research committees, and it is scarcely too much to say that every pound of this large sum has been well expended. The grants are allocated each year by the Committee of Recommendations, which usually consists of the presidents and recorders of the various sections, together with the general officers. Every research committee has thus to present its case for support to an expert body of adjudicators which frequently devotes several hours to dividing up the 1000*l.* or so available at the end of each meeting into grants of 5*l.* and upwards for research committees put forward by the sectional committees. It has been suggested that in view of other claims upon the revenue of the Association the funds devoted to purposes connected with research should be more closely limited to incidental expenses inasmuch as other funds are now available to assist research itself. However this may be, the principle by which men of science themselves allocate grants in aid of research, as they do at a British Association meeting, is generally accepted to be the best, whether the funds are their own contributions or are entrusted to them for research purposes. The Association is, therefore, to continue the present system by which grants are allocated by the Committee of Recommendations, but the list of grants so made is afterwards to be submitted to the Department of Scientific and Industrial Research, which will select subjects it can support, and will relieve the Association of the financial obligations relating to such subjects.

It remains to be seen whether this method will provide the most effective link between the Department and the Association. A joint Committee, consisting of four members appointed by the General Committee, and four by the Council, is to inquire into the whole matter of the existing provision of grants in aid of scientific research and the organisation of research. No change in the Association's method is contemplated, but there is a feeling that a useful purpose would be served by a survey of what is now being done to promote research through grants in aid by various societies and other bodies, the methods by which such grants are allocated, and the conditions to be fulfilled by the recipients.

Next year's meeting is to be held at Cardiff under the presidency of Prof. W. A. Herdman, who has been succeeded as general secretary by Prof. J. L. Myres. An invitation to meet in Edinburgh in 1921 was unanimously accepted by the General Committee. The new members of the Council of the Association are: Prof. A. Fowler, Dr. E. H. Griffiths, Prof. A. W. Kirkaldy, and Dr. W. H. R. Rivers.

SECTION A.

MATHEMATICAL AND PHYSICAL SCIENCE.

OPENING ADDRESS BY PROF. A. GRAY, M.A., LL.D., F.R.S., PRESIDENT OF THE SECTION.

I HAVE devoted some little time to the perusal of the addresses of my predecessors in this chair. These have a wide range. They include valuable philosophical discussions of the nature of scientific know-

ledge and expositions of scientific method, as well as highly instructive *résumés* and appreciations of the progress of mathematics and physics. But as this is the first meeting of the British Association since the conclusion of peace, I have decided to disregard in the main these precedents, and to endeavour to point out, in the first place, some of the lessons which the war has, or ought to have, taught our country and those who direct its policy, and in particular ourselves, whose vocation it is to cultivate and to teach mathematical and physical science.

Before proceeding with this task I must refer to the loss which physical science and the British Association have suffered this year through the deaths of Prof. Carey Foster and Lord Rayleigh. Both these great physicists were regular in attendance at the meetings of the association, and they will be greatly missed.

What Carey Foster was as a man of science, as a teacher, and as a friend of all students of physics has been worthily set forth in the columns of *NATURE* with all the knowledge and affectionate reverence of one who was at once his pupil and his fellow-worker at University College. To that eloquent tribute I will not, though I knew Carey Foster well, venture to add a word.

It is not for me to appraise here the work of Lord Rayleigh. But I may say that for something like half a century his name has stood, not only for things that are great in physical discovery, but for sanity of judgment and clarity, elegance, and soundness of treatment of outstanding and difficult problems of mathematical physics. His researches, too, in experimental science have been fruitful in results of the utmost importance in chemistry as well as in physics. With him there was no shirking of the toil of monotonous and systematic observation from day to day in the pursuit of the greatest attainable accuracy; take, for example, his work on electrical units. But his influence on applied mathematics has also been enormous, and places him for all time in the foremost rank of the great physical mathematicians, at the head of which stands Isaac Newton. One has only to read his treatise on "The Theory of Sound" and his papers on optics and wave theory to find some of the most striking examples in all scientific literature of the working of a mind, not only of the first order of originality, but imbued with a feeling for symmetry of form and clearness of exposition.

Lord Rayleigh's genius was, it seems to me, essentially intuitive and practical. Though he was not given to any striving after the utmost rigidity of formal proof—which, as he himself remarked, might not be more but less demonstrative to the physicist than physical reasons—no man made fewer mistakes. He is gone, but he has left an inspiring example to his order and to his countrymen of a long life consecrated to the object for which the Royal Society, of which he had been the honoured president, was founded: the furtherance of natural knowledge.

The part which physical science has played in the conduct of the war on our side has been an important one, but it has by no means been so decisive as it might and ought to have been. And here lie the lessons which I think we can draw from the terrible events which have taken place. Some few people, mostly hostile to or jealous of science, whose vision of facts and tendencies seems to me to be hopelessly obscured by prejudice, would try to impose on the advance of natural knowledge and the supposed increased influence of scientific ideas on the minds of men, or, perhaps more precisely, on the diminution of the study of the so-called humanities, the sole or the main responsibility for the outbreak of war.

It seems to me that a good many people allow themselves to be misled by a name. The name "humanity" is given in the Scottish universities to the department of the Latin language and literature, and in a wider usage the study of Latin and Greek is referred to as that of *litterae humaniores*. But I am not aware that there is any more humanity, in the common acceptance of the term, about these studies than there is in many others. And experience has shown that the assertion that these studies have a special refining influence, while the pursuit of science has a brutalising tendency, is based on ignorance and partiality. The truth is that the man who knows nothing of science, and he who has neglected the study of letters, are both imperfectly educated.

