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THE TRAINED MAN OF SCIENCE IN THE WAR[1]

THE motto of our society, as our newly initiated members now know, is one by following which unconsciously they have won admission to it: "The love of learning is the guide of life." It must have occurred to you all to ask how can this assertion be true in times like these. That an answer may be given easily is evident if we remember the circumstances under which the society was founded, at the College of William and Mary, in the midst of the Revolution. Our ancestors were engaged in a struggle for the freedom of the individual, the freedom of the soul; so are we to-day. They had entered this entirely unprepared; so did we. They were faced with difficulties which seemed at times unsurmountable; our obstacles to victory are no less formidable. The Phi Beta Kappa Society owes its origin to a recognition on the part of its founders and supporters of two great facts: the importance to the individual of the love of learning and the responsibility resting upon him as an educated man to serve his country.

I think it is only fair to say that the universities of this country have played their part well. Before we actually entered this war, in those anxious years when we were waiting to see whether we would be given an opportunity to join in the fight for the cause of honor, freedom and the teachings of Christianity, or whether we must walk through the years of our lives with heads hung in disgrace, no group of people did as much to hold aloft the illuminating torch, revealing the iniquity of the enemy of civilization, as did the presidents of our universities. Theirs will be the honor forever. They would not keep silent. Then, as soon as we were by official act in a state of war, the first to step forward and say "use

[1] Annual address before the Phi Beta Kappa Society, University of Virginia, 1918.

me" were the faculties and the student bodies. It was indeed a sight which brought tears to the eyes, and even further, to see our young men, the chosen men of our land, struggle against all restraints, eager to bring to an end that evil thing which threatened to destroy all the joy of life, all that made life worth living. Every teacher has felt thrilled by the daily farewells of his students, as one by one has obtained permission, by fair means or otherwise, to enlist in the grand adventure. We men associated with universities may well be proud.

Think for a moment what unutterable shame would have been ours if we had not acted with such certainty and such promptness. Every privilege brings its responsibility. It is a privilege to acquire an education and to share in imparting one. The country as a whole has grown to recognize this, and to look to the universities and to men trained in universities for advice, if not for guidance. It is the privilege of being a young man to-day, a college man or not, to be a soldier in the cause of civilization and to help bring victory to its colors; and what a glorious privilege this is! But upon whom rests the duty of interpreting events and their causes in language so clear that every man understands? Surely, upon the university man. And, when victory is won and men can give their minds to thoughts of safeguarding the world, there is no one to guide them but the students of history and of political science. It would be a simple matter to show how a special and particular responsibility has already come to and will continue to remain with each and every university group of scholars. I can speak with more definite knowledge of the relation borne by various branches of science with the war; and it is to this feature that I shall confine myself to-night.

A recent writer has alleged that the study of science at the expense of morals in German universities has led to this war. This is a bitter charge, but it is supported only by fallacies. Macaulay, in his brilliant essay on Dryden, shows, by a series of striking illustrations, how little is the influence upon the age of any individual, or any special group of individuals, when compared with the influence of the age on the man or group. When the time is ripe, the idea is born; the special man who reveals it is immaterial. So it is to-day, no one man, no particular department of thought or study can be held responsible for the present conditions in Europe. It is no more fair to say that the pursuit of science perverts character than to assert that the study of morals results in ennobling it. This war is due to a gradual debasement of character and nothing else, and the cause is to be sought in the will of the leaders of Germany.

One reason why science has been thought of as the scapegoat is because it was so evident from the very beginning of the war that Germany had mobilized for the purpose of war all her men of science, and was using the fruits of their investigations in ways entirely unexpected. This was a matter of great surprise to most Americans, and illustrates clearly the comparatively insignificant position held by scientific men in the minds of our people. This feature of Germany's long preparation for war, and of her manner of waging it was recognized instantly; and preparations to combat it were made promptly by all the allied peoples. Fortunately for us, the essential advantages were all with the French and British, inasmuch as their men of science had for nearly a generation been the ones who had given to the world its great discoveries and their most important applications. So their scientists came to the problems with ideas and methods which in many cases far surpassed the power of Germany to equal. The result was instantaneous; and to-day the efficiency of the forces of the Allies on the sea, on the land and in the air is due in no small degree to the men whose previous lives had been devoted to the pursuit of the pure sciences in university laboratories.

