THE MISSION OF SCIENCE*

By SIR HENRY DALE, O.M., G.B.E., F.R.S.

THE scientific men of the world now have before them the task of readjustment which, we may hope, will mean the whole-hearted devotion of the available resources of scientific research and development to their proper and beneficent uses. It has become a commonplace that the urgent needs of war have greatly accelerated discoveries and inventions which will now promote the advancement of science and its applications in peace. Some of these scientific swords and spears will be thus immediately applicable as peaceful implements, or with only a minimum of beating and bending—radar, for example, to the safety of transport by sea and air, and all the new wealth of chemotherapeutic agents and insecticides to peace-time hygiene and agriculture. There will certainly be many others of a less direct and obvious kind—discoveries and developments arising as side-issues from the urgent uses of science in war, but capable now of applications which may open new possibilities of scientific advance for its own sake, or for a whole range of peaceful purposes. The Royal Society has recently agreed to collaborate with the Service Departments concerned, in setting up committees to organize such peaceful uses of the special facilities for purely scientific observation and experiment as are presented by Service flying, including aerial photography, by the voyages undertaken by the ships and officers of the Royal Navy in the course of their normal duties, and by the large surplus of explosives—of the pre-atomic type, be it understood—which a great war leaves in hand.

Let me make brief mention, by way of another example, of an unexpected gift to science, arising as a curious side-issue from the large-scale application in war of knowledge which science had provided. Some thirty years ago my former colleague, Dr. Charles Todd, published in the *Proceedings of the Royal Society* two papers dealing with the antigenic individuality observed, even within the limits of a single breed of chickens, when the red blood corpuscles of one bird are injected into another. This was an observation, one might think, of an interest purely theoretical, though great; but the widespread application of blood transfusion during the War, to replace blood lost by the wounded, civilians now as well as warriors, has given to phenomena of this type a practical importance. Apart from the familiar natural incompatibilities, due to the known human blood groups, it was found necessary to be alert for reactions in persons who, having had an earlier transfusion, might have acquired, by an immunity reaction, a new incompatibility to the donor's red blood corpuscles. The case of such reactions hitherto most completely studied concerns an antigenic factor which Landsteiner and his colleagues had discovered, early in the War, in the red corpuscles of the Rhesus monkey, and had accordingly termed *Rh*. This factor they found to be present, as a Mendelian dominant, in the corpuscles of most white people, but absent from those of a minority. So, in the slang of the subject, about 85 per cent of people of the white races are '*Rh*-positive', while 15 per cent are '*Rh*-negative'. Now it appears that the blood serum of an *Rh*-negative person, if he receives a transfusion of *Rh*-positive blood, acquires immune

substances destructive to the 'positive' red corpuscles. In consequence, he suffers a dangerous reaction if given a second, similar transfusion. This observation has brought to light the much more important fact that, when an *Rh*-negative woman, whose husband is *Rh*-positive, becomes pregnant by him of an *Rh*-positive child, her serum is liable therewith to acquire, and to transmit through the placenta, an antibody destructive of the child's red corpuscles, so that the offspring of such a union are prone to a high rate of mortality, before or soon after birth. Whether those who survive the infantile malady thus produced show a greater liability to other hereditary defects, or whether deleterious maternal antibodies of this type can be formed in relation to other kinds of cells than the red blood corpuscles, are matters on which investigation must be awaited.

I mention the matter as an example of the gleanings which peaceful science may expect from fields of knowledge which war has been tilling and reaping. Unless I am mistaken, the widespread use of blood transfusion has thus been largely responsible for enabling human genetics now to explore a new category of congenital defects, due, not to the coincident presence of a detrimental gene in both parents, but to the possession by a father of one which is harmless, unless it excites an immunity response in a mother who lacks it.

Whether by following in new directions clues which have thus been discovered under the stimulus of war, or by resumption of researches which the War interrupted, it is clearly a matter of urgent importance that our scientific activities should now, as rapidly and as smoothly as possible, reacquire the character proper to peace. There are directions in which official action can accelerate a process of such outstanding significance to the position which our nation will be able to achieve and to hold in a world civilization, now so clearly entering its scientific era. We need our leaders and teachers in science back in the universities, and the students whom they can inspire and train, as rapidly as these can be released from war-time duty and service.

