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NATURAL SCIENCE TEACHING IN GREAT BRITAIN

REPORT OF THE COMMITTEE APPOINTED BY THE PRIME MINISTER TO INQUIRE INTO THE POSITION OF NATURAL SCIENCE IN THE EDUCATIONAL SYSTEM OF GREAT BRITAIN

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REPORT OF THE COMMITTEE APPOINTED BY THE PRIME MINISTER TO INQUIRE INTO THE POSITION OF NATURAL SCIENCE IN THE EDUCATIONAL SYSTEM OF GREAT BRITAIN.

This committee was appointed in August, 1916, and consisted of the following 17 members, eminent in the educational, scientific, and commercial life of the nation:

Sir J. J. THOMSON, O. M., P. R. S., D. Sc., master of Trinity College, Cambridge, *chairman*.
Right Hon. F. D. ACLAND, M. P. (Labor) for North West Cornwall, and secretary to Board of Agriculture.
Prof. H. B. BAKER, C. B. E., D. Sc., F. R. S., professor of chemistry at Imperial College of Science and Technology, London.
Sir GRAHAM BALFOUR, M. A., director of education, Staffordshire county council.
Sir WILLIAM BEARDMORE, Bart., chairman William Beardmore & Co. (Ltd.), engineers and ordnance manufacturers.
Sir GILBERT CLAUGHTON, Bart., chairman London and North Western Railway.
Mr. C. W. COOK, M. A., headmaster Central School and Public Training Center, Wood Green, N.
Miss E. R. GWATKIN.
Sir A. D. HALL, K. C. B., permanent secretary Board of Agriculture.
Sir HENRY HEAD, M. A., M. D., F. R. S., editor of *Brain*, and contributor to medical journals.
Sir HENRY HIBBERT, M. P., Chorley Division, Lancs.
Mr. D. H. NAGEL.
Mr. WILLIAM NEAGLE.
Maj. F. G. OGILVIE, LL. D., C. B., director of Science Museum.
Dr. MICHAEL E. SADLER, C. B., vice chancellor Leeds University.
Prof. E. H. STARLING, M. D., F. R. S., Jodrell professor of physiology, University College, London, and scientific adviser to Forces and Ministries.
Mr. W. W. VAUGHAN, M. A., master of Wellington College.

By the terms of reference the committee was "to inquire into the position occupied by natural science in the educational system of Great Britain, especially in secondary schools and universities, and to advise what measures are needed to promote its study, regard being had to the requirements of a liberal education, to the advancement of pure science, and to the interests of the trades, industries, and

[1] Compiled by Walter A. Montgomery, specialist in foreign educational systems, Bureau of Education.

professions which particularly depend upon allied sciences." In considering the provision of scholarships, bursaries, etc., the committee was instructed to take into account the report of the consultative committee of the Board of Education on this subject.

At numerous sessions the committee received the evidence of witnesses including the representatives of all branches of scientific thought in Great Britain. A large part of the information on which the report was based was obtained in answer to questionnaires addressed to schools, universities, and industrial firms, the most significant of which are appended. The separate sections dealing with Scotland and Wales, being of local interest and value, are omitted in this presentation of the report.

The complete report was formally presented to the Prime Minister on February 19, 1918.

INTRODUCTION.

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2. Not for the first time has our educational conscience been stung by the thought that we as a nation neglecting science. Attention was called to this neglect by the report of the royal commission on the nine public schools in 1864, when it was recommended that all boys should receive instruction in some branch of natural science during part at least of their school career. A committee of the British association dealt with the subject again in 1866, drawing the valuable distinction between scientific information and scientific training, and making recommendations which influenced the course of science teaching in schools. That there was need for these exhortations can be proved without any elaborate survey of the history of science teaching in England. In 1863, at the very time the public schools commission was holding its inquiry, the only instruction in science at one of the greatest schools in England was given on Saturday afternoon by a visiting teacher, and his meager apparatus was stored in so damp a cupboard that his experiments usually broke down. It is not surprising that the headmaster of this school told the commissioners that "instruction in physical sciences was, except for those who have a taste, and intended to pursue them as amateurs or professionally, practically worthless." Steps had been taken before these dates at certain schools to introduce the teaching of science, but this work was done under great difficulties and was regarded with jealously by the staffs, with contempt by the boys and with indifference by the parents.

Gradually, thanks to these reports and to the efforts of gifted teachers within the schools, this Benjamin of subjects won toleration, if not affection, in the family circle. Meantime public interest in science was being aroused by the achievements of scientific workers like Darwin and Kelvin and by the writings of Spencer, Kingsley, Tyndall, and Huxley, and this interest was reflected in the schools.

During these years, however, secondary education was within the reach of but few. The big public boarding schools—then to be numbered on the fingers of two hands—educated a limited number for whom a road had been made by family traditions or increasing wealth; the old established grammar schools scattered sparsely over the country offered to others in their immediate neighborhood opportunities of education often most eagerly seized and fruitfully used; but boys, even though they found in most schools science teaching available if they sought it out, were sometimes denied it altogether, and they were certainly discouraged from pursuing it unless they had shown incapacity for classics or mathematics. For girls even these limited opportunities did not exist. Information about their education at this period is scanty, but it may safely be said that no organized instruction in science was available for them. These weaknesses, which persisted long after the battle of science was half won, have never been entirely removed by a great stirring of public opinion, even though our defects in scientific education have been fitfully pointed out and to some extent corrected.

Further, while the secondary school, so far as it existed, remained under the classical tradition, the schools which grew up under the science and art department tended to be one-sided in the opposite direction, fostering science to the exclusion of literature. The river of educational enthusiasm, never too strong, was consequently split into two weak streams.

The problem has, of course, been affected by the wide extension of secondary education that has marked the last 15 years, but the older schools have not yet been entirely freed from all their prejudices, and the newer schools, in spite of their better balance of subjects, may perhaps have missed some of their opportunities.

3. From schools so few in number and so limited in aim, recruits for the universities could not be obtained in abundance. There were professors of scientific subjects at both Oxford and Cambridge all through the eighteenth and nineteenth centuries, and no doubt they attracted to their lecture rooms individual students, but it was not until half-way through the latter century that the establishment of honor schools in natural science gave formal recognition to the position of science. For some years the scanty class lists bear eloquent witness to the dearth of students. The reports of the university commissions show how this dearth was not the only difficulty with which the new subject had to cope. Classics and mathematics certainly held a privileged position, and it required the steady efforts of men who were looked upon as dangerous reformers to win the firm ground which science now holds.

But Oxford and Cambridge were not to be left in sole possession of the university territory in England and Wales. Durham had been founded in 1832, London University in 1836. Between that date and the end of the century the Royal College of Science was founded in London and 14 university colleges were established in the more important towns. Many of these subsequently developed into universities. At both stages of their career they did incalculable service to the cause of science in offering stimulating teaching and opportunities of research to many—men and women—who were pressing to enter the realms of new knowledge. But even though there was a bias in favor of science they were handicapped, as the elder universities were, by a lack of students. Even those with the enterprise to force their way through the obstacles of their circumstances came often ill-prepared by previous education, and much ability was left untapped. That so much was done under such conditions only intensifies our regret that so much was lost. Genius has a way of saving itself, but it can not be doubted that a sad amount of the general ability on which educational tone and steady scientific progress depend ran to waste for want of opportunity or on account of misdirection.

4. And now it is the war and its needs that have made us once again conscious of the nation's weakness in science. But it is for the sake of the long years of peace quite as much as for the days of war that some improvement in the scientific education of the country is required. Just now, everyone is prepared to receive science with open arms, to treat it as an honored guest in our educational system, and to give it of our best. Just now, it seems almost

unnecessary to take action to insure against any relapse into the old conditions, but experience of the past shows us that temporary enthusiasm needs to be fortified by some more binding material. Good will is much, but good will weakens, and we must not sacrifice the future to our fears or even to our love of liberty in educational matters. It ought not to be beyond the wit of man to devise a scheme of education that will be durable, yet elastic; a scheme that, while securing that every child should be equipped with a knowledge of science, will not cramp the teacher by a syllabus or even by a rigid tradition.