When this country entered the war, it is true beyond any doubt that the American people had great expectations, nay a conviction, that with our so-called inventive genius we would seriously influence the war, perhaps stop it, by the epoch-making inventions which our professional, highly advertised, inventors

would quickly make. The newspapers helped in fostering this belief, and many were the proud boasts which we heard. There was a great disappointment, almost a shock, as the days went by, the periods promised for great accomplishment passed, and certain names almost disappeared from the public press. We have in fact stopped asking what has happened to the "wizards." The reason is that the problem of this war is not to perfect an old device, but to design a new one; the knowledge required is not that of the amateur or even of the trained engineer, but definitely that of the scientific investigator, the man who by his own laboratory investigations has added to our store of knowledge. One illustration of this may suffice; one government board, with whose activity I am familiar, has had submitted to it in the course of the year 16,000 projects and devices, proposed by so-called inventors; of these only five had sufficient value to deserve encouragement. I have nothing but admiration for these 15,995 men, whose disappointment must have been keen. Most of them were more than willing to give their inventions freely to the government. The point I wish to emphasize is that the ability and knowledge required in waging this war successfully are not those possessed by any body of men except those with a profound knowledge of science and of scientific method. The problems are too complicated. It is true that with the help of trained technical men we will get better engines, better explosives, better guns; and for these we should be truly grateful to our much-boasted American genius. But, consider a problem like this: to devise a light signal, which can be used by day or by night, and which will be absolutely invisible to the enemy. Who can solve that? The answer is obvious: only a physicist.

In times of peace, when commercial development is uppermost in men's minds, the university scholar is at a great disadvantage. He rarely knows what problem is to be solved. He is busy with his own studies and researches, and does not come in contact, in the ordinary course of his life, with the demands of the technical trades. His discoveries are made use of, and are always—sooner or later—of commercial value; but in this later stage he does not take part. Nearly all of our great technical companies maintain extensive laboratories where trained men pursue investigations in pure science; but problems are rarely given them to solve. To-day, in order to meet the insistent demands of the war, the whole process is changed. On every battle front of Europe, attached to the various staffs, are men from university faculties, skilled in observing, quick to learn what is needed. In Paris, London and Rome there are groups of university men whose duty it is to collect data from the Allied powers along similar lines. Reports containing clear statements of the problems are cabled to Washington. To this same center come requests for help from our own forces on this side of the ocean. Then, as soon as the problem can be formulated with definiteness, one or more men are asked to find the solution. For the first time in the history of science, men who are devoting their lives to it have an immediate opportunity of proving their worth to their country. It is a wonderful moment; and the universities of this country are seizing it. The stimulus to scientific work is simply enormous; and the growth of our knowledge is astounding. In many cases investigations are prolonged for months, and in the end possibly the much desired solution is not obtained; but in any case new methods are made available for future use, new instruments are perfected, and the store of human knowledge is vastly increased. Let me give one illustration of this reaction of the demands of war upon pure research. In the construction of a mask to be used in case of a gas-attack it is obvious that one method of defense is to make use of charcoal which is known to absorb many gases with great rapidity. A scientific problem was to try to increase the efficiency of this absorbing action; and it was soon discovered that by a special treatment of charcoal made in special sizes from special wood the absorptive power could be increased enormously. Here is a fact of the greatest importance to the chemist, a fact which will be remembered in countless investi-

gations of the future; and yet it is doubtful if it would have been discovered for many years to come if a particular chemist had not been asked by the military officers to help them.

As I trust you have already discovered, my thesis to-night is the importance of the work of the trained man of science in this war, with emphasis upon the fact that his great usefulness should not be a matter of surprise, as it is to most Americans. The best way of demonstrating this is to give a few illustrations, chosen from a wide field and not limited to the scientific work of any one country. Naturally I can refer only to those matters which have been revealed to the public; but I trust that many of them will be new to this audience. I have this confidence because so far the newspapers of this country have not believed that these questions would make what is called a "story."