A number of our leading men of science have learned much from war-time experience of organization and team-work in research, and have been freely devoting great abilities to planning and to securing proper conditions for researches by others. It is unlikely that the debt of the nation and of its allies to the work of many of these will ever be fully known, beyond the limits of certain circles. The experience of these men should help them still to serve the nation in peace, by counsel and by advocacy, when the needs of scientific reconstruction demand these.

I venture to hope, however, that there will be no such demands on the time and the energies of those who should now be our leaders in research, as to keep them away from their benches and their studies, and to deprive of their inspiration the younger men who should now be their pupils and collaborators. When the world emerged from the War of 1914-18, the scientific men who in Britain and other countries were then at the height of their powers for research, who, in Newton's fine phrase about himself, were 'in the prime of their age for invention', were back in their laboratories with little delay. As a result, even in the two decades of uneasy armistice which followed, curtailed at both ends by the confusion of recovery from one war and the gathering menace of another, research for the normal

* From the anniversary address to the Royal Society, delivered on November 30.

purposes of peace was resumed with an astonishing promptitude, and the advance of knowledge surged forward with an imposing acceleration. Almost any man of science who can cast his mind back to the state of knowledge in his own special subject in 1919, and compare it with that which had been reached in 1939, must be impressed by the transformation. To mention an example which cannot be far, at the moment, from anyone's thoughts, consider the revolutionary changes made, between the wars, in our whole conception of the material universe, by new theories of atomic structure, with new apparatus of mathematics to deal with them, by the experimental attack on the atomic nucleus leading to transmutation of elements and, still before war's dark curtain fell again, clear evidence of atomic fission, with the release of atomic energy. As one other example, who would have predicted in 1919 that, of the vitamins and hormones then known and differentiated only by the effects of their withdrawal and replacement, imposing ranges would have been isolated, identified and made by artificial synthesis before 1939? Now that we are emerging from another war, into what, if we men of science can do anything to prevent it, will not be just another precarious interlude before a worse disaster, we must try to ensure that the free advancement of natural knowledge, which this Society exists to promote, is able to claim again, with as little delay as possible, the full service of its natural leaders.

Another condition of the revival of scientific activity for the normal purposes of peace, seen clearly by our predecessors in 1919, was a rapid reconstruction of the international community of science. Before there had been time for the full attainment of their aim, the forces of cleavage had again begun to operate; but, as soon as it became possible once again to think of rebuilding what another war had broken, it was the first duty of the Royal Society to ensure that use was made of all that was of proved value in the framework of international collaboration which had been constructed between the wars. Past officers of the Royal Society, especially Sir Arthur Schuster and Sir Henry Lyons, had taken prominent parts in the foundation and development of this organ of international collaboration. Our foreign secretary, Sir Henry Tizard, now coming to the end of his term of office, was early at work preparing for its revival with the chairmen of the British national committees, in consultation with its present general secretary, Prof. F. J. M. Stratton, and with such representative scientific men of other countries as were accessible. Their aim was to review the past achievements and potential value of this system of the international scientific unions, and the possible need for its extension or modification in certain directions. The Council's reports record the progress which has been made.

While, however, the Royal Society has had a special responsibility for our national participation in this existing system, it has always welcomed any opportunity of the fullest and most friendly collaboration with any other agency for the promotion of international friendship and community of action among the scientific workers of different countries. The Society looks forward now to the possibility of collaborating also with any scheme or mechanism for the promotion of international relations in science, which may arise under the general Organisation of the United Nations. We recognize that, through such channels, it may be possible, not only to give most

valuable support to the existing unions for international action in the various fields of scientific research, but also to supplement the functions of these in many other directions in which the interests of science may yet require to be internationally organized and promoted. The Society stands ready and eager, now as ever, to work with any responsible agency for the restoration and extension of international friendship and collaboration in science.

