FAMILY HISTORIES AND EUGENICS.

IN the thirteenth bulletin (June, 1915) from the Eugenics Record Office (Cold Spring Harbour, Long Island, New York), Messrs. C. B. Davenport and H. H. Laughlin give precise directions for making "a eugenical family study." The general lines are similar to those of the records of family histories which Sir Francis Galton sought to initiate in Britain many years ago. Such a study, carefully made, is, the authors tell us, important to the individual, who may understand and guide himself better if he knows his hereditary assets and liabilities; important to society, which "can treat the delinquent individual more reasonably, more effectively, and more humanely, if it knows the 'past performance' of his germ-plasm"; important with a view to "vocational selection," the end of which is to get the right man in the right place; important for education, which should take some account of the inborn potentialities of the individual; and important, finally, in the selection of marriage-mates, or at least in avoiding obviously unfit unions.

The bulletin tells the inquirer how to construct his "family tree" when the facts have been secured, and how to make an "individual analysis." This rather formidable enterprise involves answering sixty questions as to life-history, and as to physical, mental, and temperamental traits. The framing of the questions embodies long experience, and even to put them to oneself is interesting. Drs. Hoch and Amsden supply an even more elaborate *questionnaire* as to mental and temperamental traits. It will be hard to discover any trait that this catechism leaves out. It begins by asking the victim "if his education is up to his opportunities," and it ends by asking in what he gets "his deepest satisfaction." The questions are much more penetrating than those of the census paper or the income-tax return, and some of them seem to demand for their truthful answer a rare degree of detachment. But the authors meet this objection by pointing out that the records are to be kept as confidential documents in the central bureau, and that one must not think too much of personal privacy when the welfare of the race is concerned. Certain it is that a scientific genealogy is worth working towards, and that this bulletin is a useful step in that direction—useful in educating public opinion and in giving critics something to work on. In this connection it may be doubted, for instance, whether it is a wise discretion to refrain from any attempt to differentiate in the recording of family data between heritable and non-heritable traits. It may also be asked whether there is not a distinct risk of developing a self-conscious pre-occupation about one's "traits"—that Herbert Spencer was always talking about—and a paralysing obsessional conviction of the fatalism of heredity, which is only one side of the case.

CHARACTER AND INTELLIGENCE.

THE *British Journal of Psychology* has published as a monograph supplement (Cambridge University Press) the results of a research by Mr. Edward Webb on character and intelligence. The subjects of the inquiry were ninety-eight men students at a training college in 1912, ninety-six students at the same college in 1913, and four groups of schoolboys, amounting in all to 140. At the training college the prefects (second-year students), and at the schools the class-masters were utilised as judges, a pair of independent judges being employed in each case. Very careful instructions were given and detailed lists of qualities supplied. Examination results and experimental tests of intelligence were also used. All the assessments were ultimately translated into a scale of marks from $+3$ to -3. The "reliability coefficients" (correlations between the estimates of the same quality in the same individual by the two judges) were in many cases very low, the average being rather under 0·5, and nearly one-seventh of the qualities marked were rejected on the ground of unreliability. For those retained the average reliability coefficient is 0·55. The lowness of the "reliability coefficient" is held in part to be due to the care taken to secure independence between the estimates of the two judges. For intelligence-qualities the results are held to give a "strikingly thorough support" to the theory of a general factor. The deduced correlations of the general factor with the various estimates are discussed in detail, and give some interesting and unexpected results. Amongst the latter may be mentioned the fact that sense of humour, which has little correlation with the general factor, is fairly highly correlated with the estimates, the prefects' judgments being apparently biased by this quality. The character-qualities are discussed in the same way, and here again there is held to be evidence of a central factor, and this factor is in some close relation to "persistence of motives." This general factor markedly dominates all the correlations yielded by the estimates of moral qualities, the deeper social virtues, perseverance and persistence; also, negatively, qualities related to instability of the emotions and the lighter side of sociality.