Well, the accusation I refer to may be dismissed without argument. This is certainly not the time or the place for a discussion of the causes of the war, or of the ethics of the extraordinary methods introduced into warfare by our enemies. But one thing I will say in this connection. Even poison gas is innocent in itself, and it occurs as a product in perfectly indispensable and eminently useful chemical processes. The extraordinary potency of scientific knowledge for the good of civilised mankind is frequently conjoined with a potency for evil; but the responsibility for an inhuman use of it does not lie with the scientific investigator. The guilt lies at the door of the High Command, of the high and mighty persons, themselves in feeling and temper utterly unscientific, who approved and directed the employment of methods of attack which destroyed the wounded and helpless, and wrecked for ever the health of many of those who emerged alive from the inferno.

As regards the help which British science was able to render in the defence against the German attack and the operations which followed when the fortune of war changed so dramatically, and the enemy was driven back towards the chain of fastnesses from behind which he originally emerged, one or two obvious reflections must have occurred to everyone. In one form or another these have been referred to by various writers, but I may recall one or two of them; for as a people we are incorrigibly forgetful, and appear to be almost incapable of profiting from experience, which, according to the Latin proverb, teaches even fools.

Nearly twenty years ago the urgent necessity for the reorganisation of our military machinery had been, in the view of civilians at least, who had to bear the cost of the war in South Africa, demonstrated *ad nauseam*, but nothing of real importance in the way of reforming the War Office seems to have been done. The shocks we had received were forgotten, and soon the nation returned to its insular complacency, the old party cries resounded in the market-place, the hacks of party politics again resumed their occupation of camouflage and hoodwinking, and the country drifted on towards its fate.

All this time an enormously powerful war machine was being built up on the Continent, and its different parts tested so far as that could be done without actual warfare. The real object of these preparations was carefully veiled by an appearance of frankness and professions of goodwill, though it was revealed every now and then by the indiscretions of the German military caste. To these indications and to others the country, ostrich-like, closed its eyes.

Now it is often alleged that men engrossed in the pursuit of science are unbusinesslike, but I think that if there had been any truly scientific element in the *personnel* of the Government (there never is by any chance), attention would have been directed at a much earlier period to our hopeless state of unpreparedness

for the storm which was gradually gathering against us on the other side of the German Ocean. In discussions of our unpreparedness the emphasis has been placed on our lack of arms and munitions. But important as these are, the entire absence of a scientific organisation to guide us in the exigencies of a defensive war with the most scientific and most military nation of Europe was even more serious.

It is this deficiency in our organisation—a deficiency the avoidance of which would have had no provocative effect whatever—which concerns us here very specially. It is, moreover, a deficiency which, in spite of the lessons they have received, has, I fear, not yet been brought home to our military chiefs. When war broke out nothing had been done to ensure the utilisation for special service, in the multitude of scientific operations which war as carried on by the German armies involved, of the great number of well-trained young scientific men available in the country. The one single idea of our mobilisers was to send men to the trenches to kill Germans, and for this simple duty all except certain munition workers and men in the public services were summoned to the Army. Some modifications were made afterwards, but I am speaking of the failure of prevision at the outset. The need of men for special service, the inevitable expansion of the Navy for patrol and other purposes and the like, were, if they were thought of at all, put aside, without regard to the difficulties which would inevitably arise if these matters were delayed. Even how the new soldiers were to be trained, almost without rifles or machine-guns, to meet the Germans in the field nobody knew. And I for one believe that but for the vigour and energy of Lord Kitchener, and the almost too late expression of conviction of our danger, and consequent action, by one outstanding politician, all would have been lost. We worried through, but at a loss of life and treasure from which it will take us long to recover, and which I could wish seemed to weigh more heavily on the minds and consciences of politicians.

The Germans, I believe, had a complete record, not only of all their men fitted only for the rank-and-file, but also of all who had been trained to observe and measure. For the use of even the very simplest apparatus of observation a certain expertness in reading graduated scales, and generally a certain amount of trained intelligence, is required. For this the laboratories of Germany amply provided, and the provision had its place in the enemy's mobilisation. Our people apparently did not even know that such a need existed or might arise.

In a letter which I sent to the council of the Royal Society at the end of 1915 I ventured to propose that the Royal Society might set on foot an organisation of some such character as the following:—First, a central committee should be established, in some degree representative of the different centres of scientific teaching and work in pure and applied science. Then this committee should nominate representatives at each centre, at least one at each university or college, and one at the headquarters of each local society, such, for example, as the Institution of Engineers and Shipbuilders of Scotland and the similar society which represents the North-East of England and has its offices at Newcastle-upon-Tyne. This arrangement, it was hoped, would enable the central committee to obtain readily information as to what men were available, and would therefore do something to bring the schools of science, and all the great workshops and laboratories of applied science, into co-operation. Thus could be formed at once a list of men available for particular posts, for the task of solving the problems that were certain to arise

from day to day, and for the special corps which it was soon, if dimly, perceived were a necessity. Some such linking-up of London with the provinces is really indispensable. The districts of, for example, the Tyne and the Clyde are too much ignored in almost all Government action of a general kind.