Some of the advocates of scientific training have damaged their cause by claiming too much for their subject and by seeming to depreciate the value of the literary studies which had tended to monopolize the attention of the ablest boys who enjoyed secondary education. To many, Greek and Latin have seemed enemies who, from having occupied the educational ground betimes, have been able to dig themselves in and to hold an almost impregnable position, due not to their merit as educational instruments but to the accident of priority. There is truth in this, but we do not think that the surest method of victory is to be found in the overstatement of the merits of science or the depreciation of the value of classics. Some of the ablest minds have received from their classical instruction enduring gifts that have been of great service to the State and of great refreshment to their possessors. It is our belief that a better service can be done and a like refreshment gained by those whom we hope to see educated on the wider lines laid down in our report. The humanizing influence of the subject has too often been obscured. We are, however, confident that the teaching of science must be vivified by a development of its human interest side by side with its material and mechanical aspects, and that while it should be valued as the bringer of prosperity and power to the individual or the nation, it must never be divorced from those literary and historical studies which touch most naturally the heart and the hopes of mankind.

5. There can be no need now to labor the important part that science should play in our education, but memories are short and it may be well to register in formal words for future comfort, if not reproach, what all would readily grant at this moment. It is not possible to give an exhaustive account of the scope of science, but it is not superfluous to point out that it has several distinct kinds of educational value. It can arouse and satisfy the element of wonder in our natures. As an intellectual exercise it disciplines our powers of mind. Its utility and applicability are obvious. It quickens and cultivates directly the faculty of observation. It teaches the learner to reason from facts which come under his own notice. By it the power of rapid and accurate generalization is strengthened. Without it there is a real danger of the mental habit of method and arrangement never being acquired. Those who have had much to do with the teaching of the young know that their worst foe is indolence, often not willful but due to the fact that curiosity has never been stimulated and the thinking powers never awakened. Memory has generally been cultivated, sometimes imagination, but those whose faculties can best be reached through external and sensible objects have been left dull or made dull by being expected to remember and appreciate without being allowed to see and criticize. In the science lesson the eye and the judgment are always being called upon for an effort, and because the result is within the vision and appreciation of the learner he is encouraged as he seldom can be when he is dealing with literature. It has often been noticed that boys when they begin to learn science receive an intellectual refreshment which makes a difference even to their literary work. It is possible to imagine a time when the obstacle to progress in scientific education might be the attitude of scientific teachers, but that time

is far distant, and it is hard to believe that the teaching of a subject whose life depends on discovery can for long be sterilized, as has been at one time or another instruction in almost all the other branches of human knowledge.

Too few parents of this generation can satisfy their children's curiosity about the wonders of the heavens, the movement of the planets, the growth of plants, the history of the rocks, the dawn of animal life, the causes of tide and tempest.

How necessary science is in war, in defense and offense, we have learned at a great price. How it contributes to the prosperity of industries and trade, all are ready to admit. How valuable it may be in opening the mind, in training the judgment, in stirring the imagination and in cultivating a spirit of reverence, few have yet accepted in full faith.

A nation thoroughly trained in scientific method and stirred with an enthusiasm for penetrating and understanding the secrets of nature would no doubt, reap a rich material harvest of comfort and prosperity, but its truest reward would be that it would be fitted by "an ample and generous education to perform justly, skilfully, and magnanimously the offices both private and public of peace and war."

6. Our terms of reference have been stated above. We are conscious that in some directions we have not carried out our instructions to the extreme limit of their interpretation. Time and the circumstances of the war have prevented us from probing by personal inspection the way in which the work in the universities and schools of all kinds is actually being done. We have taken good faith for granted in all cases and have on this basis tried to assess the aims professed and the material arrangements made. Our recommendations in the main refer to the multiplication of opportunities, to the creation of a suitable environment, and to the removal of hampering restrictions; we must not be taken to underestimate the less ponderable elements of a scientific education. If, on the other hand, we may seem to have overstepped our terms of reference in some directions, it must be remembered that scientific education can not be disentangled from the general educational problem. Boundaries that in theory seem to the looker-on well defined are in practice obliterated.

The war, as we have said, has continually hampered us in our inquiry, and it must sadly retard the realization of our hopes; on the other hand, it has increased the urgent need of action and it may be it has silenced some opposition. It certainly gives no excuse for the postponement of a start to recover lost and to win new ground. Such ground, it is true, will never be surely held unless it is slowly won. But it will never be won at all unless the present opportunity is seized. To postpone action until equipment and buildings are perfect, or the supply of wise teachers abundant, until the enthusiasm of the parent is roused or the patronage of the employer is secured, until all fear of officials has vanished and complete confidence exists between the literary lion and the scientific lamb, is to place an obstacle in the way of progress, an obstacle greater even than the war.

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I. SECONDARY, ELEMENTARY, AND TECHNICAL EDUCATION.

7. In our terms of reference special emphasis is laid on the consideration of the position of science in secondary schools and universities. As it is in secondary schools that questions as to the neglect of science and improvements in science teaching are raised in the most acute form, we think it desirable at the outset to consider at some length the conditions at present existing in these schools and the modifications which in our opinion are desirable.

THE POSITION OF SCIENCE IN SECONDARY SCHOOLS.

A.—Boys' Schools in England.

8. Under this heading we propose to deal with those schools which educate boys up to the age of 16 or over, and whose curriculum covers the subjects generally regarded as essential for a liberal education. These schools comprise—

(a) A number of well-known endowed schools commonly described as "public school," including the seven public schools of the public schools act, 1868;

(b) A number of grammar schools and county and municipal schools, which receive grants from the State.

(c) Proprietary and private schools.

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9. To avoid any misunderstanding with regard to the classification of schools which we have adopted as a matter of convenience, two considerations must be borne in mind—

(1) Whether a school applies for the parliamentary grant or not may depend on financial or other considerations which are only indirectly of educational significance. The character and status of a school are not necessarily determined by its relations to the board of education. There is, indeed, from the educational point of view, no sharp dividing line which separates schools receiving grants from those which are independent of State aid.

(2) Again, so far as the science subjects studied and the scope of the instruction in science are concerned, no real distinction can be drawn between those State-aided schools which succeed in keeping a number of their boys up to 18 and other schools with the same leaving age. In both groups of schools the science teaching is in general confined to the elements of physics and chemistry; botany and zoology are, as a rule, taught only to those boys who intend to enter the medical profession, while geology, as far as it is taught at all, is taken in connection with geography, or informally as part of the activities of the school scientific society.

I. GRANT-EARNING SECONDARY SCHOOLS.

10. Nearly 30 per cent of the boys in grant-earning schools enter before the age of 12 and nearly 90 per cent before the age of 14. Under favorable circumstances, where entry takes place not later than the age of 12, there is usually a course of work in physics and chemistry extending over four years up to the age of 16 and leading up to an examination such as the senior local, or the matriculation examination of the University of London or the northern universities. The provision of science teaching, which must include practical work, is not a matter of choice but of regulation. Each school must submit its curriculum for the approval of the board of education and must further satisfy the board that the provision made in the time table for the teaching of science is adequate in amount, having regard to the legitimate claims of other subjects. If it is desired that individual pupils should omit science—applications of this kind are rare in boys' schools—the reasons must be stated to the board's inspector and the exemptions approved. Science is thus included in the normal course of all boys attending these schools, and the course in science will continue to about the age of 16, except in a small number of schools in which the curriculum includes three languages other than English. The control exercised by

the board through their regulations is supplemented by the system of inspection and allows wide freedom to the schools in devising their curricula.

Apart from the control exercised by the board of education, there is the influence of tradition. Some grant-earning schools were at one time organized science schools under the science and art department. In these schools specific and considerable requirements were made by the department with regard to the time to be given to science, and special grants were paid for science teaching. Though these conditions no longer hold, their effect to some extent persists. In the schools which have been established since the act of 1902 science has, from the first been included on an equal footing with other subjects as an essential element of the curriculum.

11. The weight which it attached to science in the curriculum varies from school to school, being dependent on local circumstances—the character of the boys' aftercareers, the influence of public opinion as reflected in the views of school governors, the predilections of the head masters, and so forth—but in regard to grant-earning schools taken as a whole, we feel able to accept the assurance of the representatives of the Assistant Masters' Association that "science occupies a position in no way inferior to that of any other subject."