SCIENCE IN THE WAR AND AFTER THE WAR.[1]

IT is universally acknowledged that the outcome of the present war must be an entirely new chapter in human history and a point of fresh departure in social, economical, and intellectual life. Hence it is well to begin even now to take stock of our resources, to examine not only the reasons for our deficiencies but the directions of our reforms. Particularly are we concerned with the improved attitude which we shall have to take nationally with regard to all that study and knowledge which we call science and scientific research and invention. Hence an important matter is to consider the position of science in the war and after the war.

Scientific knowledge is the accumulation of exact information concerning the facts and laws of nature, and the scientific method is the process by which we gain it, viz., by experiment or observation and logical deduction therefrom.

The cardinal fact which lies at the basis of all this nature-study is that there is no finality in it. Its possibilities are infinite, and we can never touch bottom in all that there is to be known about the simplest objects or phenomena of nature.

Hence the very essence of scientific study is that the votary should himself make some advances. Merely to know what others have done or discovered may be necessary, but this alone does not make a scientific student. Accordingly the training required is that which imparts the power to make new knowledge, and the results must be judged by the degree to which it succeeds in so doing.

At this stage we may distinguish, however, two classes of workers. There are first those who are most interested in new facts or principles regardless of immediate utility, and, secondly, those who show ability in utilising this knowledge in so-called useful applications of science. The first class em-

[1] An introductory lecture delivered at University College, London, on October 6, by Prof. J. A. Fleming, F.R.S.

braces the purely scientific investigators, and the second the inventors.

The public is, unfortunately, apt to attach more importance to the inventions than to the investigations, regardless of the fact that there could be no applications if there were no knowledge to apply. This failure to recognise the value and unspeakable importance of a progressive disinterested study of nature is a characteristic British quality, and it is something very much more serious than a mere national trait or idiosyncrasy.

Philosophical students of politics have long recognised that all forms of government have their special defects, and democratic or representative Parliamentary government is no exception. One of the chief defects of the latter is that the men who gain the upper hand are too often the fluent or persuasive speakers or those who are skilled in managing public assemblies and masters in oratory and debate.

Hence, as Mr. F. S. Oliver points out in his very suggestive book, "Ordeal by Battle," in all countries where representative government prevails this type of leader exercises a considerable and predominant influence on public affairs. But with the professional speaker and politician an over-great importance attaches generally to phrases and to words. Success with them depends very much on how a thing is put, and the form of expression often overrules even the subject-matter itself. But the whole object of scientific work is the discovery of the truth, and not its obscuration. Therefore the ascertainment of fact or principle is in all this work of infinitely more value than the form of words in which it is expressed. Hence to the politician there is a certain uncongeniality about the scientific habit of mind, whilst the man of serious scientific training becomes at times impatient of the methods of the party politician, which have not facts at the back of them.

Accordingly the principal idea which it is necessary to instil into the public mind and drive home by every means is that our chief concern should be to bring the scientific method to bear upon all the affairs of the nation.

The second equally important truth is that the disinterested but systematic study of nature is of primary importance for national well-being. By disinterested study we mean pure scientific research not undertaken mainly for commercial reasons. Pope, I think, tells us that the proper study of mankind is man; but an even more important object of study for man is that of nature, and if we undertake that properly all other things in the way of applications will be added unto us. The point to notice, however, is that it is not everyone who possesses the necessary turn of mind for scientific investigation. There is a mysterious aptitude in some children for music, drawing, or other pursuits, and suitable training cultivates it. It is the same with the ability to discover or invent. Hence the primary duty of the nation with regard to its children is from the very earliest days to begin with them the study of nature, not in the repulsive form of learning things out of books, but by taking the child direct to the lap of Mother Nature and letting her teach the lessons about flowers, animals, stars, and earth structure.

All this, of course, means expenditure, but the nation has to learn this hard lesson, that education of the right kind cannot be given without wise and large outlay, and that there is nothing so expensive in the long run as cheap education. Another thing that has to be drilled into the public mind at all costs is that there are no short cuts to national efficiency or scientific pre-eminence.