It is not easy to make a selection of the scientific problems, nor to arrange them in any logical order. There are two subjects uppermost in the minds of every one: the airplane and the submarine. The scientific questions which have arisen in regard to each are most varied. The airplane itself is an engineering structure; and we have confined ourselves in this country largely to the design and production of an engine. This does not really come under my general subject, but every one is so interested in it that I feel justified in referring briefly to what we have done. Our task was to produce on a great scale a powerful, efficient engine. This is now being done. The so-called Liberty 12-cylinder engine does not have its superior in the world, and further, it was so designed that it could be manufactured on an enormous scale, at least 1,500 a month. This engine has over 400 horse-power and weighs close to 800 pounds, and therefore it is useful for seaplanes, two-seater machines and bomb-droppers, but not for small machines. When the same engine is made with 6 cylinders, developing about 220 horse-power, and weighing about 400 pounds, we will have an ideal engine, not equalled by any now in existence, for speed scout machines. We could not have followed any plan more useful to ourselves and the Allies than to make this concentration of effort. Our eminent success is a cause of pride to every American. With regard to the airplanes, considered apart from their engines, a few statements of fact must suffice, but they are facts. The best airplanes in service to-day, for each and every purpose, are those of British and French design. This is the result of real scientific investigation. The resistance offered by wings of different sections, the stability of the airplane, the character of the covering surfaces have all been investigated, and the finished product is the result of the knowledge thus acquired. We are doing similar scientific work in this country to-day, and, as we have engineers and manufacturers unsurpassed in the world, the time is not long distant when a truly American airplane will be made. We shall suffer, however, one serious detriment during the war; we are so far away that it will be extremely difficult for us to make the alterations in design which the varying conditions of modern war impose. Difficulties of transportation are great, and it is a serious question whether it would not be best for us to remove bodily our most important airplane shops directly to the Continent. From a scientific standpoint the most important questions arising in connection with airplanes are instruments of navigation and methods of signalling to and from the ground and each other Each machine should have for ordinary flights an instrument to indicate height above the ground, another to give the speed of flight through the air, another to tell how steep is the ascent or the descent, and many others. For long-distance flights a compass is necessary, and other instruments as well. The design of each of these is a distinct scientific problem. Think of the requirements for a compass to be used with an airplane; for a ship on the ocean the problem is complicated, but how much more so for a vessel which turns rapidly, revolves in spirals, and which practically never keeps a constant course. In practise even more difficulties arise. The whole question of airplane instruments is still unsettled to a certain extent; many essential instruments have not as

yet been designed, and improvements are needed in them all. Scientific men in all countries, including our own, have the matter under study; and the results so far accomplished are truly wonderful. In the use of airplanes for observation purposes, or in squadron formation in making attacks, it is essential for the men in the machine to communicate with the ground. Many systems are in use, involving the application of light signals, wireless telegraph, etc. Obviously the proper instrument would be the wireless telephone, and that is surely coming, and soon it will be possible for one pilot to talk with another or with the commanding officer on the earth; and the latter can give orders to all of his machines in the air. The objection to the use of all forms of wireless apparatus, telegraph or telephone, is that the enemy may confuse the signals by using the same wave-length for his disturbing impulses. This may be prevented however. Under the demands of the modern army, all forms of wireless have been so perfected that the progress made is a source of surprise and wonder. In fact there have been made in this country certain modifications and improvements which are held rigidly secret. It is interesting to note that every one of these alterations in wireless operation was first worked out in physical laboratories, by trained physicists. Bomb dropping as practised to-day is not a scientific operation; there are too many variables. In spite of this, though, the accuracy of hits is increasing daily; and new processes are being developed. When it is seen that one method can not be made accurate, the next step is to devise one that will be. It will not be long before all the countries in the war will realize the fact that the tactics of fighting in the air are essentially unique, and there will be a land-service, a sea-service and an air-service. Both the army and the navy need airplanes for their operations; but after their demands are supplied, there remains the wide expanse of the air through which attacks can be made upon the enemy, far away from the battle-front and the coast. Great Britain has recognized this all-important fact, and is building a great fleet of airplanes for this new service. In this, new instruments, new types of machines, new guns and bombs are required.