My letter was printed and sent out to some prominent men, by whom its proposals were highly approved. A conference on its subject was held in London, and two special committees were appointed. I was a member of one of these, the principal duty of which was to provide scientific men for special service. It included representatives of the various great departments actively engaged in the conduct of the war. For some reason or other, which I never learned, the committee after a week or two ceased to be called, and I believe that little was done in comparison with what might have been accomplished. It was certainly not because such a committee would not work. Everybody was most willing, with proper notice, to attend such meetings as were involved, and to take any amount of personal trouble; moreover, the scheme was such as to provide that there should always be a nucleus of members in London to consult and act in any emergency.

I may briefly refer to one or two examples of the chaos which prevailed and the attempts that were made to cope with it. Very soon after the formation of the first Kitchener Army the organisation of the different corps apparently became a source of anxiety to the War Office. It began to be seen that officers in sufficient numbers could not possibly be obtained by the usual channels, so the expedient (a poor one by itself) was hit upon of placing the nominations to commissions in one at least of the two great scientific corps of the Army—the Royal Engineers—in the hands of the presidents of certain technical institutions which have their headquarters in London. These gentlemen, with the help of the official secretaries, no doubt did the best they could, but a very regrettable, though perfectly natural, amount of strong feeling was evoked among the young scientifically educated men in the provinces, who were keenly anxious to join this corps. The Engineers, I may scarcely say, is no refuge for men who are in the least concerned about their personal safety, for the percentage of casualties among engineers on active service was notably higher than in the regiments of the line. Over and over again young engineers came to me and complained that under the arrangements made they had no chance of obtaining commissions or of qualifying as cadets, and begged me to write to the authorities. Of course, young graduate engineers do not, as a rule, join societies such as the Institutions of Civil, Mechanical, or Electrical Engineers until they have made their way to some little extent and begun to earn a little money.

The procedure I have indicated had in time to be relaxed, but such a central committee as I suggested, with antennae stretching out to the educational and technical centres of the country, would, I am sure, have recruited the Engineers quickly with the best possible material for officers to be found in the country, to the satisfaction of all concerned. It may be said that full information regarding every man in the country was in the hands of the authorities. In a sense, this was true; the information existed in millions of returns and thousands of pigeon-holes, but no attempt was made, or could be made, by office staffs in London, enormous as these quickly became, to digest and utilise it.

A large number of engineers and physicists and many others of mechanical skill and aptitudes found congenial occupation in the Royal Naval Air Service

and the Royal Flying Corps; but even there, where things could be better done, since a new force had to be brought into existence, arrangements were to a considerable extent haphazard and ill thought out. Excellent self-sacrificing service was rendered by many who risked and gave their lives, and of what was done we may well be proud. But from a scientific point of view there is room for great improvement. The hasty and ill-considered—as I think—amalgamation of these two branches of the Air Service, in which naval traditions were sacrificed to those of the War Office, which deserved no such deference, will certainly have to be undone in the near future or very greatly transformed. To anyone who considers the possibilities and probabilities of warfare in the future, it appears clear that this country will have to depend more and more upon its Navy, and that an Air Service Corps will be the companion of every division of our Fleet, with landings on the warships. Thus a new and highly scientific Service, which will have to be to a great extent naval, will be brought into existence.

Well, then, to return for a moment to my proposal to the Royal Society, why should the organisation which I suggested in 1915 not be established now? I wish all success to the League of Nations, but we shall prove ourselves even greater fools than we have been in the past if we do not use all possible means to prepare ourselves against eventualities. One attempt by our enemies outside our own borders to hold us to ransom has failed. Can we be so sure that no other attempt will ever be made, or that no *casus belli* between ourselves and another great nation will ever arise? This, I notice, is beginning to be assumed even in the midst of the welter of confusion and unrest that exists, and, among others, by just the very people who used to teach that the possibility of war was a great illusion.

The formation of a record of scientific graduates for special service ought not to be difficult. The material already in great measure exists. Each university and college has its roll of graduates or diploma-holders, and with slightly more detailed entries these rolls would give the record. Each graduate of a university is kept track of through the necessity for keeping the electoral roll up-to-date, and it ought to be possible to devise a means of maintaining touch with the diploma-holder. If each university or college were a local centre of the central committee, the making of the roll of graduates would be achieved at the different local headquarters, and would be a valuable supplement to the O.T.C. work now undertaken so willingly and done so well. The Government machinery which manages the O.T.C. movement might control the keeping of the register which I have suggested.

I turn now to another side of scientific work during the war. It was my lot to serve for nearly three years on the Inventions Panel of the Ministry of Munitions, and as the result of that experience I venture to make some observations on the utilisation of scientific knowledge and genius in the production of inventions useful for the public service. We had an enormous multitude of inventions to consider, and the Panel was divided into Committees for this purpose. For each invention or proposal a file or *dossier* was prepared and most carefully kept. There were also present at the meetings of the Panel very efficient officers representing different branches of the Service. Everything received careful attention, and for the ability and fairness with which the initial examination was made by the corps of examiners, and the *précis* of the invention presented, I have great admiration. Much has been said about the inefficiency and the mistakes of

various Government Departments during the war. The Ministry of Munitions Inventions Department was, so far as I could see, eminently well managed.