The moment a deficiency is discovered, the tendency of the public is to cry out for some quick remedy; but quick remedies are very often quack remedies at best. We require, therefore, in the first place an entirely altered attitude of mind on the part of our public men, statesmen, and, above all, editors and managers of great daily newspapers towards scientific work, research, and teaching. We want a far greater appreciation of its supreme importance and of the attention that should be given to the cultivation of it under the guidance of expert leaders. The small degree to which genuine scientific work is appreciated, contrasted with mere sensational announcements not based on genuine discoveries or inventions, is seen in the treatment of scientific work by the daily Press, which, after all, only reflects the attitude of mind of the general public. Compare, for instance, the attention accorded before the war to politics, amusement, and fashion, and that accorded to accounts of scientific researches or lectures, in the principal daily papers. Worse still, some of them are apparently easily led to take up and boom perfectly unscientific but sensational announcements.

An illustration of this occurred not long ago in connection with a supposed great invention of a flying train. The scientific principle utilised was one discovered thirty years ago independently by Prof. Elihu Thomson and by me, and familiar for years to all electricians, viz. the repulsion exerted on electric conductors by a powerful alternating-current magnet. By this means the inventor proposed to raise a train off the rails and propel it, I think, at three hundred miles an hour. Every engineering student, however, knows well that the resistance to the motion of a train at high speed is largely air resistance, and that this increases very rapidly with the speed. Hence even if there were no rail or axle friction at all, an economical limit to the velocity is soon reached at which the cost of driving power becomes prohibitive.

The inventor ignored this important fact, and for a week at least the utmost nonsense was written in daily papers by journalists whose only qualification for the task was an exuberance of language and metaphor combined with an utter ignorance of scientific facts. New inventions or suggestions require careful, sympathetic, yet critical treatment, but the public are misled when imagination is allowed to run riot too soon. Nevertheless, even great discoveries or inventions, such as the Röntgen rays or wireless telegraphy, have been received with scepticism and their utility denied at first.

The daily Press, which has such immense influence on public opinion, should exercise wise guidance in these matters, aided by competent scientific opinion, yet with discrimination and care not to denounce novelty merely because it is new or strange.

Turning to the applications of science in the war, we can mention four chief departments of it under the headings: chemical, mechanical, electrical, and physical, which cover such appliances as high explosives, aeroplanes and dirigibles, submarines, wireless telegraphy, and range-finders. I shall not attempt to discuss the details of a fraction of all these applications, but just touch briefly on two departments which happen to have occupied my own attention during the vacation, viz. range-finders and wireless telegraphy from aeroplanes.

An extremely important matter in all war with projectiles is to ascertain the exact distance of the objective, whether it be ship or gun or building. The range of the projectile depends on the angle of elevation of the gun and the character of the ammunition and several other factors.

The proper setting of the gun can, of course, be determined by trial shots, but the larger the gun the more expensive this process, and the more necessary not to let the enemy know anything until a shot or shell falls exactly where it can do most damage to him.

Range-finders have for their object to determine this distance by some optical appliance. They are divided into two classes: first, prism or base range-finders, and, secondly, subtend range-finders. We can explain the principle of these by reference to our eyes and the method by which we roughly judge the distance of an object. When we look at an object the optic axes of the eyes converge on it, and by long practice we are able to appreciate the inclination of the axes. The centres of the eyes are about $2\frac{1}{2}$ in. apart. Hence we have a very short-based isosceles triangle, but we are enabled by our muscular sense to give a rough guess as to the angles at the base and practically to infer something about the length of the triangle. Again, we do it in another way by estimating the relative sizes of the image of known objects, such as a man or house or other thing which is formed on the retina. Another thing which assists us is the amount of detail we see in the object looked at.

The range-finders used in war are only more exact applications of the same principles. One of the most accurate is that of Profs. Barr and Stroud. This is a base or prism range-finder. It consists of a tube varying from half a metre to two metres, about 6 ft. in length. At the ends of this tube are two totally reflecting prisms, which receive rays from the object and send them down the tube. At each end of the tube is an object glass, which forms an image which is received on a peculiarly cut prism at the centre and by an eye-piece. The arrangement virtually forms a sort of double telescope corresponding to two eyes set 6 ft. apart. When the observer looks into the right eye-piece he sees a field of view which is divided into two parts, one produced by light coming into one object glass, and the other by that coming in at the other. If the object seen is a mast, say, of a ship, it appears broken in two parts. The observer can rectify or bring into agreement these two parts of the image by moving to or fro in the tube a thin prism. The position of this prism is read off on a scale seen with the left eye-piece. This scale shows the distance in yards of the object.

