remove the calves, as soon as they are born, from the tuberculous mothers, and to feed them on milk originally free from tubercle bacilli, or so heated that any bacilli present are destroyed. It will of course be evident that if the womb of the cow is tuberculous the calf may be born into the world suffering from tuberculosis, but that is because the bacilli in the lesion of the womb have made their way into the tissues of the embryo calf. This is not a true hereditary process, it is rather a condition transmitted from the dam to the calf, the bacillus passing directly from the tissues of the one to the other and only in those cases in which the womb is the seat of tuberculous lesions. If the womb be not affected (when it is so affected the calf is frequently slipped—tubercular lesions in the womb being a recognised cause of abortion in cattle) however widespread the disease may be in other parts or organs the calf is not affected, and it escapes the disease altogether provided that it be removed from its dam and protected against the attack of the tubercle bacillus by any of its many channels of invasion. This is a most important addition to our knowledge, for through it we have the assurance that in process of time we should be able to stamp out the disease in cattle if we can only put the rising generations under conditions favourable to the building up of sound healthy bodies and unfavourable to the multiplication, development, or persistence, of the tubercle bacillus. If this is true in the case of cattle, should it not also hold good where the human subject is concerned. Our methods may have to be modified or altered, and difficulties not met with in the case of cattle may here present themselves, but there can be no doubt that what will ultimately (and from what one can see, ere very long) be done by stock breeders and their advisers will have to be tackled in good earnest by doctors and sanitary authorities.

I may perhaps be allowed to give my reasons for being so hopeful on this score. Early in the present year I received an invitation from the Cheshire Chamber of Agriculture, to deliver a lecture and open a discussion on tuberculosis as it affects dairy farming, stock breeding and feeding. I was astonished and delighted to find that the discussion that followed was not confined to the medical officers of health present, but that country squires, tenant farmers, cattle breeders and butchers, all of whom seemed to have been giving some attention to the subject, came forward to give their experience or to ask for further information. Those speaking not only desired information, but gave evidence that they were anxious to act in conjunction with and follow the advice of those whom they deemed worthy of their confidence. Professor Delépine tells me that he had a similar experience at Keswick, where at the invitation of the Rev. Canon Rawnsley, he delivered a lecture before an audience consisting of farmers, county and other council authorities, and a number of others interested in this question. Quite recently it has been my privilege to listen to another lecture by Professor Delépine, given at Lord Vernon's request, at Sudbury, Derbyshire, where a most interested audience of farmers, medical officers of health, and others, including the Rt. Hon. Walter Long, President of the Board of Agriculture, Sir William Broadbent, President of the Association for the Study and Suppression of Tuberculosis, Sir James Crichton Browne, Professors Hamilton and Boyce, and Drs. Buzzard, Niven and Ransome, and Dr. Livesey, Lord Vernon's adviser in these matters, had gathered. Incidentally, the question of the use of tuberculin was brought up, and the President of the Board of Agriculture (who very properly insisted that the farmers and cattle keepers should not be the only people called upon to take steps for the eradication of tuberculosis, when we are aware that so many other more important channels of the spread of tubercular infection exist) asserted that he had not the slightest hesitation in saying that, once those in authority were convinced that tuberculin was thoroughly relied upon and generally accepted by scientific experts and practical veterinary and medical authorities as an almost unfailing means of making a diagnosis in doubtful cases of tuberculosis, they would empower him to make arrangements for the supply of tuberculin to qualified veterinary surgeons throughout the kingdom for the purpose of testing cattle. Now-a-days unless some fee were paid along with the cost of the tuberculin the claim on the Treasury would amount to a most insignificant sum, but the weight of the sanction of the Board of Agriculture in such a matter would be so important that the influence of the mere money-grant might be left entirely out of the question.

Every investigator who has used tuberculin as it should be used, and under conditions now much better understood than they were even a couple of years ago, knows that the tuberculin re-action is almost specifically diagnostic; most of those in this room are convinced that whatever may be the value of Koch's tuberculin as a therapeutic agent its value in diagnosis in obscure cases of tuberculosis is almost incalculable, and, I think, we should be greatly strengthening the hands of our veterinary brethren and assisting both farmers and medical officers of health were we to send from this Congress to the President of the Board of Agriculture a resolution to that effect.