Many of the so-called inventions were not inventions at all. Some were not at all new; in other cases an idea only was mooted. Could so-and-so not be done? and so on, and the Department was supposed to be grateful for the idea, and to do the rest, besides rewarding the proposer. A favourite notion, which illustrates the diffusion of scientific knowledge among different classes of people, was that of taking a magnet—any magnet—up on an aeroplane, and using it to attract Zeppelins and other aircraft. Others suggested electromagnets fed by machines which would have involved carrying into the air on an aeroplane a fully equipped power-house! Another favourite notion, inspired, no doubt, by a certain sensational type of article in the fiction magazines, was that of rays charged in some way with electricity, or some other mysterious agency, and therefore intensely destructive.

But there was a residuum of valuable inventions which fully justified the existence of the Department. These were recommended for further consideration by the various departments of the Services or by General Headquarters. It by no means followed that all that came to this stage received careful further consideration. Everybody was very hard worked, and many were overdriven. And it was by no means certain that when important approved appliances were sent to G.H.Q. a thoroughly well-informed and capable officer would in all cases have the duty of explaining and showing their action. The absence of such an officer, I am sure, often resulted in delay and serious error, and, I fear, also in the rejection of what was in itself exceedingly good, but was not understood. People who knew nothing about the matter took charge, and ordered things to be done which brought disaster to the apparatus. I know of one very important machine which was ruined, with much resulting delay. A brigadier or major-general with a confidence born of blank ignorance ordered a motor-generator to be put on town electric mains, and, of course, burnt it out.

Then, again, we were told that G.H.Q. did not want this or that, and here, as in all human affairs, mental inertia certainly played a considerable part. The willingness, however, of some Departments to adopt at once a device captured from the enemy was pathetic. Often quite clumsy and relatively inferior contrivances were adopted in the midst of hesitation about our own. Anything German of this sort some people assumed must be good—a foolish idea, the result of want of confidence, often well founded, I am afraid, in their own judgment. It is legitimate to copy from the enemy, and in several important things we have not been slow to do so.

The delays that occurred were to some of us at home, who were anxiously dealing with all kinds of contrivances, exceedingly exasperating. Some were undoubtedly unavoidable, but others were, as I have indicated, far otherwise. Deficiency in scientific education was the cause. It is to enforce the need for such education that I refer to such matters at all. The "playing fields of Eton" are all very well. I for one do not scoff at what the old saying stands for, but scientific laboratories and good intelligent work in them are indispensable. A man who directs in whole or in part a great machine must know something of its structure and capabilities.

I feel bound to allude to another aspect of the inventions business which, to my mind, was very serious. In doing so, however, I wish it to be clearly understood that I am criticising a system, and in no

way here referring to particular individuals concerned in its administration. Various inventions which had passed satisfactorily the first examinations by responsible judges were submitted to technical departments at home to be subjected to practical tests. These inventions were frequently proposed solutions of problems on which technical officers, of the departments required to conduct the tests, had long been engaged. It was natural, indeed inevitable, that some of these officers should have come to regard the solving of these problems as their own special job, and so did not much welcome the coming of the outside inventor. Then, no doubt, they often felt that they were just on the point of arriving at a solution—a feeling that certainly could not facilitate the avoidance of delay. It was manifestly most unfair to ask them to judge the work of the outside inventor, or to place in their hands details of his proposals, for exactly the same reason which in civil life restrains a man from acting as a juror in a case in which he is personally interested. Nobody of good sense feels offended when attention is directed to such a rule in practice.

Thus I have no hesitation in expressing the opinion that a testing board of practical, well-qualified physicists and other experts, with a properly qualified staff, should be formed for the purpose of carrying out all tests of inventions. No insuperable difficulty would, I believe, be experienced in forming such a board. It should be formed carefully, not by more or less casual nomination of one another by a few persons. Expert knowledge of a subject should be a necessary qualification; the so-called "open mind" of the much-lauded but untrained practical man is not worth having. But on that board neither inside nor outside inventors of the same kind of appliances should have any place, though, of course, consultation with the author of an invention under test would be absolutely necessary. Also those actually carrying out the tests and those collating the results should not be men in any way in the employment of, or under the supervision of, inventors, whether "outside" or "inside." It is imperative in the interests of the country that delay in such matters should be avoided, and that all such work should be done without fear or favour.

The value of university and college men trained in science has been thoroughly proved in the Artillery, the Engineers, and in their offshoots, the Special Sound-ranging and Survey Corps, though its recognition by the authorities of Whitehall has been scanty and grudging. Some of the old-fashioned generals and staff officers could not be got to see the use of men who had not been trained to field exercises by a long course of drill. What is the good of officers, they said, who are not skilled leaders of men? This is the old crude idea again of destroying Germans with rifles, bayonets, and hand-grenades. The falsity of these antiquated notions has now, I believe, been amply demonstrated.

The objection to these men, however, lies a good deal deeper. Even those scientifically educated officers who came into the new armies when they were formed, and were trained by the service of years of warfare superadded to the initial course of drill, have been demobilised in a nearly wholesale manner, without the least regard to even very exceptional qualifications. Many of these were, it seems to me, the very men who ought, above all, to have been retained in the Service. Now (though, as I write, improved regulations are being issued) they are to a great extent to be replaced by the public school-cum-Sandhurst young gentlemen, who, it appears, are the "pukka" officers *par excellence*.

The old system of the rule of politician chiefs whose only or main function is to sign the edicts of heads of departments seems to have returned in full force, and the coming of the cleansing Hercules that many people desire for the War Office does not seem to be within the bounds of possibility.