Thus on board our battleships a range-finder of this kind is placed in one of the fighting-tops on the masts, and the observer looking at a distant ship can in a few seconds move the prism, adjust the two parts of the image to agreement, and read off the range. He then sends down the range by telephone to the gun-layers. Thus in the battle of the Dogger Bank, and in that of the Falkland Islands, firing by our battleships began at about 17,000 or 18,000 yards. The range-finder would thus be continually sending down the ranges 20,000, 19,000, 18,000 yards, etc., and the gunners would keep the object vessel in sight and fire when the command was given as the known range of hitting was reached.

The same principle is applied in a smaller instrument for military use, called the Marindin range-finder, invented by Major Marindin, only in the latter instrument the means adopted for bringing the two parts of the field of view or image into agreement are by a movement of one of the prisms.

The Barr and Stroud range-finder is a very accurate instrument, and will determine ranges up to 20,000 yards, or about 12 miles, with an accuracy of 50 to 100 yards.

In the next place there are range-finders called subtend range-finders, which depend on the measurement of the size of an image of a known object. When we look at an object either with the eye or with a telescope at different distances, it appears to be smaller the farther away we are from it. In the case of the eye we have no means of measuring accurately this variation in size except by comparing the apparent size of the distant object with some near object the size of which is known. Hence judging distance by the eye requires long training, as all sportsmen, sailors, and travellers know.

Moreover, we are apt to be deceived as to the apparent size. Ask anyone, for instance: How large appears the full moon? Many people would say, As large as a shilling—meaning that it has the same apparent angular magnitude as a shilling seen at 10 ins. or 1 ft., which is the usual distance we hold a book or paper when reading.

But now, if you try the experiment, you will find that the full moon is covered by a very small pencil, like a pocket-book or dance-programme pencil, held at 10 in. from the eye. In scientific language, the apparent size of the moon is about half a degree, which means that it is covered by an object 1/10th in. in diameter held 1 ft. from the eye.

A man 6 ft. high would subtend the same angle at a distance of 720 ft. Hence you can tell the distance of a man by ascertaining the distance at which an object of known size, say a pencil, must be held so as just to cover his height. An ordinary pencil $\frac{1}{4}$ in. in diameter held horizontally at arm's length (=2 ft.) would just cover a man 5 ft. 8 in. high at a distance of 544 ft., or 181 yd. The subtend range-finder works on the principle of measuring the angular magnitude of the object. One way of doing this is to place in the focus of the eyepiece a plate of glass with divisions ruled on it with a diamond. If we know how many divisions are covered by an object of known height at a known distance, we can tell the distance of any other object of known height.

It is very seldom, however, that we do know the exact height of the object, and, moreover, it is very difficult to count up accurately many very small divisions ruled on glass when the object seen is at all dark.

During the vacation I have been turning attention to methods for overcoming some of these difficulties. As these inventions are being submitted to the Ministry of Munitions, I do not think it desirable to go into details as to the methods, but I will tell you the results. I have invented three forms of range-finder—one which is an improved subtend range-finder with which I can find the distance of any object the dimensions of which are known, whether height or width, or any part of it. Also I have invented methods for using two such instruments to measure the distance of objects the dimensions of which are not known. In the second place, I have invented a simple form of base range-finder which measures what is called in astronomy the parallax of any distant object, and hence determines its distance. In the third place, I have devised a simple form of depression or elevation angle meter by means of which the height of any hill, and also the distance of any object from it, or from an elevated position, can be determined by an observer standing at the top of the hill, provided that he can also see two marks placed at the base in line with the point of observation on the hill and at a known distance apart. These instruments are simple and inexpensive to construct, and give an accuracy of measurement quite sufficient to direct rifle or artillery fire or bomb throwing in trenches. One great advantage of my range-finder is that it can be used with a periscope from the bottom of a trench so that the observer need not be exposed at all, but can determine the distance of the enemy's trench by observation on any post of a wire entanglement or stick or rock or anything with a sharp outline. Another principle which may be applied in making a range-finder, which I have also done in my instruments, is to observe the variation in the size of an object as seen in a small telescope by moving away from it a certain distance. Thus, suppose that a man was seen at a distance of 200 yd., or 600 ft., then his apparent height would be covered by the width of a pencil held about 2 ft. from the eye. Suppose the observer were to approach to half that distance or move in 300 ft., then the apparent size of the man would be doubled. If, however, the man were a mile away, then moving towards him 100 yd. would only increase his apparent height by about 6 per cent. Hence we can determine the distance of an object by finding out how much the apparent size is increased when we move in towards it 100 yd. or any assigned distance.