Indeed, so far as work beyond the age of 16 is concerned there are more grant-earning schools providing organized instruction of an advanced kind in science and mathematics than in classics or modern studies. The result is seen in the scholarship awards at Cambridge. For a large group of colleges statistics covering a period of 10 years show that 249 scholarships and 96 exhibitions were won in all subjects by boys from 113 grant-earning schools, and that of these scholarships and exhibitions the number awarded for science (88 scholarships and 45 exhibitions) was larger than for any other subject on which awards were made. These figures show that the number of the abler boys who specialize in science is a satisfactory proportion of all those who receive advanced instruction at grant-earning schools.

12. It must not, however, be assumed that the conditions of science teaching in grant-earning schools are wholly satisfactory.

(i) It is agreed that entry into grant-earning secondary schools should not, as a rule, be deferred to a later age than 12; but many boys are admitted at 13 or 14, in some cases unsuitably or ill prepared, with the result that their progress in school subjects is adversely affected, and harm is done to those with whom they are classified.

(ii) It is even more serious that large numbers leave before completing the course required to carry them up to the stage marked by a first school examination appropriate for boys of about 16. Statistics published by the Board of Education show that in the three years ending July, 1913, nearly 71 per cent of the fee-paying boys and 49 per cent of the boys who paid no fees left after having spent less than three years at a secondary school; and that 84 per cent of all the boys who left in this same period had not attained the age of 15. The large proportion of boys leaving at this early age is due to (1) the parents' inability or reluctance to forego the wages which boys of 14 can earn; (2) the want of appreciation of the value of secondary education, even from the point of view of success in after life; (3) the tradition of beginning work at as early an age as possible; (4) the desire of the boys themselves to escape from the restraints of school life.

We shall return to these matters again, but in the meantime we would point out that the position of science, or indeed of any other subject, in the grant-earning schools will never be satisfactory until the schools can depend on the great mass of their pupils entering at an age which should certainly not be later than 12, and remaining at least to the stage marked by the first school examination.

(iii) We have already pointed out that in respect of advanced work science in grant-earning schools stands generally in a better position than other subjects. But the actual number of schools providing properly organized advanced instruction in science, that is to say not merely giving teaching to isolated individuals, is all too small, not from lack of will on the part of the schools or of ability to give advanced instruction on the part of the teachers, but chiefly from dearth of pupils willing or able to remain at school for a further course of instruction from 16 to 18. Only a very small proportion of boys who attend grant-earning schools pass on to the universities. The resulting deficiency in advanced instruction is perhaps the most serious source of weakness in these schools. It affects not only the work done in the highest forms, but also the whole course, for the existence of a class of boys carrying the study of science up to a relatively high standard is a stimulus to the teachers and reacts favorably on the work throughout.

(iv) If adequate provision is to be made both for the general work of the school and for advanced courses, it is clearly necessary that the schools should be suitably staffed and equipped. These matters are further dealt with in a later section of the report, but we would here point out that the scale of staffing is not always sufficiently generous, and that often it is devised without regard to the fact that advanced work involves a larger proportion of masters to boys in the school as a whole. Unless this fact is recognized, the work either of the advanced classes or of the main part of the school is bound to suffer. Inasmuch as the extent of the science instruction will necessarily vary in different schools, it follows that the requirements of each individual school require to be separately considered by the responsible authorities.

(v) The amount of time to be allotted to science is not specified in the regulations of the board of education, but must come up to the minimum which the board, having regard to the circumstances of the school, are prepared to accept. Though in many schools the time actually given to science in the third and fourth years of the period 12–16 amounts to one-fifth of the whole time spent in school, we were informed that in a considerable number of schools the time for science might be as little as four three-quarter-hour periods a week, or even less. In some schools, owing to the pressure of other subjects, the time allotted to science has been reduced in recent years, and the minimum which the board has accepted is in our opinion too low to insure that sufficient opportunity is afforded for the carrying out of a satisfactory course. As a consequence of an inadequate allowance of time, either physics or chemistry is not uncommonly dropped at the age of 15, with prejudicial results if no other science subject is taken.

(vi) Again, the scope of the work is often too restricted, even within the two main subjects to which it is almost universally confined. Thus important branches of physics, such as light or electricity, may be wholly omitted, and we were informed that in some cases physics up to the age of 16 means little more than practical measurements and heat, while in chemistry the theoretical foundations of the subject are often neglected.

(vii) Further, in spite of the fact that the majority of boys leave at or before 16, the schemes of work are often only the initial stages of a plan which will never be completed. They are, in fact, influenced indirectly by the requirements of university entrance scholarship examinations, which are designed for those boys who have specialized in science. This holds good even in those schools in which few boys intend to go to the universities or remain after the age of 16.

(viii) Lastly, we are in agreement with the view that there might be a greater differentiation between the curricula of secondary schools in the more thickly populated areas where several schools are easily accessible. There is room indeed for the modification of curricula so as to allow of less time being allotted in some of the schools to the study of languages other than English, and of more time being given to science, mathematics, manual instruction and drawing (including mechanical drawing) in the last year or two years of the course. This would not be difficult to arrange, at any rate in those schools where a large proportion of the boys learn only one language other than English. A curriculum of this kind is more especially to be desired in schools from which boys pass into engineering and other industries of a scientific character, and might well be framed with an eye to its suitability for pupils who will enter senior technical schools.

What we are here suggesting is already done in a few schools, and we understand that the work as a whole has become more effective and is more successful in stimulating the interest of the boys just because it has a more obvious purpose. We think that the plan might usefully be extended to a larger number of secondary schools where local circumstances are favorable. We would go further and suggest that in some secondary schools no foreign language should be compulsory. In all schools where no time or only a limited time is given to the teaching of a modern language it is essential that English subjects should be regarded as of at least equal importance to science and receive corresponding attention.

II. PUBLIC AND PREPARATORY SCHOOLS.

13. In a large number of public schools the practice is for boys to enter at 13½ to 14, after having spent three or four years at a separate preparatory school. Some schools have preparatory departments for boys between the ages of 9 and 13; but even in these schools the majority of boys over 13 have come from preparatory schools under separate control.

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PUBLIC SCHOOLS.

14. While grant-earning secondary schools are compelled by regulation to make provision for the teaching of science, those public schools which are not State-aided are under no such obligation, except so far as science may be prescribed by scheme as part of the curriculum. Forty or fifty years ago higher secondary education in this country was to all intents and purposes an education in classics and mathematics. Since then it has come to be recognized that other subjects, including science, have a claim on school time-tables and curricula. The problem of finding room for what are called modern subjects was not

everywhere dealt with on the same lines. The schools have responded to a varying extent and in different ways to the claims which have been made on educational and utilitarian grounds for the recognition of subjects formerly left out of account. Nor is it only in the schools of comparatively modern foundation that such claims have found recognition. The older schools, too, have established laboratories and provided opportunities for a considerable amount of instruction in science for those boys at least who desire to learn the subject. With a view to arriving at the facts with regard to the present position of science in the public schools we issued at an early stage of our proceedings a questionnaire to those schools which are represented on the Head Masters' Conference but are not in receipt of parliamentary grant. An examination of the answers shows that while the great majority of these schools offer adequate opportunities for the study of sceince to those boys whose parents desire it, there has in the public schools as a whole been no general recognition of the principle that science should form an essential part of secondary education. If this principle were recognized, all boys would receive a reasonable amount of instruction in science, extending over a substantial part of the school course. They do not now.

15. The majority of the larger schools are organized into separate classical and modern sides,[1] the division between the two sides extending half or two-thirds of the way down, or even from the top to the bottom of the school. On the modern side the time given to science is as a rule adequate, and full opportunities are provided for boys who wish to specialize in the subject in the upper forms. On the classical side the position is very different. It varies, however, greatly in different schools. In one famous school no provision is made for any teaching of science on the classical side as part of the regular school curriculum. In another, boys on the classical and modern sides have equal opportunities for receiving instruction up to the stage at which specialization begins. More commonly some small provision for science is made in the time-table of the lower or middle forms of the classical side. It should be observed that if the teaching of science on the classical side is confined to the lower forms, a clever boy who is placed on entry high up on the classical side may altogether miss instruction in science. Again, in certain schools science can be taken in the upper forms of the classical side as an alternative to a modern language, but here it tends to be neglected by boys aiming at classical scholarships. Lastly, where science appears as a necessary subject in the classical side curriculum, the time given to it is usually limited to two periods or even to one period a week. The evidence justifies us in saying that science has received scant attention on the classical sides of the public schools.