There are two main problems in connection with the submarine, first to locate it, second to destroy it. Methods of destruction are at hand in the shape of depth bombs; but methods of detection so far have not been eminently successful. From an airplane one can see through the water only to a limited depth, never more than twenty feet, and so the main reason why the seaplanes have been so successful in destroying submarines is not due to the fact that the observer in the airplane discovers his prey, but is that his machine has such great speed, three times that of a destroyer, that when news is flashed that a vessel is being attacked by a submarine it can often reach the spot in time to drop its bomb effectively. The detection of the presence of a submarine is a definite physical problem; and it is not an exaggeration to say that at least one fourth of the physicists of note in England, France and this country have been engaged in the attempt to solve it. What lines of attack upon it are open? Not many. The submarine in motion emits certain sounds; can they be heard? It is a solid body; can one obtain an echo from it? It is made of iron; can this fact help through some magnetic action? These are the obvious lines of approach, but one should not hastily conclude that there are not others. Without stating, and I may not, how far successful these efforts of the physicists have been, I may note that the method which is now being tested by our Navy is one elaborated by a distinguished professor of mathematical physics. In the course of these extremely numerous experiments upon the submarine question several beautiful methods have been developed which after the war will have great scientific importance; one of these, due to a French physicist, is one of the most interesting developments in physics made within a decade. Another submarine problem, which is by no means of secondary importance, is to develop a method by which one submarine may communicate with another or with the shore. I do not think I

am saying too much when I state that this has been solved, even for considerable distances.

Closely associated with the airplane and the submarine is the balloon, either a dirigible or an observation one. The great problem here is to find a means of inflating it with some gas which is non-inflammable. Hydrogen is now used in general; and, when a balloon is brought down in flames, it means that the hydrogen has caught on fire. This problem is partly physical and partly chemical; and numerous experiments are now in progress, all being directed by university men.

I can not leave the subject of the airplane and the observation balloon without referring to the question of maps and map-making, in connection with which the former are so important. Until one has been at the headquarters of an army, it is not possible to realize the extent to which maps are used, or the various types of maps required. There are maps showing roads, paths and trenches; maps for staff officers, for regimental commanders, for company captains, for sergeants; there are maps showing the position of the enemy's ammunition dumps, aerodromes, signal stations, anti-aircraft guns; there are maps showing the location of the enemy's batteries; there are special maps for the use of the quartermaster, etc., showing where each horse trough, each well, each storehouse is. Map-making has long been a function of engineers; and in this war the most marked improvements have been in the main mechanical, first in introducting quickly on a map the revelations made by aerial photographs, second in increasing the speed of production of a map. In many cases, entirely new sets of maps are made each day, each one containing the information obtained within the preceding twelve hours.

Another department of science closely connected with airplanes and balloons is meteorology. We associate this word with weather prediction and with uninteresting data; but it must be remembered that these data include observations of temperature, of moisture content of the air, of air pressure, of wind direction and velocity at different heights above the earth. A knowledge of all of these is absolutely essential for each day's battle. Artillery at a long range is useless unless the temperature, the moisture content and the wind are known accurately. Gas attacks are controlled by the knowledge of winds and barometric pressure. The safe strata for airplanes must be known; and for long distance work weather prediction of every description is essential. So important is the subject that observation stations with competent forecasters and scientific observers dot the battle-front at close intervals; and the home offices send almost hourly reports to the fleets and the coast-stations. What strikes a layman most forcibly when inspecting a meteorological station near the battle-line is the rapidity of operation. Only minutes lapse between the observations and the deduction of the conclusion. One realizes then how much meteorology has grown into an exact science.

Modern artillery is a good illustration of the application of pure science. All of us are now familiar with the method by which artillery fire is controlled by the aid of airplanes; but you may not realize its wonderful accuracy. If the enemy's battery is located, by any means, this implies that its position on a topographic map is known to within, say, fifty feet, often less. It may be at a distance of ten, fifteen or more miles. Then to hit it, an exact knowledge of the properties of the powder used and of ballistics is required. With this, the target is reached in an astonishingly short time. I have witnessed myself the destruction of a German battery at a distance of eleven miles by a French battery of three thirteen-inch guns, all done within ten minutes, the exact aim being secured after three salvoes. The perfection of the mechanism of the French 75 and 37 millimeter guns is known to us all; but we hear much less of the English and American guns. I can assure you that this is only a curious bit of camouflage. Of all the numerous ways in which physics has been called in to assist artillery, I known none so interesting as is illustrated by anti-aircraft gunnery. The problem is most difficult. An airplane may be traveling at a