In my address to the Royal Society last year, I referred to the aim of building anew, and on a firm and broadening foundation, a world community in science, as "an aim worthy of our utmost effort and devotion". Can it be doubted now, after what has happened since then, that upon our success in achieving that aim may well depend, not only the free progress of science henceforward, but even the survival of civilization? I have spoken of existing and prospective mechanisms for promoting scientific intercourse between the people of different nations. We must use and develop these to the full limit of their value, but we shall still want something which no formal mechanism can restore to us. Meetings of national representatives and delegates may, indeed, do service of great importance to science, as by framing and accepting international conventions on units of scientific measurement, or on technical terminology; but no mechanism which merely brings scientific men together as national representatives, no finding of formulae or passage of resolutions, will do for science to-day what the world so desperately needs.

If we are to achieve anything really to meet that need, we must somehow get rid of barriers which hinder the scientists of different countries from meeting simply as scientists, for the frank and informal interchange and friendly criticism of each others' observations and ideas, in complete freedom from any national inhibitions or restrictions. Before 1914 we were able to claim that science belonged thus to the world, knew no frontiers, was one and indivisible. Many of us had been cherishing the hope that the union of so much of the world in a war for the defence of freedom—freedom, we understood, for science as for all man's other activities—would have brought, with victory, a possibility of reviving this claim and restoring this ideal, which the intervening years had so shaken and obscured. Even a few weeks ago the trend of events did not appear to encourage that aspiration; but we may find, in the end, that it will suffer less from an open challenge, which all the world can see, than from a more gradual discouragement.

To all but a few men of science, as to the rest of the world, the use of the atomic bombs on Japanese cities brought the first news of a tremendous scientific and technical achievement, as well as the recognition of a new problem of overpowering importance to the world. Scientific workers might well take pride in it, as a triumphant verification of a purely scientific prediction. The main lines of this had been completed before the outbreak of war in 1939, by experimental and theoretical physicists of many countries. We think proudly here of the pioneer part which our own Rutherford with his pupils and associates had played in the opening of a new science of nuclear physics; but we recognize that its development was a widely international achievement. The practical realization in a little over three years of what these academic scientists had foreseen as a distant possibility required a scientific and technical undertaking of a new order. It is unlikely that any stimulus

other than the urgency of war would have sufficed to induce any national, or other, organization to embark upon such an enterprise. It is certain that, under the world conditions in which that stimulus was applied, the United States of America was the only country in the world where the project could have been undertaken. The result was a prodigy of organization and achievement, both scientific and technical; and though, in the nature of the case, America made the largest contribution even to the team of scientific workers engaged in the great volume of theoretical and experimental researches still required, we may be glad to think that, on that side, the enterprise still owed much to a widely international effort. It drew into its service a large proportion of the nuclear physicists of Britain and of Canada, with others who had escaped from the clutches of the German invader in Denmark and in France, and yet others who had fled before the War from Germany, from Austria and from Italy to conditions of freedom and new opportunity in Britain and the United States.

The enthusiasm with which the world of science would normally have received the news of an event of such magnitude in scientific history was qualified by the unique conditions of its general announcement. The world at large has not been slow to grasp the tremendous implications which it may hold for the future of civilization, and the nature of the choice with which it has so dramatically faced mankind. The problems which it has raised are clearly everybody's concern. Nevertheless, and in spite of certain threats and rumblings, I believe that general opinion will allow to us men of science, in addition to our common rights as citizens, a special claim to be heard on the uses which the world is to make of this great new gift of science to mankind. General opinion, I think, would further recognize that the many scientific workers who have taken a direct part in this great achievement have a special right and duty to let the world know how, in the light of their intimate and expert knowledge, they view the promise and the threat which it offers to humanity. Surely they, if any, have a right to speak; and we others can welcome the firmness and the substantial unanimity with which many of them have let their opinions be known. We have a duty, indeed, to the statesmen, who are carrying this new and heavy burden of responsibility for the world's future, and who have to deal with aspects of the problem in which science is not directly concerned. It is a part of that duty, however, to keep them in touch with the general body of opinion among the scientific workers of the free peoples whom they represent, so that, in framing their policy, they may be confident that the service required of science to make it effective will be given with enthusiasm and conviction, and not, if at all, with a reluctant acquiescence. Most, if not all of you, will have read words which the Prime Minister spoke to the Canadian Parliament, and emphasized by repeating them to our own House of Commons a week ago. "Unless we apply to the solution of these problems a moral enthusiasm as great as that which scientists bring to their research work, then our civilization, built up over so many centuries, will surely perish." I do not doubt that you will share my glow of gratitude for a tribute which we must try to deserve.