Another marvellous application of science in war is that of wireless telegraphy in connection with aeroplanes and airships as a means of scouting and rapid communication of intelligence.

The difficulties connected with it are, however, considerable, and it has greater limitations than the uninitiated would suppose.

In the case of aeroplanes the first of these is the weight of the apparatus. The military aeroplane is already loaded to its fullest extent. In addition to the pilot and observer and the bomb ammunition, it carries in nearly all cases some gun equipment. Hence any wireless apparatus must be made as light and compact as possible. A wireless transmitter of the so-called spark type involves three elements: (i) some source of electromotive force such as a battery or dynamo, (ii) an induction coil or transformer for creating a high electric potential or pressure, and (iii) some form of condenser or Leyden jar which is charged and then discharged across a spark gap, thus creating rapid movements of electricity called electric oscillations. These oscillations are then caused to create others in a long wire called the aerial wire.

In the case of aeroplanes and airships the source of electromotive force is generally a small dynamo or alternator, which is coupled to the engine, and the voltage or pressure is raised to 30,000 volts or so by a small transformer sealed up in oil in a box. The condenser consists of metal plates sandwiched between sheets of glass or ebonite, and the spark balls between which the spark passes are also enclosed. The weight of the whole apparatus has to be kept below 100 lb., and such apparatus has been designed having a weight of not more than 30 lb. The French use a set weighing about 70 lb. One of the difficulties is to dispose the aerial wire conveniently and safely. It is sometimes made of aluminium and stretched on insulators carried by light supports on the wings, but the difficulty is to obtain in this way sufficient length. One plan adopted is to coil the wire on a reel, which the observer can uncoil and let it float out behind the aeroplane.

The wire must be connected to the reel by a safety catch so as to be released at once if it catches in trees or buildings. By this means an aerial wire of 100 ft. in length can be employed. The observer has near his hand a key by which he controls the spark discharges and so sets up in the aerial wire groups of electric oscillations which create electric waves in the æther, and signal the message in Morse code.

In this manner there is not much difficulty in equipping aeroplanes with transmitters which will send messages 30 miles or so to a corresponding earth station.

These latter are the military portable motor-car or pack stations, the details of which were described in a lecture given here last year on "Wireless Telegraphy in War."

The receiving arrangements used on aeroplanes comprise a head-telephone which is worn by the observer associated with some simple form of detector such as a carborundum crystal, aided by which the observer hears the signals sent to him in Morse code as long and short sounds in the telephone.

The noise of the aeroplane engine and that of the rush of air renders this method of aural reception a matter of great difficulty, especially as the messages must be sent in secret code, and the observer must therefore hear every letter distinctly if the message is to be intelligible. Great efforts have been made to devise methods of reception which shall appeal to the eye by a visual signal rather than to the ear, but the exceedingly small electric currents set up in the aerial wire by the arriving waves make this a matter of extreme difficulty, and the problem has not yet been completely solved. There is then the difficulty caused by "jamming." If the signals from an aeroplane are picked up by a hostile station, this latter at once sends out powerful but unmeaning signals the object of which is to blur and drown out the reception or sending of signals by this aeroplane. Moreover, the sending of wireless signals by an aeroplane reveals its presence to hostile earth stations before it can be seen by the eye.

Hence wireless telegraphy may be a means of revealing the enemies' scouts, and it involves a certain kind of war in the æther as well as war in the air.