speed of 100 or 10 miles an hour, it rarely keeps a constant course, it may be at a height above the earth of 20,000 feet, nearly four miles. The man aiming the gun must know the position of the airplane and its speed, and then must make his calculations so that when his shell reaches the immense height, it shall be so timed as to meet the airplane. It is true that it is rather a question of the airplane meeting some fragment of the shell, than the converse; but the problem is the same. When it is realized that numerous hits are recorded at heights of 20,000 feet, and when one hears the personal experiences of the pilots, it is clear that the problem has been solved fairly well. A former student of mine writing to me a few days ago, after telling how he had "speared his first Hun" on his first day at the front, added that the German shells rarely missed him by more than ten feet, and he was flying a rapid scout machine and was manouvering for position all the time. I am familiar with the French and British methods of aiming their guns; and, as you can yourself decide from reading the newspapers, they are not inferior to the ones used by the Germans.

One can not speak of artillery without thinking of gas shells and gas attacks. The Germans were the first to use this hideous means of warfare, although it is well known that it was proposed to the British war office many years ago and the decision was reached that it should not be adopted. When poisonous gases first became a weapon, it was in the form of gas clouds, rolled along the ground by the wind, the gas having been released from cylinders in the front line of trenches. For perfectly obvious reasons this mode of gas attack was soon replaced by the use of large shells filled with the liquefied gas. When the shell was exploded by a contact- or a time-fuse, the gas would escape and work its action in all the neighborhood. There are two problems associated with this mode of warfare: an offensive and a defensive one. The former is to make a gas which can be liquefied, is not so light as to diffuse upward too rapidly, and which will either kill the man who breathes it or will in some way incapacitate him; the latter is to make a mask or a suit of clothing, if necessary, which will enable the wearer to breath and do his work in the contaminated atmosphere. We hear most of course about the terrors of the gases used by the Germans; but, if they would only describe to us their feelings about the gases sent them, our point of view would change. Some might even have a feeling of pity. Both the questions, of defense and offense, are strictly scientific ones, in the main belonging to chemistry. The researches undertaken in Great Britain, France and this country are so numerous that the truth is almost unbelievable. It is safe to say that to-day there are at least 2,000 chemists in America alone working on problems connected with the military use of gas. We can well be proud of the achievements of our chemists. Among many things which I may say I shall select two: they have devised a mask for use inside a gun turret on our large ships where a particularly dangerous gas is liberated during a battle, and the masks supplied our soldiers are at least 20 per cent. better than either the British or French mask, and they are better than the German model. As another illustration of the usefulness of chemists in this war, one should state what has been done by them to render the allied countries and our own independent of Germany from an economic standpoint. All I shall do, however, will be to mention two subjects: dye-stuffs and drugs; and you know the rest. It should be remembered, though, that this is not the full story, only an interesting chapter.

One of the most important military questions, which in the end is a purely physical one, is that of signals. Our army is most fortunate in having as its Chief Signal Officer a man who is a doctor of philosophy in physics, from Johns Hopkins University, Major General George O. Squier. He certainly knows his subject from the scientific standpoint as few military officers can know it. Think for a moment of the variety of signals required. Those to and from airplanes and submarines have been referred to. In addition, each trench, each outpost, each reserve force,

each artillery battery must be in unbroken communication with the brigade headquarters, and the division and staff officers. Wireless telegraphy and telephone are used in various ways; ordinary telephones are installed everywhere: carrier pigeons must be bred and trained; signals using both sound and light are most useful. It is not merely a matter of perfecting signals which work satisfactorily; much more is required, safeguards must be devised which make it impossible for the enemy to observe or read them. When I say that all this has been done, and done to a large degree by our American physicists, I am telling only the bare truth. I wish it were permitted to tell more.

Signals as used by the Navy are not as varied as those required by the Army. But there is one special problem which concerns the American Navy more than any other. We are sending ships and transports to Europe in large groups, as you know, and at night no lights are shown by any vessel; the question then arises, how is it possible to maintain relative distances and positions? This sounds as if it were an almost hopeless proposition; but it is not; and I have seen a solution which seems satisfactory, again the ingenious idea of an American physicist.