Such questions as "Tuberculosis and its relation to meat and milk derived from tuberculous cattle," "The death-rate amongst children from abdominal tuberculosis," "The incidence of meningeal tuberculosis in early life and of pulmonary tuberculosis in later years," "The effect of moisture," "of ventilation," "of light," and of various other agents upon tuberculosis have all been discussed, and the best means of getting rid of this disease have from time to time been brought before this Congress, but I feel convinced that if for the next year or two we devoted our energies to pointing out that wherever there is tuberculosis there must be the bacillus, and then to indicating that the converse may hold good, pointing out the various positions in, and the conditions under which, the bacillus may be carried from host to host, and at the same time combat the notion that tuberculosis is hereditary, and insist that in its early stages it is a most curable disease, we shall be going still further in the direction of creating an intelligent appreciation of what can be done to stop the spread of the disease and bringing comfort to many who at present look upon a certain proportion of their children as doomed to an early death from tuberculosis.

Within the last year or two the medical officers of health of Glasgow and Freebridge Lynn Rural District Council, and no doubt of other towns and districts have drawn up most admirable circulars dealing with the treatment of tuberculous patients, giving both general and detailed instructions for the prevention of the transmission and distribution of the infective material. These leaflets, spread broadcast by the sanitary authorities, are calculated to do an enormous amount of good, not merely as they effect immediate action, but because of the powerful educational influence they must exert upon those amongst whom they are distributed, and I for one should like to see them adopted by every medical officer of health and sanitary authority in the kingdom, not only in regard to tuberculosis, but also in dealing with other specific infective diseases. With all these signs of deepening interest in this subject amongst all classes, and with the above examples of the efforts made to spread information on the question of the causation and treatment of tuberculosis before us, I am convinced that during the next decade we shall see a marked diminution in the death-rate from tuberculosis, and I hope that this Section will be able to take its due part in bringing about of a consummation so devoutly to be wished.

Diphtheria.

For the last three or four years most of us have been carefully noting the results of the antitoxin treatment of diphtheria. For my own part, I may state at once that I am satisfied that where antitoxin is given early enough and in sufficient quantity it is practically a specific in the treatment of diphtheria. It may be asked, why then does not diphtheria disappear from amongst us? To those who have studied the genesis of the disease the answer is simple enough. Although antitoxin can never take the place of improved sanitary conditions in doing away with the breeding places of the diphtheria bacillus outside the human body, it may be looked upon as an almost perfect protective against the action of the diphtherial poison in the body. As regards the curative action of antitoxic serum, I have little new to tell you beyond the fact that during the year 1897 the death-rate from diphtheria in the hospitals of the Metropolitan Asylums Board fell to a still lower figure than in any previous year, the mortality last year being only 17·5 per cent., a figure that at one time would have been looked upon as absolutely chimerical, taking into consideration the fact that so many of the cases have already been under treatment for considerable periods, and are only sent into hospital either for surgical interference, or because there remains little hope of recovery outside. Amongst cases of post-scarlatinal diphtheria there has been a still greater falling off in the mortality. At one time something like 60 per cent. of the convalescent scarlatinal patients who afterwards contracted diphtheria succumbed. Now under the antitoxin treatment, in one hospital of which I have statistics the death-rate is about 2 per cent., whilst in another nearly 100 cases were treated last year without a single death.

Now, gentlemen, does not all this point in one direction, and in one direction only? Wherever there is an outbreak of diphtheria the first thing to be done is to inject not only the patient with a curative dose, but all who can possibly be exposed to infection with a protective dose of antitoxin. This is the only logical outcome of the experiments and experience of the last few years. It has been proved up to the hilt that whichever agent, toxin or antitoxin, first gains access to the tissues, it holds the field, except against the attacks of enormously greater quantities of the other. If the diphtheria toxin gets in first and is left unmolested for some time it so makes good its position that it can with difficulty be ousted or neutralised and then only by large quantities of antitoxin, whilst on the other hand small quantities of antitoxin already circulating in the fluids of the body can render innocuous the attacks of comparatively large doses of toxin. Now that antitoxin is so much more potent than it was at one time and that the conditions of preparation and storage have been so much improved, most of the objections to the administration of protective doses have been removed, and the advantages to be gained are so great that I look forward with confidence to the time when this method of assisting sanitary administrators will be received with the favour that it deserves. It is a step which may be taken at once as soon as there is even a suspicion of the presence of the disease, the earlier the better; it is not even necessary to isolate immediately, as all those injected are at once protected. It does not in any way interfere with the carrying out of sanitary improvements, and although it does not ultimately take the place of these improvements it protects the inmates of the infected houses whilst the improvements are being carried out.