16. It is not, however, always realized that in the bigger schools a large and increasing majority of the boys are to be found on the modern sides where, as a rule, the time given to science is reasonable. But any satisfaction that might conceivably be felt on this score must be largely qualified by the following considerations. The modern sides in the older public schools are a later growth, originating in response to a demand for an education of a nonclassical type. It can not, however, be said that up to the present there has been either in the schools or in the universities any clear conception of modern studies which might give these sides a meaning and an aim. The teaching of classics has behind it a longer tradition and is on the whole better understood, with the result that teachers are on surer ground. It looks forward to an end which

[1] The term "Modern Sides" is here used to include what is sometimes called a "Science Side." In a few schools the organization includes separate classical, modern, and science sides. In these the opportunities for science instruction are less on the modern sides than when no separate science side exists.

is clearly marked by the Oxford School of Literæ Humaniores or the Cambridge Classical Tripos. The modern side teachers, on the other hand, have to deal not only with the future candidate for a university honors degree in science, mathematics, or modern languages, but with a large number of boys who will pass directly into the ranks of commerce or industry. Again, the classical sides have all the advantages of a more effective working of the form system than is easily attainable on the modern sides, where the work is so much distributed among a larger number of masters that no one master sees any group of boys for a large part of the school week. The modern sides suffer, in fact, from diversity of effort and indefiniteness of aim, and these conditions do not make for strenuous work. These weaknesses are aggravated by the fact that, for reasons dealt with elsewhere, the classical sides include a large proportion of the abler boys. Further, the establishment of modern sides had the unforeseen result of providing an excuse for the neglect of science on the classical sides. In our view it is a very real defect in public-school organization that boys should in many schools have to make their choice between a classical side in which science is almost wholly neglected and a modern side in which the general educational conditions are in many ways unfavorable.

We believe that if these defects are to be remedied it will be necessary to secure; firstly, that the character of the existing entrance scholarship examinations both at the schools and at the colleges of Oxford and Cambridge should be altered so as to get rid of the excessive specialization by which the work in all subjects is now characterized; secondly, that the aims and character of a modern education should be more clearly defined, not only in schools but also at the universities.

School organization is still further complicated by the existence of army sides to meet the supposed requirements of thos boys who are competing for cadetships at Woolwich and Sandhurst. In this connection it seems to us most important that science should be made a compulsory subject for entrance to the Royal Military College, for, apart from the importance of the subject for an officer, dealt with elsewhere in our report, the present liberty to neglect it would thwart any scheme for a general education such as we recommend, and perpetuate the existence of special army sides. We see no reason why the education of army candidates should differ from the education of other boys of the same age.

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18. It is noticeable that in several of the larger public schools no provision is made for the teaching of science in the lower forms, which often contain a substantial proportion of the total number of boys in the school. This implies that, except in the case of those boys who, will later specialize in science, instruction in the subject is confined to a period of two years—i. e., from about 14½ to 16½. In view of the fact that in State-aided schools introductory work in experimental science is comonly begun at 12½, and of the experience of the Royal Naval College, Osborne, that satisfactory work can be done by boys of this age, we can see no reason in the nature of the subject for the postponement till 14 or 14½ of similar work in public schools. We are confirmed in this opinion by the evidence of one of the representatives of the Head Masters' Association, who stated that "between 12 and 13 boys arrive at a stage when they could appreciate experimental investigation," and added that "a beginning would then be made with general chemistry and physics." The postponement of such work till 14½ results in limiting unduly the period over

which science teaching is given, and setting boys of 14½ to do work which is too elementary for their years.

19. It has already been pointed out that the abler boys at the public schools tend to pursue a classical course. This is largely due to the influence of (a) the school entrance scholarship examinations and (b) the entrance scholarship examinations at the colleges of Oxford and Cambridge.

(a) In the examination for entrance scholarships at most of the public schools, the papers set in classics are of such a character that to do well in them a boy must have devoted much more time to this subject than to any other. As great weight is assigned to these papers, it follows that many of those who compete for these scholarships have already specialized to a very considerable extent in classics, and before leaving the preparatory schools have received a bias which makes them choose classics as their main subject of study at the public schools and the universities. It results from this that (1) some boys whose abilities lie in other directions than classics miss the encouragement which is legitimately attached to the winning of a scholarship; (2) others are enticed along a path which does not lead them to their true destination; (3) the curricula of many preparatory schools are unnaturally distorted.

(b) The system by which entrance scholarships are distributed among the different subjects is not the same in the two universities. At Oxford the practice is to announce that a definite number will be given to natural science and to each of the other subjects. For the period 1906-1915 the total number of scholarships and exhibitions awarded for all subjects at the Oxford colleges was 1,028 scholarships and 615 exhibitions. Of these, 115 scholarships and 59 exhibitions were awarded for science, 650 scholarships and 358 exhibitions for classics, 122 scholarships and 137 exhibitions for history, 141 scholarships and 61 exhibitions for mathematics, and 61 scholarships and exhibitions for other subjects or combinations of subjects. The number of scholarships and exhibitions awarded for science, 10.6 per cent of all the awards, seems to us far too small in comparison with those awarded for some other subjects, and we think that an increase in the number would promote the study of science at the public schools. As things stand there is a definite financial inducement for the abler boys to pursue a classical course.

At Cambridge there is, in general, no allotment of scholarships to special subjects before the examination, and the number of scholarships in any subject is determined by the relative performance of the candidates who reach scholarship standard in the several subjects. There is reason to believe that science is, in respect of entrance scholarships, on an equal footing with other subjects. For instance, at the large group of colleges already mentioned, out of 895 scholarships and 378 exhibitions in all subjects 228 scholarships and 109 exhibitions were awarded for science or for science and mathematics combined.

That a substantial majority of the abler boys present classics as their subject in the scholarship examinations even at Cambridge is evident from the scholarship and exhibition statistics of the past 10 years; and, further, the scholarship winners at the universities are, as might be expected, largely drawn from those who have already won entrance scholarships at the public schools. * * * The significance of these facts is unmistakable. Not only is it true that a considerable majority of the abler boys in many of the public schools pursue a course designed to lead up to university entrance scholarship examinations in classics, but these abler boys are to a large extent directed toward a course of this kind by the character of the entrance-scholarship examinations conducted by the schools themselves.

We can not think that there is any natural distribution of ability in relation to literary and scientific studies which corresponds in any way to the actual distribution of scholarship awards for these two kinds of study; and it is impossible to avoid the conclusion that the effect of existing entrance scholarship examinations at the public schools is to divert to specialized literary and linguistic studies of a particular kind boys who might have been successful in other fields. In this view we are confirmed by the evidence given by the head master of Rugby, who remarked "that it was perfectly true that the scholarship system as it was at present worked at schools and the two universites (Oxford and Cambridge) had the effect of encouraging boys to pursue classical studies when they might have taken up other subjects."

University entrance scholarship examinations have a further effect in that they influence the character of the science work of the schools from which scholarship candidates are drawn. We have already referred to this point in connection with the State-aided schools; the same criticism applies, though in a less degree, to the public schools, as they lose many of their boys at 16 to 17.

20. We have had some criticisms to make on the organization and curricula of public schools, but it is a mistake to regard the public-school curriculum as something for which head masters must bear the sole responsibility. The schools are influenced not only by the requirements of the universities, but also by the changing values which are attached to different branches of study and by the pressure of public opinion; and our main concern must be to secure that all who guide such opinion should recognize that a living knowledge of the facts and principles of science forms an essential part of every well-balanced educational course.

To sum up, we think it is manifest that so far there has been no general and sufficient recognition of science as an essential part of the curriculum for all boys in the public schools, that the effect of the scholarship examinations, both at the schools themselves and at the universities, and the inequality in the number and value of the scholarships awarded in different subjects tell against such recognition; and that many of the ablest boys who enter the public schools pass on to the universities ignorant of science and with little or no idea of its importance as a factor in the progress of civilization or of its influence on human thought.

PREPARATORY SCHOOLS.