It is not fitting that I should discuss here matters which belong to a much wider constituency than ours,

and my particular purpose to-day is to ask you to consider an aspect of this world problem, which is, beyond challenge, our special concern as men of science—the effect of present and prospective developments upon the integrity of science itself. Will any deny our claim to hold that as a sacred trust for the world, and to be alert to defend it from any danger which may seem to threaten it? I believe that we have a duty to be watchful now against a serious danger to it from the intrusion of secrecy, which we know here from long tradition and experience to be alien to the spirit of science as we have known and cherished it. I cannot claim the time which would be required to deal adequately with such a theme. Permit me, however, to bring certain aspects of it briefly to your notice, without attempt at full or ordered discussion.

1. This danger, of course, has not newly arisen with the explosion of the first atomic bomb. We have known it long in connexion with the use of scientific research by industry, and with the relatively minor and accessory part played, until recently, by science in preparing the apparatus of war. Even in those connexions, there was a growing recognition of the detrimental effect of secrecy on the relations between the scientific men concerned and the general scientific community, and a consequent effort to reduce its applications to the minimum which industrial or military opinion would accept.

2. The real and growing danger arises, however, from the new conception of war, due to the breach and consequent abandonment, in rapid succession, of conventions and restrictions which, not long ago, seemed permanent and sacred. Thus by the end of this recent War, step by step, with Germany always leading, the combatant nations had come to regard, as a proper war aim, not merely the winning of mastery over the enemy's fighting forces, but also the compulsion of his surrender by indiscriminate destruction, by any means, of his people and their possessions. This principle of 'total war', as we learned too easily from our enemies to call it, having once been accepted, science found itself no longer a mere accessory of military action, but increasingly a central agent, a direct combatant, and the provider of a limitless vista of destructive possibilities. Last year I spoke of the warning of such developments which the German 'V' weapons had given, and the dropping of the first atomic bombs has now given to that warning a new and a sterner emphasis.

3. Preparation by our enemies for the use of science in such total war, and our own for defence against it by reprisal, have alike involved the binding of a nation's scientific effort to secrecy on a scale beyond all earlier experience. This we accepted readily, with so much else, as a necessity of war. The freedom of science, as of all that made life worth living, was at stake; if by submitting for a while to secrecy we could help to save that freedom and to establish it for ever, we could not hesitate; but we must be watchful now against any easy assumption that that submission will be continued into peace.

4. As has now been recognized by international pronouncement, it cannot be assumed that the atomic bomb, or any contrivance using the release of atomic energy, represents the only direction, or even of necessity the most effective one, in which science could be perverted to the purposes of this 'total war', as a direct agent for the destruction of one people by another, or of dominance by the threat of it. The atomic bomb has given immediate prominence to the

problem, but the world might have had to face it, even if the attempt to release atomic energy had failed, or had never been made. The nations, in fact, have now to decide how they intend to use the powers and the resources which science stands ready to offer in growing abundance. Will they let science work again and henceforward in freedom, once more as an international community, and use what it offers for the raising of all mankind to levels of material prosperity and of culture above any that we can picture? Or will they try still to bind science to secrecy, for the competitive invention of ever more effective means of destruction, and thus hold civilization in instant peril of dissolution? It is surely our duty as men of science to help the world with our knowledge to make that decision, and to make clear our own views and intentions.