In this matter we are much behind our brethren in New York, where, as Dr. Hermann Biggs informs me, they have brought down the mortality from diphtheria at least one half. The whole question of the prevention of diphtheria has to be re-opened. By ventilation and good drainage two things may be effected. All possible breeding grounds for the diphtheria bacillus may be removed and the protective coverings of the body, the epithelium of the throat, nose and lung maintained in as efficient a condition as possible, whilst the cells and fluids in the body which deal with straying and wandering organisms may be kept vigorous and healthy. The presence of the diphtheria bacillus in the throat of a patient should be looked upon first as essentially a means of diagnosis, but then also as a danger signal, for it may be accepted that wherever these bacilli occur in the throat they give indication of two things (*a*) that diphtheria toxin is being continuously formed in larger or smaller quantities and (*b*) that the patient is a source of danger as a centre of infection to all, especially children, with whom he may be brought in contact.

Bearing all this in mind may we not hope that ere long something like the following routine will be observed in outbreaks of diphtheria. In every suspicious case of throat mischief a swab will be taken and a microscopic and cultural examination made, and then without waiting for the result of this examination, an injection of antitoxin given. Should the case prove bacteriologically to be one of diphtheria, injections will be given to all those (especially children) who have been exposed to the infection, and none of these will be allowed to go back to school or come in contact with other children not so protected until it has been proved that they harbour no diphtheria bacilli in their throats. This rule should apply to patients as well as to those not actually suffering from the disease but with the bacilli in their throat. It may be objected that in certain cases it takes months to get rid of the bacillus from the throat. I have seen one or two cases out of 12,000 examined in which the bacilli have remained demonstrable in the secretions of the throat for eight months. In all of these cases there appear to have been abnormal conditions in the tonsils—hypertrophy, follicular enlargement, &c., but that such cases do occur affords food for very serious reflection, and indicates that we are not even yet sufficiently careful to disinfect throats and isolate for long enough periods, patients who may be dangerous centres of infection long after all naked-eye evidence of diphtheria has disappeared. The isolation of those cases in which diphtheria bacilli persist would, of course, be attended by great difficulties and inconvenience, and it might be necessary to make some special provision for the carrying on of the education of the infected children, but even if this could not be done it is surely a far less evil that the education of a few children should receive a temporary check than that they should prove a source of infection to schoolmates and playfellows.

I believe that by *early injection in all cases which may turn out to be diphtheria* the percentage mortality will be still further greatly reduced, whilst by a combination of protective injection with strict isolation and disinfection of every throat, whether apparently healthy or not, in which diphtheria bacilli are found the incidence of the disease would be enormously diminished. Such has been the experience in New York and such it would be with us. Remember that here universal injection is not necessary, it is merely a precautionary measure to be applied in cases where there is a danger that infection may have been carried before the disease has been recognised, or before arrangements can be made for the isolation of a known centre of infection. I am convinced that we are not asking too much in this matter, and that given a fair trial the adoption of this system would be followed by a diminution in the number of cases and deaths from diphtheria, such as those who have not gone into the question can have little idea of. It is for you, gentlemen, to bring this home to every individual with whom you have the slightest influence or authority.

The Treatment of Sewage.