21. For information in regard to preparatory schools we are chiefly indebted to the witnesses who spoke for the schools represented on the Association of Preparatory Schools and to the summary of answers to a questionnaire circulated by these witnesses before they gave evidence. From these answers it appears that, in the majority of the 307 preparatory schools replying, no provision is made for the teaching of science (including under this head nature study and practical measurements) as part of the regular curriculum. It is even more significant that, while the report drawn up by the joint committee of the Head Masters' Conference and the Association of Preparatory School Masters and adopted in 1916 includes an appendix on elementary science training, no time is alloted for science teaching in the time-table suggested for preparatory schools. There are, in our opinion, sound educational reasons for postponing the beginning of the systematic study of chemistry and physics till the age of 12½ or 13, apart from the fact that the schools in question have not the necessary staff or equipment to undertake work of this kind. But it is much to be regretted that, as an introduction to more formal work in science, there should be no preliminary instruction in nature study, broadly interpreted,

or in practical measurements... Further, it does not appear that the omission of such teaching is compensated for by increased attention to handwork and drawing. There is no doubt that in framing their curricula the preparatory schoolmasters have been largely influenced by the requirements of the entrance examinations and entrance scholarship examinations at the public schools. It is also clear, from the answers to the questionnaire circulated to the public schools, that while these examinations are designed to test the knowledge and ability of boys in English subjects, French, Latin, mathematics, and sometimes Greek, knowledge of such science as might properly be taught to boys of preparatory school age is either not tested at all or tested only in an incidental manner. Again, until three years ago, nature study was included as an optional subject in the common entrance examination for public schools, but we were informed by one of the representatives of the Preparatory Schools Association that "few candidates took it, the reason being that the subject was not required as a condition for entrance into public schools."

22. It is most unfortunate that the curricula of many preparatory schools should be so far determined by the examination requirements of the public schools as to lead to the omission or comparative neglect of subjects which are appropriate elements in the education of boys of preparatory school age. Quite apart from the question of examinations, we are of opinion that all preparatory schools should make regular provision for the teaching of the elements of natural science with handicraft and drawing. By the elements of natural science we here understand what is known as nature study, i. e., physiography and an elementary study of animal and plant life, together with practical exercises.

The elements of natural science thus defined should, in our opinion, be a necessary subject in the entrance examinations of public schools.

We also recommend that steps should be taken to secure that this subject should be included in the entrance scholarship examinations at public schools, and that failure in it should have as much influence as failure in any other subject in disqualifying a candidate for election to a scholarship. There is, it is true, some difference of opinion as to the advisability of imposing any test in science for boys of 13 or 14. * * * Experience alone can show how the difficulties of examining boys of the age of 13 or 14 in science, admittedly greater than in the case of classics or mathematics, can best be overcome.

If the necessary reforms are to be effected in preparatory school time-tables and curricula, it will be clearly desirable to secure the maximum amount of cooperation between the head masters of the preparatory schools and of the public schools. The establishment of the joint committee is a step in the right direction. We recognize in particular the efforts which have been made to give more importance to English subjects in the entrance scholarship examinations, and we think that, in the best interests of later science teaching, great importance should be attached to sound work in elementary mathematics and physical measurements and to familiarity with the use of decimals and the metric system.

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In our view the examinations for entrance scholarships, if they are to continue, should be designed mainly to test intelligence and general ability. They should not be used primarily for the purpose of picking out likely specialists in classics, mathematics, or any other subjects. Neither should they be of such a character as to demand or favor special intensive preparation. The evils of the present system would be mitigated by reforms in the character of

the examinations, in particular by a reduction in the range and difficulty of the questions set and by the recognition of subjects at present largely or wholly ignored.

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B. Girls' Schools in England.

24. In considering the facilities for instruction in science which are available for girls of secondary school age, it is necessary to refer in the first place to the character and extent of the existing provision of secondary schools for girls. At present 333 girls' schools and 224 mixed schools (with a school population of some 95,000 girls) are in receipt of parliamentary grant. In addition, 4 mixed schools and 65 girls' schools (of which 17 are private schools, the remainder being company or foundation schools or schools under the control of religious societies) have been inspected by the board of education and declared "efficient." There is also a large number of private schools which have not been inspected, and in regard to which no official information is available.[1] There can, indeed, be little doubt that private schools play a much larger part in the educational provision for girls than for boys.

In the last 40 years the ideals of women's education have been raised and the opportunities vastly increased, but there still remains some uncertainty in the public mind, if not in the minds of those best qualified to speak for education, as to the nature of the education to be provided for girls and the relative importance of the various subjects. Some parents still confine their ideas of education to the literary subjects, together with music and art.

Among the schools, whether grant earning, "efficient," or uninspected, which provide secondary education for girls, there are a certain number of well-known schools which are more or less comparable to the large public schools for boys—schools from which a proportion of girls normally pass on to the universities and other places of higher education. But the custom by which boys are sent to preparatory and public schools for a course of education extending from 8 or 9 to 18 or 19 is not followed to the same extent in the case of girls. A certain number of girls of secondary school age belonging to the wealthier classes of the community receive their education largely or wholly at home; others spend a short period at a secondary day or boarding school—often a private school—and later go abroad. A considerable proportion of those attending schools in which the course extends over a period up to the age of 18 or 19 have not in the past looked forward to entering any professional occupation; indeed, few professions except that of teaching have been open to them. There is in consequence proportionately less advanced work done in girls' than in boys' secondary schools of similar type.

It can, we think, hardly be questioned that while the majority of the parents of these girls desire or are at least prepared to acquiesce in a secondary education for their sons in which science shall find a place, the recognition of science as an essential element in the secondary education of girls is far less general. This applies with even greater force to mathematics. We are not suggesting that this implied distinction between the educational requirements of boys and girls in respect of science is justified, either by the evidence of psychology or by considerations based on the competing claims of other subjects in a crowded curriculum or by the nature of the after careers to which girls may properly look forward. We are only calling attention to the fact that, consciously or unconsciously, a distinction of this kind is not infrequently made.

[1] The same is true of a large number of schools under the control of religious communities.

When we turn to consider the actual position of science in girls' secondary schools, it becomes necessary to point out that in regard to the great majority of private schools we are unable to speak with any certain knowledge. These schools exist because they meet a certain public demand. They include some schools of high standing, and, in addition to the other good work they do, provide useful opportunities for experiments in education, but it can scarcely be doubted that they are more likely to be influenced by that traditional conception of girls' secondary education which lays special stress on languages, literature, and art, and are less likely to be adequately equipped for the teaching of science than schools which are in receipt of public funds. We were not, indeed surprised, to learn from the representatives of the Association of Science Teachers[1] that in a large number of private schools science was altogether omitted from the curriculum.

25. In the important group of secondary schools in receipt of grant it is noticeable that the regulations of the board of education require that provision should be made for the teaching of science, including practical work, but allow girls who have reached the age of 15 to omit science or mathematics (other than arithmetic) in order to take an approved course in domestic subjects. From the evidence before us, it appears that in inspected girls' schools the time given to science between 12 and 16 is not more on an average than 2 hours per week, representing one-tenth or less of the whole time spent in school. Except in the forms preparing for an examination, such as the senior local, it is quite commonly 1½ hours per week. That a much smaller amount of time is given to science in girls' schools than in boys' schools is due to various causes. (i) The shorter school week, the increased pressure on the time-table, caused by the inclusion of domestic subjects, and the greater attention given to music and drawing; (ii) the lack in some schools of adequate laboratory accommodation; (iii) a shortage of teachers qualified to teach science. * * *

In the memorandum of evidence submitted by the Association of Science Teachers it is suggested that between the ages of 12 and 16 not less than one-seventh of the total school time—say three hours—should be devoted to science. We think this is desirable if serious attention is to be given to science instruction in girls' schools. But it is necessary to add that the representatives of the Association of Head Mistresses, who were no less anxious that science should be regarded as an essential element in the secondary curriculum for girls, thought "it would be difficult to find the time for other subjects if three hours a week were allotted to science as proposed by the Association of Science Teachers." Under the circumstances it is difficult to make a recommendation which can be carried out in all types of schools. * * *

26. There can be no doubt that the problem of the curriculum is more difficult in girls' schools than in boys' schools. Existing girls' schools have for the most part grown up during a period which has seen a great increase in the number and variety of the callings followed by women. Despite the increasing prominence of these vocational aims, it is still true that the curriculum remains something of a compromise between conflicting ideals for women's education. It is not within our reference to deal with the larger questions involved, but we feel bound to express our opinion that there is real need at the present time, both for a clearer definition on the part of those principally concerned of the scope and aims of secondary education for girls and for a franker recognition of the limitations imposed by the shorter school week. We have faced these limitations by acquiescing in a smaller minimum of time for science

[1] This is an association of women teachers, mainly in secondary schools.

for girls than for boys; even this is an increase on the time commonly given at present. It is possibly outside our province to make proposals for the consequent adjustment of the time-table, but in view of the importance of the matter two suggestions may be thrown out:

(i) In many girls' schools (and indeed in many boys' schools also) a greater amount of time is devoted to the study of mathematics than is really needed to attain the standard aimed at. This is largely due to the division of the subject, for teaching purposes, into three compartments—arithmetic, geometry, algebra—often taught to the same class by different teachers. Experience has shown that the ground can be covered at a much more rapid rate if the subject of mathematics is treated as a whole, and that a shorter time suffices if the mathematical mistress can distribute it as she thinks fit. Still greater saving of time can be effected if science and mathematics are taught in proper relation to one another.