The demands upon photography are great, largely in connection with airplanes; and the methods elaborated by the British and French scientists are beautiful. There are other phases, though, of almost equal importance. Can we not take photographs of objects which the eye can not see, owing to clouds, haze or distance? This matter is solved in a large degree as a result of our spectroscopic knowledge. By photographic methods it is possible to discover the location of the enemy's batteries unless they are hidden with the utmost care. In this last case resort is had, as you know, to what is called sound-ranging. When a gun ejects its shell in the direction of the enemy, the latter hears in succession three sounds; first that due to the passing of the shell through the air, in general a hissing sound; then the proper sound from the gun mouth, a boom; and finally the sound of the explosion of the shell. Sound waves travel through the air with a comparatively slow velocity, slightly over 1,000 feet per second, and so if observing stations are placed at different distances from the gun, any one type of the three sounds, *e. g.*, the boom, will be heard at different instants of time. It is easily seen, then, that methods may be devised by means of a system of triangulation, by which the location of the gun may be determined.. The accuracy of the methods in use is so great that now within a few minutes after the firing of a gun its position is known definitely to within limits less the accuracy of the guns which are responsible for the destruction of the enemy's battery. This last limitation is due to an unavoidable variation in shells and their powder charges, and to variations in the atmosphere. This method of sound-ranging is simple in theory, but extremely difficult in practise, owing to vagaries of the wind and to the confusion caused by simultaneous discharges of guns. The former difficulty has been overcome by a brilliant British physicist; but, as you have probably seen in the papers, one of the ways used by the Germans to conceal the position of its big guns by which they were bombarding Paris was to discharge a dozen other guns simultaneously.

A somewhat similar problem arises in connection with determining the position of an airplane at night, or in cloudy weather. One inherent difficulty here lies in the great speed and great height of the airplane. Rumors have reached us that the British have found a method; but, whether this is true or not, the problem is not hopeless. The airplane in flight emits sounds, loud ones; with that fact as a basis, its detection is therefore certain.

I am not sure that any of you would of your own account think of astronomy as being a practical science; yet there has been found a definite usefulness for these disturbances on the sun, known as sunspots; and astronomers easily turn from calculations of the motions of comets, planets and satellites to those of twelve-inch shells and bombs dropped from airplanes. The instruments used by navigators on the sea and in the air when the flights

are long are essentially those invented and adopted by astronomers. In fact an American astronomer has perfected within the past few months an entirely new instrument for the use of navigators, an instrument which will mean a great deal to both our sea and our air force.

Another science which seems remote from war is geology, and yet it has proved not simply useful, but essential. The minute you realize that this war is concerned with trenches, dugouts, military mines, tunnels, water-supply, etc., you see that here the geologist must be summoned to help. He alone knows from his maps, made in times of peace, how to plan for any emergency requiring one to go below the surface of the earth.

There is a group of sciences, not physical, which has, in the end, the greatest responsibility in bringing victory to our arms. The men who are directing the work, in the laboratory and in the field, are university men almost without exception. This group includes experimental psychology, medicine and surgery and hygiene. The function of the first of these is to devise such tests that we may be reasonably sure that a man selected for a certain duty can perform it. As a simple illustration, think of an airplane pilot. It is not difficult to analyze his responsibilities and to state the qualities which he should possess; further it is not impossible to devise experimental tests which may be performed on the ground in order to see if he has these qualities or, if not, to see whether he can acquire them in a short time. Our aviation section of the army has equipped laboratories along these lines, and the results obtained are most interesting. Certain generalizations will undoubtedly be deduced, and the examination of candidates can proceed more rapidly. As soon as our military departments can be persuaded to recognize the fact that experimental psychology can in many, if not all, cases state definitely that a man with such and such reactions ought not to command a company, a regiment or a ship, our fighting forces will become efficient, not before.

The varied activities of our medical departments are known to you all. When I think of them, what is uppermost in my mind is their progress in combating disease. I may be pardoned for speaking of two illustrations. The gas-bacillus, the cause of hospital gangrene, has lost its terrors absolutely; first by the Carrel-Dakin treatment of wounds, second by Dr. Bull's discovery of a serum which may be used exactly as diphtheria anti-toxin is used. Dr. Carrel is a Frenchman and Dr. Dakin is an Englishman; but both have lived long in this country; and Dr. Bull perfected his method at the Rockefeller Institute, New York. My second illustration is the discovery of the means by which trench fever is conveyed from patient to patient. This is not a dangerous disease, but is one which renders soldiers non-combatants for the time being. This discovery has just been made in France by two of our American doctors, both attached in normal times to American universities.