The real cause of the prevailing neglect of science, with all its pernicious results, is that almost all our political leaders have received the most favoured and fashionable form of public school education, and are without any scientific education. An education in classics and dialectics, the education of a lawyer, may be a good thing—for lawyers; though even that is doubtful. For the training of men who are to govern a State the very existence of which depends on applications of science, and on the proper utilisation of available stores of energy, it is ludicrously unsuitable. We hear of the judicial frame of mind which lawyers bring to the discussion of matters of high policy, but in the majority of scientific cases it is the open mind of crass ignorance. The result is lamentable; I myself heard a very eminent counsel declare in a case of some importance, involving practical applications of science, that one of Newton's laws of motion was that "friction is the cause of oscillations"! And the helplessness of some eminent counsel and judges in patent cases is a byword.

As things are, eminence in science is no qualification; it would even seem to be a positive disqualification for any share in the conduct of the affairs of this great industrial country. The scientific sides of public questions are ignored—nay, in many cases our rulers are unconscious of their existence. Recently in a discussion on the Forestry Bill in the House of Lords a member of that illustrious body made the foolish assertion that forestry had nothing to do with science; all that was needed was to dig holes and stick young trees into them. Could fatuity go further? This hereditary legislator who, as things are, has it in his power to manage, or mismanage, the conversion into available energy of the radiation beneficently showered on a certain area (his area) of this country of ours does not seem to be aware that the growing of trees is a highly scientific industry; that there are habits and diseases of trees which have been profoundly studied; that, in short, the whole subject of sylviculture bristles with scientific problems, the solutions of which have by patient labour been to a considerable extent obtained.

Take also the case of the dyes industries. The publicists and the good business men—the supermen of the present age—who wish to control and foster an industry which owes its very existence to an English chemist, refuse to have on the committee which is to manage this important affair any man of scientific eminence, and no remonstrance has any effect. These great business men are, as a rule, not scientific at all. They are all very well for finance; in other respects their businesses are run by their works-managers, and, in general, they are not remarkable for paying handsomely their scientific assistants.

I myself once heard it suggested by an eminent statesman that an electrical efficiency of 98 per cent. might by the progress of electrical science be increased fourfold. This, I am afraid, is more or less typical of the highly educated classical man's appreciation of the law of conservation of energy; and he is—save the mark!—to be our Minister or Proconsul and the conservator of our national resources. It is not surprising, therefore, that in connection with a subject which for several weeks occupied a great space in the newspapers, and is now agitating a large section of the community, the nationalisation of our coal-mines, there was not a single word, except perhaps a casual

vague reference in the report of the chairman, to the question which is intimately bound up with any solution of the problem which statesmen may adopt—I mean the question of the economic utilisation, in the interests of the country at large, of this great inheritance which Nature has bestowed upon us. In short, are Tom, Dick, and Harry, if we may so refer to noble and other coalowners, and to our masters the miners, to remain free to waste or to conserve at their own sweet will, or to exploit as they please, this necessity of the country's existence?

The fact is that until scientific education has gone forward far beyond the point it has yet reached, until it has become a living force in the world of politics and statesmanship, we shall scarcely escape the ruin of our country. The business men will not save us; as has been said with much truth, the products of modern business methods are, to a great extent, slums and millionaires. It lies to a great extent with scientific men themselves to see that reform is forthcoming; and more power to the British Science Guild and to any other agency which can help to bring about this much-needed result.

While scientifically educated men, whether doing special work or acting as officers, have been held of far slighter account in the Services than they ought to have been, for physicists as such there has been little or no recognition, except, I believe, when they happened to be ranked as research chemists! How did this happen? Why, the various trades asserted themselves, and the result was a sufficiently long list of "reserved occupations"—a list remarkable both for its inclusions and for its exclusions. There was, for example, a class of "opticians," many of whom have no knowledge of optics worth mentioning. They are merely traders. One of these, for example, the proprietor of a business, made a plaintive appeal to myself as to how he could determine the magnifying powers of certain field-glasses which he wished the Ministry of Munitions to purchase. But for a young scientific man, even if he were an eminent authority on theoretical and practical optics, but who was not in the trade, there was no place.

Research chemists received their recognition in consequence of the existence of the Institute of Chemistry. I am extremely glad to find that something is now being done to found an Institute of Physics. I hope this movement will be successful, and that it will be thoroughly practical and efficient. I hope its president and council, its members and its associates, will be jealous for science, and especially for physics. It ought to be a thoroughly hard-working body, without any frills, destitute of work value. They have an example in the General Medical Council, which has so effectively cared for the interests of the medical profession.

I am glad that something is being done at last for the organisation of scientific research. This movement has started well in several, if not in all, respects, and I wish it all success. There are, however, one or two dangers to be avoided, and I am not sure—I may be much too timid and suspicious—that they are fully recognised, and that the result will not be too much of a bureaucracy. Somehow or other I am reminded by the papers I have seen of the remark of a poor man who, asking charity of someone in Glasgow, was referred to the Charity Organisation Society of that city. "No, thank you," he said; "there is a good deal more organisation than charity about that institution." So I hope that in the movement on foot the organisation will not be more prominent than the science, and the organisers than the scientific workers.