(ii) In schools which keep the greater proportion of their girls to the age of 18, some time might be spared from other subjects in the 12 to 16 period. This could be fully compensated for by giving increased attention to these subjects in the 16 to 18 period.

27. With regard to the general conditions affecting the education given in grant-earning girls' schools, the observations we have made in section 12 in connection with boys' schools on the desirability of securing early entry and a longer school life apply equally to schools for girls. The statistics published by the board of education show that in the three years ending July, 1913, nearly 70 per cent of the girls who pay fees and nearly 24 per cent of those who do not left after having spent less than three years at a secondary school, and that 29 per cent of all the girls who left did so before they had attained the age of 15. These figures, though far from satisfactory, are an improvement on those quoted for boys, the reason probably being that girls of that age have been less in demand as wage earners, and that more of them remain at school in order to prepare for the teaching profession.

28. Turning to the nature of the science teaching which is actually provided in inspected girls' schools, we find that, after a course of nature study in the earlier years, and elementary physics and chemistry between 12 and 14, botany is the subject taken from 14 or 15 onwards in the majority of schools. The number of schools in which there is any serious teaching of physics apart from the introductory work between 12 and 14 is quite insignificant. Advanced work takes the form of botany, or, less usually, chemistry, or both of these subjects.

There has been a striking improvement in the teaching of botany in the last 10 years, due to the greater insistence on the physiological aspects of the subject for which the earlier introductory study of physics and chemistry is a necessary basis. The continued prevalence of botany as the chief science subject in girls' schools, and the position formerly held by descriptive botany as the sole science subject in many schools, can be explained by the belief that the subject is in itself better suited to girls than sciences which demand some knowledge of mathematics, and also by the absence in some schools of adequate accommodation for work in experimental science. These conditions explain that general neglect of physics in girls' schools to which our attention was called by more than one witness. It was strongly urged upon us that the neglect of physics in these schools is much to be regretted, not only in virtue of the importance and interest of this branch of natural knowledge, but also because ignorance of physics is a hindrance to the proper training of future science teachers and a serious impediment in the way of increasing the number of women who look forward to entering the medical profession. We think these considerations deserve serious notice.

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30. The general conditions of science teaching in girls' schools are less favorable than in similar schools for boys; and it would appear that, despite the progress made in recent years, the results are less satisfactory. We feel, indeed, that there is need for a fuller realization than has so far existed of the importance of science in the secondary education of girls. Every young mind, whether of boy or girl, should be led to appreciate the wide field of interest opened out by the study of natural science and should be trained to understand and apply the methods of scientific reasoning and investigation. Moreover, without wishing to press too far the claims of vocational instruction, we would point out that, in connection with a large number of the after careers followed by women, a knowledge of natural science and a training in scientific method is much to be desired. We are thinking not only of those girls who are destined to undertake science teaching or to enter the medical profession and closely allied careers; there will be many others who will take up industrial research, different types of social work (factory inspection, welfare work, sanitary inspection, health visiting, etc.; others again will be mainly concerned with domestic duties. For all a training in science is invaluable.

GENERAL EDUCATION IN A SECONDARY SCHOOL.

31. We consider that the best preparation for any occupation or profession is a general education up to the stage reached by the average boy at the age of 16, followed, where possible, by a more specialized course on a limited range of subjects. This general education should provide normally for the study of English, including history and geography, languages other than English, mathematics, and natural science; each of these subjects should be regarded as an integral part of the education of both boys and girls, and a fair balance should be maintained between the time allotted to them. We are supported in this view by the unanimous testimony of all the witnesses who have given evidence on this point.

It is contended by some that a general education need not include all these subjects; there is, however, no consensus of opinion in favor of the omission of any one of them. We have ourselves suggested that there might well be some schools doing work of a secondary grade in which no foreign language would be compulsory. (See secs. 12 (viii) and 96.)

The point is sometimes made that the study of science can be more effectively pursued if it is taken up in the later stages of school life. This may be true for the boy of marked ability who at a certain stage throws his whole energies into the intensive study of science. But we are concerned with the education of the citizen, with the diffusion of scientific conceptions and the habit of mind their study induces among the general mass of the educated population. If the practice were adopted of making no provision for the study of science till 16 or later, the majority of students would miss the opportunity of gaining any knowledge of the subject.

We suggest that for boys' schools when the secondary school course covers a period of four years, from 12 to 16, the time given to science should be not less than four periods in the first year, nor on the average less than six periods in each of the following three years. When the course begins at a later age not less than six periods in each year will be required. It may be convenient at some stages to give more than six periods, at others less, but we consider that nothing less than an average of six periods at the later stages will provide for a satisfactory training in natural science. It is not within our reference to suggest the minimum time to be given to other subjects, but we have satisfied ourselves that the time we have suggested for science is compatible with English and mathematics receiving as much time as they have hitherto done in the great majority of schools in this country, that it would admit of attainment by the age of 16 of a substantial knowledge of two foreign languages if the study of one of them is begun at an early age, and that students with special linguistic ability should be able to make good progress in a third. In addition, we think that time would be available for the study of such subjects as drawing and music and for manual training.

32. A practical and technical consequence of the establishment of a general course for all boys up to the age of about 16 would be the abolition of the existing division into sides now so usual in the larger schools. This would involve the provision in the main block of the school of a system of options or alternatives. The last thing we would suggest is that there should be for all boys, even in the same school and during the stage ending at 16, one cast-iron-curriculum. As long as the division into sides persists, not only is a bias inevitably given to a boy's education, involving sometimes the sacrifice of his abilities and tastes, but it is very difficult to prevent the intellectual strength of the school being concentrated on one side.

INSPECTION OF SCHOOLS.

33. We recommend that systematic instruction in science should be part of the general course of education up to 16 in every secondary school, and that science should be included among the compulsory subjects for the first school examination. We do not, however, think that examination by itself will be able to secure the efficient teaching of science in schools, and we are strongly of opinion that it would be in the interests of education in general and of science in particular that all schools should be inspected.

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Provision is made in the education bill for "requiring particulars from every school or educational institution," but we think that this collection of information is not sufficient to enable an effective judgment to be formed as to the nature of the education offered by the school. The information supplied by the school must be checked and its value determined by independent inspection.

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The task is not insuperable, and much of the work of inspection is already done. * * * The amount of science taught at these schools may require to be increased or its quality improved, but it is not here that entire absence of such teaching will be found. The grant-earning schools are all fully inspected by the Board of Education, and the fullest information concerning them is obtainable. There are, however, many schools for boys, and even more for girls, which are under no obligation whatever to provide any instruction in science. Many of these, as a matter of fact, either do not teach the subject at all or teach it in a most incomplete and unsatisfactory manner. In the national interest it is essential that this neglect should be remedied, and to this end we strongly urge the introduction of compulsory inspection. We consider that this should be applied impartially and that no discrimination should be made in favor of any one class of schools.

It has been urged on behalf of private schools that much valuable progress in education is due to experiments made in schools where the teachers have been free to disregard tradition and convention and to follow the promptings of their own genius. But it is not schools of this type which would be checked or extinguished by inspection. The object of modern inspection is not to impose uniformity or to destroy individual effort, but rather to obtain and record information as to the work and efficiency of the schools and to give advice, based on a wide experience in other schools.

We recommend—

(I) That periodical inspection should be compulsory on all schools.

(II) That this inspection should be under the direction of the State.

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THE FIRST SCHOOL EXAMINATION.