5. The danger to science from the intrusion of secrecy, against which I suggest that we need to be alert, does not arise, of course, simply from the question whether a particular technical invention shall be given away at once, or not until somebody else has made it. If policies now developing can bring about a frank and effective abandonment of all national secrecy about science, we need not, as men of science, be critical of their beginnings. Our experience so far, however, of the application of secrecy to science for military or industrial advantage must keep us on guard. It has not, in our experience hitherto, dealt with inventions which can, once for all, be locked up or given away. The most that it has hoped to achieve has been to keep its particular employer, at each new stage, a jump ahead of his rivals. What we have now to fear is that, in default of the international agreement which we must hope and work for, national military secrecy should try to maintain, or to extend, its war-time dominance. If that were to happen, we must expect it, with its new experience of the possibilities of science in total war, to be watchful for any advance, whether fundamental or technical, whether in nuclear physics or in any other progressive field of science, which could be impounded and put under seal for war-like preparation, presumably under the name of 'security'. It is impossible to forecast how much of science might thus become involved. The release of atomic energy is yet a novelty, and we have to think what might be made of it, for good or ill, twenty, thirty or forty years ahead. I think that we, as men of science, should make it clear to the world that, if national military secrecy were allowed thus progressively to encroach upon the freedom of science, even if civilization should yet for a while escape the danger of final destruction, a terrible, possibly a mortal wound would have been inflicted on the free spirit of science itself, to the immeasurable loss of what it stands ready to offer to a wiser world.

6. I do not believe that there is any division of opinion on this issue among scientists, anywhere in the world, in so far as they are able to express it simply as scientists. We scientists of the United Nations, in despite of all our normal traditions and instincts, were ready to submit for years to any secrecy or restriction which could help or hasten victory in the War for the world's freedom. The War has been won, and we shall not be ready to accept, as its result for science, a tightening of the chains. We have the right to expect that its freedom will be restored; and the freedoms which we ask for science are freedom from secrecy and freedom from national barriers.

7. Secrecy as the enemy, and resistance to the attempt of authority to impose it, are no new experiences for science or for scientists. Giordano Bruno was burned at the stake and Galileo was imprisoned and threatened, because they refused to be secret about discoveries which were thought to be harmful to religion in their day; and, in a later century, there was an attempt, for a like reason, to discourage scientific men by moral ostracism from telling the truth as they had seen and discovered it. Science was not halted, the world still moved, the moral stature of mankind was raised by the encounter, and organized religion gained more from it in wisdom than it lost in intellectual dominance. We do not know yet who, or how many, of Europe's men of science, in the terrible years now closing, have suffered for the scientific truths which political tyrannies desired to suppress or to distort. Unless the growth of international understanding and confidence can now prevent it, unless efforts to outlaw the abuse of science for 'total war' should succeed, science may find itself again facing an attempt to impose secrecy upon it, this time in the interests of national suspicion and rivalry, and in flat negation of its true service to mankind. If that danger should threaten, can we hope that the scientists of all the world may yet stand together against it, determined to preserve the integrity of science, to prevent its further perversion from its proper and beneficent uses, and to save civilization from misusing science for its own destruction?

Our Charter of 1663 lays down, as the object of the Royal Society, "promoting by the authority of experiments the sciences of natural things and of useful arts, to the glory of God the Creator, and the advantage of the human race". Each of us may read these old words to-day in terms of his personal convictions. Freely to seek "by the authority of experiments" and freely to proclaim the truth as science reveals it, for its own beauty and excellence and for the help, the healing and the enlargement of the means of happiness which it can bring to all mankind—does any man of science, anywhere in the world, whatever his creed or his loyalties, desire for science any aim but this? The old mandate still embodies the purpose for which the Royal Society has stood for more than 280 years, and still must stand, as a beacon to the world and as one of its centres of inspiration.

AN ELECTRICAL HYPOTHESIS OF SYNAPTIC AND NEUROMUSCULAR TRANSMISSION

By PROF. J. C. ECCLES, F.R.S.

Physiology Department, University of Otago

SINCE 1933 the transmission of impulses across synaptic or neuromuscular junctions (henceforth called junctional transmission) has been the occasion of a controversy¹. The electrical hypothesis has had the grave defect that (except for the falsified isochronism theory) it has never been stated in such precise terms that it could be subjected to crucial tests^{1,2,3,4,5,6}. On the other hand, the chemical hypothesis in its original form (acetylcholine as transmitter) was falsified by an investigation of the action of eserine, and has had to be modified by the addition of *ad hoc* hypotheses⁷; but the