There is, to my mind, too much centralisation aimed at. Everything is to be done from London;

a body sitting there is to decide the subjects of research and to allocate the grants. There may be a good deal to be said for that in the case of funds obtained in London. But apparently already existing local incentives to research work are to be transferred to London. The Carnegie Trust for the Universities of Scotland, soon after its work began, inaugurated a scheme for research work in connection with these universities. The beneficiaries of the Trust, it is well known, must be students of Scottish nationality. The action of the Trust has been most excellent, and much good work has been done. Now, so far as chemistry and physics are concerned, it has been proposed, if not decided, to hand over to the organisation in London the making of the awards, a process of centralisation that will probably not end with these subjects. I venture to protest against any such proceeding. The more incentives and endowments of research that exist and are administered in the provinces the better. Moreover, this is a benefaction to Scottish students which ought not to be withdrawn and merged in any provision made for the whole country, and administered in London by a bureau which may know little of the Scottish universities or of Scottish students. The bureau might, with equal justice or injustice, be given command of the special research scholarships of all the universities both in England and Scotland, and administer them in the name of the fetish of unification of effort. I do not know, but can imagine, what Oxford and Cambridge and Manchester and Liverpool would say to that. But even Scotland, where of course we know little or nothing about education of any kind, may also have something to say before this ultra-centralisation becomes an accomplished fact.

There is, it seems to me, another danger to be avoided besides that of undue centralisation in London. In most of the statements I have seen regarding the promotion of research work, the emphasis seems to be on industrial research—that is, in applied science. This kind of research includes the investigation of physical and chemical products of various kinds which may be used in arts and manufactures, and its deliberate organised promotion ought to be a commercial affair. I observed, by the way, with some amusement, that according to the proposals of one committee for applied science, which is prepared to give grants and premiums for researches and results, the professor or head of a department, from whom will generally come what are most important, the ideas, is to have no payment. He is supposed to be so well paid by the institution he belongs to as to require no remuneration for his supervision of the committee's researches. And the results are to be the sole property of the committee!

There is in this delightfully calm proposal at least a suggestion of compulsion and of interference with institutions and their staffs which ought to be well examined. Also some light is thrown on the ideas of such people as managing directors of limited liability companies, who are members of such a committee, as to what might reasonably be expected of men of high attainments and skill whose emoluments taken all round are, on the whole, miserably insufficient.

I think that it is in danger of being forgotten that, after all, pure science is by far the most important thing. Most of the great applications of science have been the products of discoveries which were made without any notion of such an outcome. Witness the tremendous series of results in electricity of which the beginning was Faraday's and Henry's researches on induction of currents, and the conclusion was the work of Hertz on electric waves. From the first came the production and transmission of power by

electricity; from the last the world has received the gift of wireless telegraphy. I am not at all sure whether the great men who worked in the sixty or seventy years which I have indicated would have always received grants for proposed researches, which to many of the good business directors and other supermen serving on a great bureau of investigation, had such then existed, would have appeared fantastic and visionary. In research, in pure science at least, control will inevitably defeat itself. The scientific discoverer scarcely knows whether he is being led; by a path he knows not he comes to his own. He should be free as the wind. But I must not be misunderstood. Most certainly it is right to encourage research in applied science by all available and legitimate means. But beware of attempting to control or "capture" the laboratories of pure science in the universities and colleges of the country. Let there be also ample provision for the pursuit of science for its own sake; the return will, in the future as in the past, surpass all expectation.

I had intended to say something about scientific education as exemplified by the teaching of physics. I have left myself little time or space for this. I cannot quite pass the matter over, but I shall compress my remarks. In the first place, I regard dynamics, especially rotational dynamics, as the foundation of all physics, and it is axiomatic that the foundation of a great structure should be soundly and solidly laid. The implications of dynamics are at present undergoing a very strict and searching examination, and now we may say that a step in advance has been taken from the Newtonian point of view, and that a new and important development of dynamics has come into being. I refer, of course, to the new theories of relativity which are now attracting so much attention. I hope to learn from the discussions, which we may possibly have, something of the latest ideas on this very fundamental subject of research. It is a matter for congratulation that so many excellent accounts of relativity are now available in English. Some earlier discussions are so very general in their mathematical treatment and notation as to be exceedingly difficult to master completely. I have attacked Minkowski's paper more than once, but have felt repelled, not by the difficulties of his analysis, but by that of marshalling and keeping track of all his results. Einstein's papers I have not yet been able to obtain. Hence it is a source of gratification to have Prof. Eddington's interesting report to the Physical Society and the other excellent treatises which we have in English. But continual thought and envisaging of the subject is still required to give anything approaching to instinctive appreciation such as we have in ordinary Newtonian dynamics. I venture to say that the subject is pre-eminently one for physicists and physical mathematicians. In some ways the new ideas bring us back to Newton's point of view as regards so-called absolute rotation—a subject on which I have never thought that discussions of the foundations of dynamics had said absolutely the last word. I, for one, still cling to the æther, and am strongly of opinion that the whole subject of æther and matter and electrons require much more complete physical treatment than it has yet received from relativists.

The better the student of physics is grounded in the older dynamics, and especially in the dynamics of rotation, the sooner will he be able to place himself at the new point of view, and the sooner will his way of looking at things begin to become instructive.