34. At the completion of the general course of study at a secondary school there should be an examination to test the results of the instruction given in English subjects, languages, mathematics, and science. The passing of an examination in some of the subjects of general education is required as a condition of admission to most of the professions and to the universities. At present the number of such examinations is large; the differences between them are not of educational importance, though enough to cause a great waste of time and energy. A system of examinations sufficiently elastic to meet diverse requirements and at the same time so far coordinated that proficiency in secondary school subjects could be tested by any one of them would bring about a real and valuable simplification for the schools, provided that the results were accepted so far as they went by the universities and professions. We are of opinion that, subject to one important modification, the first school examination proposed by the Board of Education is well suited for this purpose.

35. In the scheme outlined by the board the subjects for examination are treated as falling into three main groups: (I) English subjects, (II) languages, (III) science and mathematics, and (IV) a subsidiary group containing drawing, music, manual instruction, housecraft, etc. Every candidate will be expected to show a reasonable amount of attainment in the first three of these groups—the group of subjects, and not the individual subject, being the unit in respect of which success or failure will be determined. It will be seen that natural science and mathematics are placed together in the same group, and it would appear as the proposals now stand that a candidate might pass in this group, even if he did not present himself in science at all.

We consider that it is essential that every boy should be required to satisfy the examiners both in science and in mathematics, subject to the generous application of the principle of compensation hereinafter mentioned. In many boys' schools the teaching of mathematics throughout the school is much more developed than that of science, and there will, if science is not required, be a tendency to concentrate on mathematics and to neglect the teaching of science. If teachers and boys know that while it is necessary to pass in English subjects and in a foreign language the omission of either mathematics or science does not involve failure in the examination, it is quite safe to predict that one or other of these subjects will receive less attention; and the subject which is the more costly to equip, and in some ways the more difficult to teach, is likely to be the one which will suffer.

36. To make any subject compulsory in an examination in order to guard against its neglect is not the ideal method of obtaining the best education, but in the present condition of affairs it seems to be the most efficacious means we can find. * * * The effect of the present freedom is indicated by the following statistics. At the school certificate examination of the Oxford and

Cambridge board in July, 1917, which is taken mainly by the public schools, out of 699 boys only 226 offered one or more science subjects.

It is proposed in some quarters that "in inspected schools boys should be certified by the science master as having taken a proper course and reached a satisfactory standard in science." But we have had no satisfactory reason presented to us for the treatment of science in a different way from all other school subjects in respect to examinations, and even if such ground were shown we should find it impossible to recommend the adoption of this plan. The inequalities of experience among teachers would render it almost impossible to attain any common standard of judgment.

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The examination should be regarded as a test of satisfactory work during the pupils' school course and should be of such a character that it can be taken without any special preparation which would interfere with that course. The work of each candidate in the examination should be regarded as a whole, and the principle of compensation should be recognized both between the different groups, including group (IV) and the different subjects of the same group. By this we mean that comparative weakness in one part of the examination should not necessarily involve failure if the candidate has done really good work in other parts.

37. We recommend that in the first examination there should be as close cooperation as possible between teachers and examiners. Not only should the examination be adapted to the curriculum of the particular school, but great weight should be attached to the teacher's estimate of the merits of the pupils and to their school record. An examination conducted on these lines would not have the effect often ascribed to external examinations of cramping the curriculum, but would permit of all reasonable freedom of teaching. Nor could it be fairly said to discourage either wide variation in types of curricula or liberty for educational experiments.

38. There is much difference of opinion on the question whether any modification of the arrangements is needed for girls. On the one hand representatives of the Head Mistresses' Association stated that the association was opposed to making mathematics a compulsory subject in the examination, but felt less difficulty about compulsory science. On the other hand, representatives of the Association of Science Teachers thought that all girls should be required, for a mere pass in the examination, to satisfy the examiners in science and arithmetic, and that for a pass with credit in mathematics a knowledge of algebra and geometry should be required. If success in the examination is to carry the same privileges for boys and for girls, it is difficult to see that variation of its essential features is possible. We are therefore of opinion that the minimum requirements for passing the first examination should be the same for girls as for boys. If it is urged that the largest amount of time which our witnesses have demanded for science in girls' schools (see sec. 25) is not more than what is now regarded as inadequate for boys' schools, we would point out that many girls will take the examination at a somewhat later age than boys and that the wise application of the principle of compensation should meet any remaining difficulty, especially if sufficient attention is paid to proficiency in the subjects of group (IV).

39. We concur with the proposal of the Board of Education that a certificate should be given to those who pass this examination, and that on the certificate only those subjects should be recorded in which the student has reached a recognized standard considerably higher than that required for a mere pass. The board proposes that a full certificate bearing the name of the school and

particulars as to the course pursued at it should be given only to candidates who have followed an approved course at a school inspected by the board and recognized as "efficient," and that other candidates should receive a certificate stating only that they had passed the examination. This latter proposal seems to us to require consideration in relation to two classes of candidates, those who have attended secondary schools which have not been inspected by the Board of Education, and those who have not attended secondary schools at all.

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40. The proposals of the board of education are based on the view, with which we are in accord, that examinations should be determined by curricula, not curricula by examinations. It is difficult to decide how far an examination designed to suit the curricula of existing secondary schools and intended for pupils of about the age of 16 who have followed an approved course in those schools would be suitable for other pupils. There are already pupils who have followed approved courses in schools not now technically described as secondary schools, but who might quite properly take a similar examination. The abolition in the near future of all exemptions from elementary school attendance until the age of 14 is reached, and the establishment of compulsory part-time continuation schools up to 18 would provide a class of pupils who, though they have not attended secondary schools, have had a continuous course of instruction in approved schools. An examination analogous to the first school examination, and carrying the same privileges, might with advantage be established for this class—an examination which would be open, for example, to pupils who had attended central schools and junior technical schools.

CONTENT OF THE SCIENCE COURSE, 12 TO 16.

41. The question of the choice of the science subjects to be included in a school course and of the method of teaching these subjects is so important that somewhat detailed consideration of the problem is necessary.

We have recommended elsewhere that science should form part of the school course for all boys and girls up to the age of 16, and that more time should be given to it than is at present usual. But these recommendations must not be taken to mean that we should like to see a great extension of science teaching exactly on the lines now customary. We consider that the conventional curriculum is in great need of reform, in respect of two important points: (*a*) The choice of subjects to be included and (*b*) the manner of treating them.

42. (*a*) At present the curriculum up to the age of 16 in a large number of boys' schools consists of nature study in the lowest forms, followed by a laboratory course in at least one branch of physics and in chemistry; in very few boys' schools is there any attempt to give a knowledge of the main facts of the life of plants and animals. Physics and chemistry must, we think, continue to be the fundamental subjects in the school curriculum, because every other science requires some knowledge of them, and also because no other science lends itself so well to a study of experimental method under the limitations of time which are inevitable in school work; but no boy should leave school with the idea that science consists of chemistry and physics alone.

It is agreed on almost all hands that the customary course, which is a growth of the last 20 years, has become too narrow, not only because physics and chemistry are the only sciences included in it, but because the choice of subject matter within these sciences is unduly restricted. Further, it is out of touch with the many applications of science. The principles are often taught without reference to the phenomena of nature which they explain; the course does not satisfy the natural curiosity of the pupils; it may give them some knowledge of laboratory methods, but little idea of wider generalizations, such as the principle of the conservation of energy, which are quite within their powers of comprehension. Again, in many schools the course is planned as if its sole object were to lay the foundations for specialized study in science at a later period. But if nothing is built on these foundations the time may have been spent to little purpose; many boys will give up the study of science when they know but little of the scientific principles which underlie the most familiar natural phenomena, or of the most important applications of science to the service of man. Their position is analogous to that of a student of a language who stops after learning some of the grammar without acquiring any knowledge of the literature.

43. (*b*) For the last 20 years the attention paid to laboratory work has been an outstanding feature of the science teaching in English schools, and results of great value have arisen from it. We need not go back many years to reach a time when there was little practical work in schools; and any science that was done, apart from chemistry, was taught by class lessons, or by lectures with occasional demonstrations of experiments by the teacher. The practical work in chemistry consisted of exercises in qualitative analysis; it had little bearing on the rest of the work, and could be learned, up to a certain point, by routine methods.

But in the last 20 years circumstances have altered; laboratories have multiplied, and it has become the practice to make the laboratory work the central feature in school science. This change of point of view has had both good and bad results. On the one hand it has brought home to many boys and girls the fundamental notion of an experimental science, that the answers to questions on its subject matter can be got directly by experiments which they can do themselves; they have seen how a series of experiments leads up to a result, how the result of one experiment suggests that another is needed; they have, in fact, learned something of the experimental method of the sciences. Such teaching and experience is of the greatest value, and any change which would diminish its effectiveness would be a step in the wrong direction.