At the recent meeting of the British Association at Bristol, Sir Wm. Crookes, F.R.S., in his most able and interesting presidential address, called attention to the fact that in the very near future wheat growing land will be so far brought under cultivation that with the present crops there will be a "shortage" in the wheat supply of the world. On the other hand he points out that by the proper use of nitrates, the supply of which, however, is by no means unlimited, the crops, per acre, could be so increased that for the immediate future we, the wheat consuming races, need be under no very great apprehension that they will starve. The supply of natural nitrates giving out, Sir Wm. Crookes very naturally turns to the chemist and the electrical engineer of the future for an economical method of fixing the nitrogen of the atmosphere in such a form that it may be utilised as food by plants and especially by wheat. But he points out "that there is still another and invaluable source of fixed nitrogen, I mean the treasure locked up in the sewage and drainage of our towns. Individually," he says, "the amount so lost is trifling, but multiply the loss by the number of inhabitants and we have the startling fact that in the United Kingdom we are content to hurry down our drains and water courses into the sea, fixed nitrogen to the value of no less than £16,000,000 per annum."

Compare this with the statement by Mr. Clare Sewell Read, commented on by Dr. Poore on page 103 of his "Essays on Rural Hygiene." "Sewage," he says, "has come to be regarded by all sensible people simply as a nuisance to be got rid of." These statements are both undoubtedly true; how are they to be reconciled? In sewage we have the solid excrement and urine from what Dr. Poore calls "wheat-eating animals;" in these should be, and are contained, most of the special elements necessary for the building up of the wheat plant—probably in the best proportions—could they be readily assimilated. As is well known by farmers, however, the substances in the solid excrement must undergo very considerable breaking down and rearrangement before they are available for the use of most of the plants. Put this in the ground, but near the surface, and a process of disintegration and oxidation commences and goes on, through which the nitrogen locked up is gradually set free in simpler or more readily assimilable form. Nitrates are produced and plants are nourished.

Dr. Poore has shown that cabbages are capable of extracting nutriment from excrement almost directly, but that wheat is somewhat more fastidious and must have its nitrogen in the specific form of nitrate or ammonia salt. It is of course held that this slow liberation of nitrates, &c., is favourable to the continuance of the manurial action over comparatively long periods, and that the plants are able to assimilate the nitrates as they are formed.

Artificial nitrates put on to the ground may be used up should there be no heavy floods to wash them beyond the roots of the plants for which they are intended, but with such floods much may be lost; the amount lost in this way from natural manure must on the other hand be very small. On coming to examine the process by which this natural manure is broken down, we find that the disintegration takes place best in the upper layers of the soil in which micro-organisms are present in large numbers, and that the longer this soil is used for this purpose the more active it becomes, *i.e.*, the micro-organisms become more active because (1) they increase in numbers, and (2) they become more energetic in the special direction in which they are called upon to exert their powers. We have probably a process of natural selection—in the true meaning of the term—going on. Those organisms that can live best under the new conditions flourish and increase in power and activity, and others which might interfere with their work are gradually ousted. The solids constitute only a certain proportion of the substances of manurial value of sewage. When they can be placed directly in the soil, at once the best and most economical results are obtained. It must be remembered, however, that much of the solid matter in water-borne sewage can never be brought into contact with the soil, except after carrying it for long distances; and water carriage has come to be looked upon as being so easy and so economical that other methods have gradually been discontinued in our large towns. The great objection of this method is that feculent matter is not, under ordinary conditions, broken down in water nearly so readily as it is in the soil; and in all processes hitherto used in the treatment of sewage, the sedimentation, separation, and disposal of the solid matter have not only increased the cost of working, but have rendered the sewage less valuable as manure. The mixture of the urine with sewage is not open to the same objections. The dilution with slop-water renders urine (which, as Dr. Poore points out, is at least twenty times too concentrated for application to plants) more suitable as a manure. It has been calculated that the daily production of urea by the human race alone, reckoning the quantity excreted by each individual at the low average of 25 grams, is something like 73,500 tons, containing 17,000 tons of combined nitrogen. (The present value of this nitrogen in the form of nitrate of soda would be nearly £1,200,000.) This valuable material cannot however be utilised directly; it must, before its nitrogen can be used, be fermented or hydrolised into carbon dioxide and ammonia, and then to get the full use of the fixed nitrogen it should be converted into nitric acid and nitrates.