With regard to the study of physics in our universities and colleges, I had written a good deal. I have put that aside for the present, and will content myself with only a few general observations. First, then,

it would, I think, be conducive to progress if it were more generally recognised that dynamics is a physical subject, and only secondarily a mathematical one. Its study should be carried on in the departments of physics, not in those of mathematics or in separate departments of applied mathematics. It is, or ought to be, essentially a subject of the physical lecture-room and the physical laboratory. The student should be able to handle rotating bodies, to observe and test the laws of precession and nutation—to work himself, in a word, into an instinctive appreciation of at least the simpler results of rotational theory. He should learn to think in vectors, without necessarily referring either to Hamilton or to Grassmann. Some people appear to censure the use of vector ideas without the introduction at the same time of some form of vector notation. I do not feel drawn to any system of vectors in particular—all have their good points, and in some ways for three-dimensional work the quaternion analysis is very attractive—but vector ideas are of the very utmost importance.

Hence I deprecate the teaching, however elementary, which as a beginning contents itself with rectilinear motion. The true meaning of rate of change of a directed quantity, even of velocity and acceleration, is missed, and instead of having laid a foundation for further progress the teacher, when he desires to go beyond the mere elements, has practically to relay his foundations; has, in fact, to extract imperfect ideas from his pupils' minds and substitute new ones, with the result that a great deal of avoidable perplexity and vexation is produced. The consideration of the manner of growth of vectors—the resultant vector or it may be component vectors, according to convenience—is the whole affair. As an illustration of what I mean, take this:—A vector quantity has a certain direction, and also a magnitude L . It is turning in a certain plane with angular speed ω . This turning causes a rate of production of the vector quantity about a line in that plane and perpendicular to the former, and towards which the former is turning, of amount $L\omega$. Thus a particle moving in a curve with speed v has momentum mv forwards along the tangent at the position of the particle. The vector is turning towards the principal radius (length R) of curvature at the point at rate v/R . Hence towards the centre of curvature momentum is growing up at time-rate mv^2/R .

Dealt with in this way, with angular momentum instead of simple momentum, the motions of the principal axes of a rigid body give the equations of Euler instantly and intuitively, and all the mind-stupefying notions of centrifugal couples and the like are swept away.

With regard to mathematics, the more the physicist knows the better, and he should continually add to his store by making each physical subject he takes up a starting-point for further acquisition. Some very philistine notions as to mathematics prevail, and are very mischievous. For example, I once heard an eminent practical engineer declare that all the calculus an engineering student requires could be learned in an hour or two. This is simply not true, nor is it true, as some exponents of ultra-simplicity seem to suggest, that the professional mathematical teacher wilfully makes his subject difficult in order to preserve its esoteric character. Like the engineer or physicist himself, he is not always so simple as he might be; but the plain truth is that no good, progressive mathematical study can be carried out without hard and continued application of the mind of the student to the subject. And why should he depend on the mathematical reader? Let him be his own teacher! There are plenty of excellent

books. If he has a determination to help himself he will, if he makes a practice of reserving difficulties and returning to them, find them vanish from his path.

As I have said, I am specially interested in rotational dynamics. In the course of the war I have been appalled by the want of appreciation of the principles of this subject which, in spite of considerable acquaintance with the formal theory, seemed to prevail in some quarters. I do not refer to mistakes made by competent people—it is human to err—but to the want of appreciation of the true physical meaning of the results expressed by equations. A gyrostatis, as ordinarily considered, is a closed system, and its dynamical theory is of a certain kind. But do away with the closedness, and the dynamical theory is quite a different affair. Take, as an example, the case of two interlinked systems which are separately unstable. This compound system can be made stable even in the presence of dissipative forces. A certain product of terms must be positive, so that the roots of a certain determinantal equation of the fourth degree may all be positive. The result shows that there must be angular acceleration, not retardation, of the gyrostatis frame. This acceleration is a means of supplying energy from without to the system, the energy necessary to preserve in operation the functions of the system.

I have ventured to think this stabilising action by acceleration of the compound motion very important. It is lost sight of by those who consider and criticise gyrostatic appliances from the usual and erroneous point of view. Also, I believe that it is by analogy a guide to the explanation of more complicated systems in the presence of energy-dissipating influences, and that the breaking down of stability or death of the system is due to the fact that energy can no longer be supplied from without in the manner prescribed for the system by its constitution.

I had just concluded this somewhat fragmentary address when the issue of NATURE for July 24 came to hand, containing a report of Sir Ernest Rutherford's lecture at the Royal Institution on June 6. The general result of Sir Ernest's experiments on the collision of α -particles with atoms of small mass is, it seems to me, a discovery of great importance, whatever may be its final interpretation. The conclusion that "the long-range atoms arising from the collision of α -particles with nitrogen are not nitrogen atoms, but probably charged atoms of hydrogen or atoms of mass 2," is of the utmost possible interest. The α -particle (the helium atom, as Rutherford supposes it to be) is extraordinarily stable in its constitution, and probably consists of three helium nuclei each of mass 4, with two attached nuclei of hydrogen, or one attached nucleus of mass 2. The intensely violent convulsion of the nitrogen atom produced by the collision causes the attached nuclei, or nucleus, to part company with the helium nuclei, and the nitrogen is resolved into helium and hydrogen.

It seems that, in order that atoms may be broken down into some primordial constituents, it is only necessary to strike the more complex atom with the proper kind of hammer. Of course, we are already familiar with the fact that radio-active forces produce changes that are never produced by so-called chemical action; but we seem now to be beginning to get a clearer notion of the rationale of radio-action. It seems to me that it might be interesting to observe whether any, or what kind of, radiation is produced by the great tribulation of the disturbed atoms and continued during its dying away. If there is such radiation, determinations of wave-lengths would be of much importance in many respects.