In the case of airships there are other difficulties as well, and it is interesting to note that there are special difficulties in connection with Zeppelins. These aerial monsters are, as everyone knows, constructed with a framework of aluminium, containing in its interior the eighteen or twenty balloons inflated with hydrogen. Now as we rise upwards in the air the electric potential increases rapidly, and if a conducting body at a height gives off water drops or products of combustion, it is rapidly brought to the potential of the air at the place where it is. In the case of Zeppelins this equalisation is no doubt brought about by the escape of products of combustion produced by the engines. When the conducting body is brought down suddenly to earth again, there may be a great difference of potential between it and the objects on the earth. If it is a good conductor, a spark may pass, and if it is, as in the case of a Zeppelin, a conducting body containing a highly inflammable gas, leakage of which cannot altogether be prevented, this spark may cause an explosion and destruction of the airship. Again, the violent electric oscillations created in all metal objects near powerful radiotelegraphic apparatus may cause sparks to jump between metal parts, and hence may inflame a hydrogen leak.

It has therefore been recognised that there are special electrical difficulties in connection with the working of wireless on rigid airships with metal frames and also in connection with the use of spark apparatus. However carefully the actual working spark is enclosed there is always risk of induced sparks.

There is room, therefore, yet for much research and experimenting in connection with the use of wireless telegraphy on aeroplanes and airships, and the practical problems are by no means completely solved.

This leads to the consideration of the methods we have adopted for dealing with these and all other suggestions of the same kind of the nature of war inventions.

The Royal Society appointed certain committees at an early stage in the war to deal with engineering or mechanical and with chemical inventions. These committees were constituted secret committees, and none of the fellows except the council and the small number of the appointed fellows were allowed even to know the names of the members. The ostensible reason for this unusual secrecy was that the committees should not be inundated with correspondence from eager inventors and that their work was confidential, but this argument is scarcely valid because the names of the members of other inventions committees, such as those afterwards appointed by the Admiralty and the Ministry of Munitions, were made public. The publication of the names of members in no way necessitates the publication of information as to their work. In the formation of such committees the important qualification should be not merely scientific or theoretical learning, but sufficient practical knowledge of the matters considered.

The men whose opinions are valuable on war inventions are the men who have to use them, namely, experienced military and naval officers. Again, the value of an invention can usually only be estimated by a practical trial, and this means expenditure. It is an almost impossible matter to judge of an invention merely from a written description. An idea may be old or a method may be familiar, and yet it may be carried out in detail in such a manner as to have great practical value under certain conditions. The ability to form a correct judgment of an engineering invention requires a very wide experience, since it is not easy to appreciate the good points or anticipate the defects of an invention or suggestion or idea which has not been put to the test of practice. Nevertheless, the experts appointed by the Ministry of Munitions are doing valuable work in sifting out the useful ideas from the hundreds already submitted to them.

It is beyond any doubt that this war is a war of engineers and chemists quite as much as of soldiers.

The 42-cm. Krupp gun which smashed in a few days the fortifications of Liège, Namur, and Antwerp, which were confidently expected to hold out for months, is only a piece of heavy engineering. The complete gun weighs 87 tons, and the foundations or carriage 37 tons. Two hundred men are necessary to erect and work each gun, which requires twelve railway wagons for its transport and is composed of 172 parts. It takes twenty-five to twenty-six hours to erect in place. The projectile or shell weighs 8 cwt., and is 5′ 4″ long and 16½″ diameter. It is fired electrically from a distance of about a quarter of a mile, and each shot costs 550*l*. The range at which the Liège forts were destroyed was fourteen miles. The mere transport and erection of this gun, let alone its manufacture, demands engineering knowledge of a special kind. It is the same with smaller arms. The rifle, except as a support for a bayonet, has almost become obsolete in face of the machine gun.

To win this war we have to achieve engineering feats. The mammoth howitzer, the great armoured triple-engined aeroplane, and the quick-firing machine guns are all products of the engineer's workshop, and the pivot round which all Germany's maleficent power turns is Krupp's works at Essen, and the chemical and ammunition factories in Westphalia. The knock-out blow will be given at those points, and they must be reached through the air if trench work proves too slow.

But in addition to the concentration of engineering knowledge and skill on the problems of the war, we have to think as well of what will come after. What is required is not merely opinions on inventions already made, but the proper organisation of inventive power and scientific research to bring about new and useful results. This is only to be achieved by bringing to bear adequate combined inventive or scientific power on definite problems which are not too far removed from practical possibilities.