It is extremely probable that the organisms (and the enzymes they produce) that bring about these conversions are far more numerous than we appreciate, as this conversion of urea, first into ammonia and then into nitrates, is taking place in all sorts of places and under very varied conditions. It is, however, very frequently going on where it could well be spared, and again in many cases the resulting products are utterly wasted. In recent years some of our best men have devoted much time and energy to the solution of the problem of sewage disposal, not at a profit but without incurring any great loss. Great advances have been made, and last year one of the most interesting discussions at the Congress was that dealing with bacteriolytic sewage beds. Dibdin, to whom we are indebted for his most valuable experiments on coke breeze beds, and his extension of the Massachusetts experiments; Scott Moncrieff, for his addition of the anaërobic bed to the oxidising plant; Adeney, for his experiments on the oxidation of the carbon and nitrogen elements; Cameron, and many others have made valuable contributions to this most important subject.

During the last few months I have had the opportunity of checking some further experiments carried on by Mr. Scott Moncrieff, and I have been delighted to find that the figures obtained by Rideal and Scott Moncrieff as to the formation of nitrates are not by any means exceptional and that there seems to be some prospect that in the immediate future much of the fixed nitrogen in sewage, that at present goes to waste, may in the form of nitrates be returned to the soil and so to the vegetable products, and especially to wheat, for which the demand is likely to increase so greatly in the near future. Every gram of nitrate that can be rescued from sewage will be a clear gain to the community, and the work of the chemist of the future will be so much lightened.

I do not intend to give you any great array of figures, but I may, merely for the information of those who take an interest in this question, give the following:—On five occasions the sewage treated in the Scott-Moncrieff trays was examined as it came from the last tray; and the average amount of nitric nitrogen found was 6·82 parts per 100,000; free ammonia ·23 parts, and albuminoid ammonia ·104. This latter ranging from ·09 to ·135, the free ammonia in all of the samples except one in which it rose to 1·27, was very low:—in this latter sample, too, the nitric nitrogen was the lowest obtained in any of those examined, 5·349 per 100,000. It would be a simple matter to calculate the amount of nitric nitrogen that might be recovered from the Birmingham sewage alone. I leave this, however, to those who have the necessary data at their disposal. The great fact brought out is that Pasteur, when he insisted upon the specific activity of different groups of micro-organisms and the power they possess of taking up putrefactive and fermentative processes at different stages and each of carrying the disintegration of organic matter a step further, had grasped the whole secret of bacteriolysis. After studying his work and that of his school I wrote the following passage in 1890, and I believe that what was then written may to-day stand *verbatim* as an accurate description of the *mineralisation* of organic matter:—

"It would appear in fact as though there were developed special organisms for the setting up of special fermentations, and also that after the breaking down has been carried a certain length by one organism, the aid of another is invoked to complete the process more thoroughly and more expeditiously. We have in this, as in the case of the process of digestion, an exemplification of the fact that nature economises her resources as much as possible: she does not call on the animal cells of the alimentary tract to do work that can be equally well done by micro-organisms, nor does she demand the exercise of more than one or two functions from each of the protoplasmic specks that we call bacteria. To each one is assigned its special work, and though it is possible that many of them started with certain powers in common, it seems that through the exercise of some of these common powers under special conditions they have become so differentiated functionally, that, as amongst organisms more highly developed, each is able to carry on its own work best at those special stages of the putrefactive process at which it is found. It might at first sight appear that all this can have but little bearing on any practical work in which we are engaged, or in which we take an interest, but on more careful consideration it will be found that these putrefactive organisms really keep up the circulation of matter, utilising the excretions of living beings and the carcases of dead animals and plants, after breaking them down into their simplest constituents, to supply those elements that are necessary for the nutrition of plants, allowing them to present themselves in their most assimilable forms, and in the proportions most suitable for the nutrition of the growing, highly organised vegetable protoplasm. Bacteria in fact serve to transform inert organic matter into organic substances. This transformation or '*Mineralisation*' in most cases commences only after protoplasm has lost its vitality, and most micro-organisms are capable of attacking this dead protoplasm only; though, as we shall find later, a certain number of bacteria have acquired the faculty of being able to attack even living protoplasm. The process of decomposition may be divided into two kinds; first, those going on as the result of the activity of organisms that are capable of taking up their oxygen from the air, and, second, those the result of the activity of organisms that so break up and re-arrange the organic molecules containing oxygen, that not only do they, the bacteria, take up oxygen themselves, but they allow of its being handed on to the product, to which in their processes of metabolism they give rise. It is probable that here we have to do, not only with nascent oxygen, but that we have certain products set free during the process of decomposition which seize upon oxygen with very great avidity. This decomposition or re-arrangement is spoken of as a process of nitrification or a conversion of the nitrogenous elements into ammonia, nitrous and nitric acids, carbonic acid and water, or speaking more generally, it may be said to be a process of mineralisation of the organic forms of nitrogen, phosphorus, carbon and hydrogen, during which they become finally oxidised or mineralised to nitric acid (HNO_3), phosphorus acid (H_3PO_4), carbonic acid (CO_2), and water (H_2O). In nature this process goes on in the superficial layers of the earth or in the presence of the atmosphere. That it takes place much more readily near the surface of the ground and in porous earth can easily be understood, if what takes place in the oxidation that goes on in spongy platinum is borne in mind."