Time fails me to speak of any more of the ever-growing number of ways in which the men of science of all countries are helping the military arms. But, if I were to stop now, I would leave unanswered one question which I know is in your mind. You are probably saying to yourselves, "Yes, this is interesting to hear about the scientific achievements of ourselves and the Allies; but what is the real use of it, when Germany, which leads the world in all branches of science, is our enemy?" Now, let me say at the very beginning that no educated man, certainly no member of the Phi Beta Kappa Society should assert that Germany is the leader of the world in science. It is true that Germany modestly acknowledges it, and every American newspaper supports the claim in ways both direct and insidious. The facts, however, do not support it. Many years ago it undoubtedly was true, but a full generation has passed since then. The Prussian form of government does not encourage individuality or freedom of thought; and these are essential for scientific discoveries and scientific development. In all seriousness I maintain that Germany has not been fruitful in ideas for many years in any of the experimental sciences, with the exception of medicine. In the fields of physics, of chemistry,

of meteorology, of metallurgy, you must look for the leaders in other countries.

It may be true, although I doubt it, that Germany has the best generals, the best guns, the best ships; she certainly has the largest army and the power to bear upon any point the greatest force; but this condition will pass. In the meantime there are two agencies at work in this country which in reality are most powerful sources of German propaganda. One of these is the interpretation given to news from the war by our public journals, and the emphasis placed upon German successes. In part this is due to the lack of realization by the managers of the papers of their responsibility in the matter, but in larger part to that policy of a newspaper office which leaves the writing of the headlines in the hands of unexperienced, comparatively uneducated, young men. The other agency of German propaganda, and a much more vicious one, is the policy adopted by our own government in regard to giving out official information. The whole policy is wrong, and should be changed. The people have lost confidence in the government agents, and rightly so; they are either optimistic to a ridiculous degree or boastful. What is required is that the government must realize the tremendous responsibility of the office charged with the dissemination of news. There is no man in America too great for this task. He must command the absolute confidence of every one; he must be able to speak the truth and nothing but the truth; he must understand the thousand phases of the war, looked at from a military, a medical, a scientific, a social standpoint; above all he must be allowed to give the American people real information in regard to the efficiency, the achievements of our people and of the Allies. It is absolutely impossible for a man trained as a newspaper writer to grasp the situation. It is one of the real tragedies of the hour that the American people are so often deceived and are not told the truth about so many matters which concern them so vitally. If our people could only realize the exact situation, Germany would lose half her power, because in fact the American people are afraid of her, a condition which is absurd.

The scientific men of America have suffered greatly at the hands of the people. As I said at the beginning of this paper, it was a matter of great surprise to the country that science had any part in this war. Even such men as the members of the engineering societies have been slow to recognize the value of the service of the investigators in science. The ablest group of scientists in America is naturally the National Academy of Sciences, and the physicists are associated in a large and powerful American Physical Society; yet, when a few years ago one of our government departments determined very wisely to form a board of professional scientific and technical advisers, neither of these national societies was invited to name a delegate or to participate in any way. It was not understood clearly why the American Mathematical Society was requested to name a member of this board until it was explained that it was thought it might be useful to have a man who could do figures for them. This was of course simply a case where the general ignorance of the country was crystallized in action.

The time has come for America to recognize the usefulness of the scholar, the thinker, the investigator of science. All the other countries of the world have done so long since. It is only in regard to such experimental sciences as physics and chemistry that there is this failure in this country to appreciate the services of its experts. If the question as to the prevalence of a particular disease in army camps is to be investigated, a board consisting of pathologists and men skilled in hygiene is selected almost automatically, not a board of practitioners. The same is true in regard to all questions of public health, of social questions, of law. It is the duty of all college and university men to make their voices heard and to bear witness to what their teachers and their associates have done and are doing.

To return to our motto; the love of learning is a good guide for life; it brings its own happiness, it makes one a useful citizen both in times of peace and in war, it prepares a man for that service which is our only justification for living.

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