I may perhaps mention here that long ago, when the cause of X-rays was a subject of speculation and the doctrine that mainly found acceptance was that they were not light-waves at all, I suggested to the late Prof. Viriamu Jones that radiation of extremely small wave-length would be produced if atomic or molecular vibration, as distinguished from what in comparison might be called molar vibration, could be excited. An illustration that suggested itself was this:—Take a vibrator composed of a series of small masses with spring connections. If these masses are of atomic or molecular dimensions any ordinary impulse or impact would leave them unaffected, while vibrations of groups of them, depending on the connections, would result. But the impact on one of the masses of a hammer of sufficiently small dimensions and mass would give vibrations depending on the structure of the mass struck, and independent of the connections, just as the bars of a xylophone ring, while the suspended series of bars, if it swings at all, does so without emitting any audible sound. This is, I believe, in accordance with the theory now held as to X-rays. We now have some information as to the mode of producing a local excitement so intense as to cause, not merely atomic disturbance, but actual disruption of the atomic structure. Further developments of Sir Ernest Rutherford's experiments and of his theory of their explanation will be eagerly awaited.

SECTION B.

CHEMISTRY.

OPENING ADDRESS BY PROF. P. PHILLIPS BEDSON,
D.Sc., PRESIDENT OF THE SECTION.

IN again taking up the work of this section, after an interval of three years, a discontinuity without parallel in the annals of the association, it is natural that our thoughts should turn to the past, and in so doing we are reminded of the gaps in the ranks of those who were accustomed to contribute to the work of our section. In 1916 we met under a shadow caused by the death of Sir W. Ramsay, whose genius added in so many ways to our science. And to-day we have to record the loss of one who in his long life contributed in a variety of ways to the advancement of chemistry, and to whom we owe an addition to the number of elementary substances in the discovery of thallium, one of the early fruits of the use of the spectroscope. The chemistry of the rare earths has been especially illumined by the researches of Sir William Crookes. With physicists we would join in a tribute to the memory of Lord Rayleigh, amongst whose experimental researches is one of special interest to chemists, namely, the revelation of the existence of argon, of which discovery Sir J. J. Thomson has recently written that it was not made "by a happy accident, or by the application of new and more powerful methods than those at the disposal of his predecessors, but by that of the oldest of chemical methods: the use of the balance."

In this connection it is but right that, despite the feelings engendered by the war, I should refer to the passing of two great chemists—Baeyer and Fischer. The former died some two years ago, and the latter within the past two months. Each of them advanced by his experimental researches the progress of organic chemistry, and brought illumination into many of the obscure departments of this branch of science. The field of investigation latterly cultivated by Fischer has revived an interest in the "vital" side of organic chemistry as distinguished from the study of chemistry of the carbon compounds. Moreover, there are many British chemists, amongst

them some of the most distinguished, who, as students, received guidance and inspiration from the teaching of Baeyer or of Fischer, and with them we gratefully acknowledge our indebtedness.

Fifty years ago Mendeléeff communicated to the Russian Chemical Society a memoir which has exercised a profound influence on chemical philosophy, and continues to serve as a guide in the interpretation of research and speculations on the nature of the elements. Without entering on the somewhat vexed question as to whom should be assigned the credit of the discovery of the periodic law, I trust I shall not be considered unmindful of the claims of Newlands by adopting the traditional history, and, as is usual, associate this discovery with the name of Mendeléeff, and consequently we may look on this year as the jubilee of the periodic law. Although there is already abundant special literature dealing with this subject, and the periodic system has been assimilated into the teaching of the science, and is dealt with in the text-books of chemistry, in some of which it forms the basis of the system employed in the exposition of the facts and theories of inorganic chemistry, still it appeared to me that I might utilise this as an opportunity of passing in brief review some of the features of the rise and development of the "periodic law."

The memoir, made known to the non-Russian reader by the abstract in German, shows the principle of periodicity, viz. the recurrence of similar properties at regular intervals with increase in the magnitude of atomic weights, the possibility of utilising the atomic weights as a basis of the classification of the elements, the necessity for the revision of the values thus assigned to the atomic weights of certain elements, and finally that the scheme demanded for its completeness the existence of many new elements.

The later writings of Mendeléeff contain the mode of tabulating the elements in the form usually adopted in chemical text-books, portraying the principle of periodicity and showing the grouping of the elements into natural families. But undoubtedly the clearest demonstration of the association between the atomic weights and the physical properties of the elements is that exhibited by the curve of atomic weights and atomic volumes, which is an outcome of the independent studies of these relationships by Lothar Meyer, and, as is well known, shows the members of the natural families of elements occupying corresponding positions on the curve. This curve, with its undulations, corresponding with the series of the elements, has contributed to impress on the mind of the student the relationship between the properties of the elements and their atomic weights, and may have exercised an influence in directing attention to these relationships which the attempts of the earlier workers in this field were not successful in doing.

Mendeléeff's table of the elements was just beginning to figure in the teaching of chemistry in my undergraduate days, and, together with the speculations underlying it, aroused considerable interest and proved an incentive and inspiration for experimental inquiry. Foremost in this country amongst those who by their writings have contributed to spread a knowledge of Mendeléeff's speculations was my fellow-student, Carnelley. His experimental investigations added materially to our knowledge and definition of the physical properties of elements and compounds, which further emphasised the periodicity in the relation of the atomic weights to the properties of the elements, and have provided data from which curves, resembling in contour the atomic volume curve, have been set up.

A valuable guide in fixing the atomic weights of