We are sometimes in our search for truth discouraged by our apparent want of success, or we are embarrassed by the croakings and moanings of men who after doing good work and advancing to a certain stage have stopped, perhaps discouraged by want of apparent success, or, it may be, having no longer the energy to continue a work well begun. Advances in sanitary science will outlast the longest lived amongst us, and we may well be anxious if we can no longer carry the torch, to hand it on to those who have strength and ability to carry it beyond the heights to which we have been enabled to attain. Let us remember the story in the Arabian Nights—that ever flowing fountain of pleasure and allegory for children of all ages—of the prince who went in search of the singing waters. When he came to climb the hilly road up which he must travel to be successful in his quest, great rocks and ponderous stones appeared to spring up in his path, and voices, seeking to discourage him, tried to prevail upon him to return. The obstacles overcome and a deaf ear turned to the cries, he was at length successful in his quest; then a spell was broken, the stones were turned to men from which the voices had come—men, every one of whom had started out to seek the same waters, had reached a certain height, but had then failed and attempting to turn back had immediately become fossilised into obstacles to further progress up the mountain. Had they continued to fight, however feebly, and to advance, however little, they might still have encouraged those younger and more energetic than themselves, and by offering them their own experience have enabled them to start at the point at which they themselves had arrived.

It is one of the great features of the age and the race to which we belong that much of the work to which men apply themselves is of such a nature that every step brings the worker to a point from which a further advance may be made.

For three hundred years now, men's thoughts and minds have been turned to the study of the great forces of Nature. Art, Literature, and Literary Philosophy, if we may so speak, are in themselves no longer sufficient to occupy the minds of men, or to develop to the full the vigour and alertness so characteristic of present day workers.

As Sir William Roberts so ably pointed out in his Harveian Oration on "Science and Modern Civilisation", delivered in 1897, "wherever we look—in all ages, among all peoples—we encounter the same story with regard to that large and varied and most precious outcome of the human mind, which may be grouped under the categories of the fine arts and literature. There is a history of improvement and growth up to a certain culmination or phase of maturity. Beyond that point no further growth seems possible, but rather, instead, a tendency to decline and decadence." "The evolution of science," he goes on to say "differs fundamentally from that of literature and the fine arts. Science advances by a succession of discoveries. Each discovery constitutes a permanent addition to natural knowledge, and furnishes a post of vantage for, and a suggestion to further discoveries. This mode of advance has no assignable limits; for the phenomena of nature—the material upon which science works—are practically infinite in extent and complexity. Moreover, science creates while it investigates;

it creates new chemical compounds, new combinations of forces, new conditions of substance, and strange new environments— such as do not exist at all on the earth's surface in primitive nature. These new natures as Bacon would have called them, open out endless vistas of lines of future research. The prospects of the scientific enquirer are therefore bounded by no horizon, and no man can tell, nor even in the least conjecture, what ultimate issues he may reach." Our poets, artists, and philosophers of to-day are no greater than those of China, of Greece, or of Rome. We have no greater than Milton or Shakespeare now with us who can improve on the masterpieces of byegone ages. But the youngest student of natural and physical science has at his disposal a basis on which he can form, and material from which he can build up a structure that fifty years ago could only have been dreamed of.

We have received a bright inheritance. It rests with us to hand it on, not only untarnished, but with an added lustre, to our successors.