We have as yet made scarcely any progress in the creation of a disciplined army of scientific workers which shall embrace all the abilities in the Empire. We are still in the stage which by comparison with an army is that of a mob of civilians equipped for war with shot guns and sticks.

One reason for this, I think, is because our chief scientific body, the Royal Society, has not taken upon itself more the function of guiding and assisting the general direction of research and invention.

The real function of the Royal Society should be to organise, direct, influence, assist, and promote scientific research, and to do it by an efficient organisation embracing the whole of its fellows. It represents, or should represent, the very best ability in all departments of scientific knowledge, and it should be organised into grand committees of subjects, as suggested by Prof. Armstrong, on one or more of which every fellow should have his place. The work of these grand committees should be to guide and instigate research in their own departments, to organise general discussions on leading questions in the manner undertaken of late years by the British Association, and to help to direct towards common and important ends the powers of scientific investigation in our universities and colleges.

The special and technical societies provide the facilities required for the reading of papers. A paper on physics, chemistry, or engineering as a rule receives better discussion and criticism if read at the Physical, Chemical, or Engineering Societies than at the Royal Society, and the discussion on a paper, if proper time and notice are given, is often quite as valuable as the paper itself. Although the individualistic method of research in which each scientific worker takes up whatever kind of research he pleases has produced good results in the past and is in agreement with our national characteristics, it is a serious question whether we shall not have to put limits to it in the future. The problems which await solution require in many cases combined or co-operative research. One of the most useful improvements in the proceedings of our learned societies would be the devotion of more time to well-organised and predetermined subjects of debate with the object of advancing knowledge at the boundaries of cognate sciences.

This applies to the purely scientific problems, as well as to the problems of industrial research. It must be remembered that, after this war is over, in a military sense we shall immediately commence another war of a different kind, in which the weapons will not be bullets and shells, but our national powers of invention, scientific research, commercial organisation, manufacturing capabilities, and education, and these will be pitted against those of a highly organised Germany determined to win back in commerce by any and every means, fair or foul, that which has been lost in war.

That commercial and industrial war will be waged by our enemies with the same ruthlessness and neglect of all scruples as their military operations. We have said good-bye now and for ever to those easy-going amateur British methods which have held us in the past. What we require is to obtain a higher percentage efficiency in all our operations. We have to attain larger and better results in education, scientific research, and industrial work to increase our national output in every way.

We have been buying dyes, chemicals, optical instruments, and drugs from Germany, glass from Austria, arc light carbons, electric machinery, and a hundred other things we have no need to buy, and the reason is that we have been shirking the effort and research necessary to make them as cheaply or as well at home. But the England with a national debt of 2000–3000 millions sterling will be a different kind of place to live in from the England of the year before last, and we shall have to adapt ourselves to the new conditions by new methods of work.

One of the most important of these, I venture to think, is the extension of co-operative research, both scientific and industrial. In the case of industrial work manufacturers are afraid of making their wants and difficulties known lest the mere statement of them should enable a British rival to find a solution and get ahead. It is necessary to appreciate, however, that rivalry between British manufacturers is not nearly such a serious matter as the competition of Germany with all of them will become, and that British manufacturers will have to stand shoulder to shoulder to meet the common foe. German firms do not hesitate to pool their knowledge if it enables Germany to get ahead of other nations, and British trades will therefore have to meet this organisation by one of a similar kind. In the same manner I have long been convinced that far greater advances might be made in purely scientific research in many departments of knowledge if we were to adopt more extensively the custom of associated work. I mean by this the formation of committees of workers, not too large for expeditious decisions, but charged with the duty of investigating certain formulated problems. It is in this respect that our learned societies might do so much more than they do. The proceedings of these societies are mostly a record of isolated, disconnected pieces of work of very different scientific value. But if properly organised discussion were brought to bear on the question, it would be possible to induce investigators of reputation and ability to associate themselves more in conjoint work to the great advantage of our common knowledge. The learned societies should therefore fulfil to the adult and experienced investigator the same function which the professor or teacher should fulfil to his research students, viz., supply them with suggestions for lines of research to stimulate thought and invention.

It is quite certain that we shall have to organise in this way to a far higher degree than we have yet done what may be called the strategy of research, and that the learned societies should act in some capacity like the great general staff of an army towards the subordinate generals and corps commanders. We require therefore to get on to the councils of our learned and technical societies and into their presidential chairs not merely men eminent for their private researches, but men of large ideas with organising abilities and inspirational power. If we do not do this, then, although by a lavish sacrifice of life and treasure we may win, as we are determined to do, in the military and naval operations, we shall in the long run be hopelessly defeated in that slower but none the less deadly scientific and commercial competition which will follow upon the cessation of actual hostilities.

THE BRITISH ASSOCIATION.

SECTION D.

ZOOLOGY.

Opening Address [1] by Prof. E. A. Minchin, M.A., Hon. Ph.D., F.R.S., President of the Section.

The Evolution of the Cell.

I propose in this address to deal with an aspect of cytology which appears to me not to have received as yet the attention which it deserves, namely, the evolution of the cell and of its complex organisation as revealed by the investigation of cytologists. Up to the present time, the labours of professed cytologists have been directed almost entirely towards the study of the cell in its most perfect form as it occurs in the Metazoa and the higher plants. Many cytologists appear, indeed, to regard the cell, as they know it in the Metazoa and Metaphyta, as the beginning of all things, the primordial unit in the evolution of living beings. For my part I would as soon postulate the special creation of man as believe that the metazoan cell, with its elaborate organisation and its extraordinarily perfected method of nuclear division by karyokinesis, represents the starting-point of the evolution of life. So long, however, as the attention of cytologists is confined to the study of the cells building up the bodies of the higher animals and plants, they are not brought face to face with the stages of evolution of the cell, but are confronted only with the cell as a finished and perfected product of evolution, that is to say, with cells which, although they may show infinite variation in subordinate points of structure and activity, are nevertheless so fundamentally of one type that their plan of structure and mode of reproduction by division can be described in general terms once and for all in the first chapter of a biological text-book or in the opening lecture of a course of elementary biology.

One of the most striking features of the general trend of biological investigation during the last two decades has been the attention paid to the Protista, that vast assemblage of living beings invisible, with few exceptions, to the unassisted human vision, and in some cases minute beyond the range of the most powerful microscopes of to-day. The study of the Protista has yielded results of the utmost importance for general scientific knowledge and theory. The morphological characteristic of the Protista, speaking generally, is that the body of the individual does not attain to a higher degree of organisation than that of the single cell. The exploitation, if I may use the term, of the Protista, though still in its initial stages, has already shown that it is amongst these organisms that we have to seek for the forms which indicate the evolution of the cell, both those lines of descent which lead on to the cell as seen in the Metazoa and Metaphyta, as well as other lines leading in directions altogether divergent from the typical cell of the text-book. We find in the Protista every possible condition of structural differentiation and elaboration, from cells as highly organised as those of Metazoa, or even in some cases much more so, back to types of structure to which the term cell can only be applied by stretching its meaning to the breaking-point.

It is impossible any longer to regard the cell as seen in the Metazoa and as defined in the text-books as the starting-point of organic evolution. It must be recognised that this type of cell has a long history of evolution behind it, which must be traced out, so far as the data permit. The construction of phylogenies and evolutionary series is, of course, purely speculative, since these theories relate to events which have taken place in a remote past, and which can only be inferred dimly and vaguely from such fragments of wreckage as are to be found stranded on the sands of the time in which we live. All attempts, therefore, to trace the evolution of the Protista must be considered as purely tentative at present. If I venture upon any such attempt, it is to be regarded as indicating a firm belief on mv part that the evolution of the cell has taken place amongst the Protista, and that its stages can be traced there, rather than as a dogmatic statement that the evolution has taken place in just the manner which seems to me most probable.

Before, however, I can proceed to deal with my main subject, it is absolutely necessary that I should define clearly the sense in which I propose to use certain terms, more especially the words "cell," "nucleus," "chromatin," "protoplasm," and "cyto-

[1] Abridged by the author.