But on the other hand there have been unfortunate consequences; many teachers have become so dominated by the idea of the supreme value of experimental work that they have left on one side and neglected those sciences which do not lend themselves to experimental treatment in school; the tendency has been to restrict the work to parts of physics and chemistry in which the boys can do experiments for themselves. We are driven to the conclusions that in many schools more time is spent in laboratory work than the results obtained can justify. We do not underrate the importance of such work; on the contrary, we regard it as an essential part of science teaching. But sometimes the performance of laboratory exercises has been considered too much an end in itself—such an exercise loses the educational value of a real experiment when it becomes a piece of drill; often exercises succeed each other without forming part of a continuous or considered scheme for building up a boy's knowledge of his subject. Sometimes a very imperfect experiment is done by all the pupils, when the point which it brings out could be better illustrated by an experiment performed by the teacher, on a scale and in a manner which would not be possible for the whole form. Insistence on the view that experiments by the class must always be preferred to demonstration experiments leads to great waste of time and provides an inferior substitute. The time gained by some diminution in the number of experiments done, and especially by avoidance of unnecessary repetition of experiments of the same type, could be well used in establishing in the pupils' minds a more real connection between their experiments and the general principles of the science or the related facts of everyday life.

Much of this waste of time is due to a conscientious desire of the teachers to encourage the spirit of inquiry by following the so-called heuristic method; the pupils are supposed to discover by their own experiments, with little or no suggestion from the teacher, the solutions of problems set to them or of problems which they themselves suggest. The spirit of inquiry should run through the whole of the science work, and everything should be done to encourage it, but it seems clear that the heuristic method can never be the main method by which the pupil acquires scientific training and knowledge. He can not expect to rediscover in his school hours all that he may fairly be expected to know; to insist that he should try to do this is to waste his time and his opportunities.

44. Some of the defects of school courses are ascribed to the influence of external examinations in limiting the freedom of the teacher to choose his material and to treat it in the way suitable to local conditions or the special needs of his form. In all examinations, especially if they are competitive, there is a tendency to set questions of such a character that there would be no serious difference between the marking of different examiners. In an examination in elementary science the questions on general principles are admittedly more difficult to mark than those which are of the nature of little sums, such, for example, as to calculate the change in temperature when a piece of hot metal is dropped into a vessel of water. The result of this is that the questions tend to concentrate on a limited range of subjects, which are not of the highest educational value, and in which the majority of students find but little to interest them.

But examinations can not be blamed for all the faults which have been pointed out to us; it seems certain that a great part of the difficulty arises from the fact that the teachers, from lack of training and of knowledge of the methods of other teachers, tend to go on teaching as they were taught themselves, and thus the work becomes stereotyped.

45. Much stress has been laid in the evidence before us on the need for correlation of school teaching in mathematics and natural science. There is evidently a strong feeling, both among school teachers and among those who have to deal with the products of the secondary schools at the universities and in the industries, that both subjects would gain if they were taught with more reference to each other, and, so far as possible, by the same teachers. At present it is easier to get a science master who is able to teach elementary mathematics than a mathematical master with a corresponding knowledge of science; but few schools can spare a science master for any part of the mathematical work. The need for cooperation is not felt only on the side of the natural sciences; the committee of the mathematical association expresses the views that effective correlation between the two subjects is rare and is not increasing, that an ideal arrangement would assign the teaching of mathematics and of physics largely to the same masters, and that the education of teachers of mathematics should be conducted with this end in view.

We agree that there are very great advantages in putting the teaching of mathematics and physics to boys up to the age of 16 into the hands of the same master. It would, we consider, improve the teaching in both subjects by giving point to the mathematics and precision to the physics; it would also increase the time the boy spent with this master, whose influence and opportunities would be considerably enhanced.

Any want of coordination between science and mathematics has a particularly unfortunate effect on the teaching of mechanics. This subject is rightly regarded as of the greatest importance. It is the basis of most parts of physics, and most schools make some provision for teaching it, either as a branch of mathematics or as an experimental subject, or from both points of view; but the evidence we have received indicates that in a considerable number of schools the results obtained are far from satisfactory. This is much to be regretted, for the subject is especially suitable for training the student to use his mathematics and to apply it to the problems which he may have to face. The power of doing this is a very valuable asset for those who will become engineers or be occupied with other applications of science to industry, while, apart from this aspect, it affords a mental training of the highest importance and gives to many an interest in mathematics and a grip of its principles which without it they would never acquire.

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47. A general course in science should fulfill two functions: (a) It should train the mind of the student to reason about things which he has observed for himself and develop his powers of weighing and interpreting evidence; (b) it should also make him acquainted with the broad outlines of great scientific principles, with the way in which these principles are exemplified in familiar phenomena and with their applications to the service of man. The evidence we have received shows that there is a tendency to overemphasize the first of these functions and to neglect unduly the second. We think it essential that the importance of both objects should be recognized, and that the choice of the subjects to be studied and of the method of instruction adopted should be made with both objects in view. The training for the first of these functions must be given by practical work in the laboratory. The second can best be carried out by demonstration lessons from the teacher, together with practical work in the laboratory planned to illustrate the principles discussed in the lecture; laboratory work alone is not sufficient. We are of opinion that this plan would not impair the efficiency of the science teaching as a training in reasoning and observation. The age of the pupils and the time at their disposal make it impossible to include more than a limited range of subjects in the course, but the need for careful arrangement to avoid waste of time only becomes the greater on this account.

The very last thing we should wish is to lay down a hard and fast rule which would stereotype science teaching throughout the country. We think it essential that the teacher should be allowed as much freedom as possible in his choice of method, and that he will probably get the best results with the one which he himself prefers. He should, however, realize that the power of settling for himself the particular course he adopts carries with it greater responsibility for seeing that it is the best which can be devised under the circumstances of the school.

48. In framing a course in science for boys up to the age of 16 it should be recognized that for many this will be the main, for some the only, opportunity of obtaining a knowledge of science, and that the course should therefore be self-contained and designed so as to give special attention to those natural phenomena which are matters of everyday experience; in fine, that the science taught in it should be kept as closely connected with human interests as possible. The keen interest which many boys feel at this age in the applications of science, such as aeroplanes, steam engines, wireless telegraphy, motor cars,

and the like, should be utilized to the fullest extent. There are great advantages in introducing the study of the principles of science by starting from a machine or a striking physical phenomenon and working backwards to the principle, rather than by starting from the abstract and proceeding to the concrete; such a method is in no way inconsistent with a logical and continuous development of the subject. The advantage of the method is that the impetus due to a boy's interest in the subject helps to carry him through the lessons, while in the ordinary method interest may be aroused only after the lessons are nearly completed. This method is in many respects analogous to that which has been introduced in the teaching of mathematics, where the old plan of beginning with a series of axioms and definitions and then deducing the properties of triangles and circles has been superseded by a course which begins by making the boys familiar with the properties of these figures, leaving the logical deductions from the axioms and definitions to a later stage.

49. (I) Preliminary Course. There is general agreement among science teachers that the best preparation for the study of science at secondary schools is a course of nature study up to the age of 12. This course should be of as practical a character as possible and should aim at arousing an interest in natural phenomena and developing the powers of observation. Full use should be made of the opportunities afforded by the school garden to make the pupils acquainted with the spirit of scientific investigation. We attach great importance at this stage to manual training, both for the sake of the discipline it supplies for hand and eye and as making an excellent introduction to laboratory work. We think that advantage should be taken of the opportunities which nature study and manual training afford for practice in free-hand drawing and drawing to scale. From the evidence we have received we have come to the conclusion that at present the teaching of nature study is far from satisfactory and demands immediate attention. In some schools it is quite admirable; in many, however, it is worthless and is frequently given by those who take but little interest in this subject.

We have been informed that the teaching of elementary physics and chemistry in the public schools is often hampered by the fact that the boys are ill-prepared in arithmetic and want practice in mental arithmetic; that they lack facility in making calculations, have an uncertain knowledge of decimals and of the metric system, and have no clear understanding of the meaning of measurement. The right remedy lies in a more intelligent treatment of arithmetic and handwork in the preparatory schools. Advantage should be taken of the opportunities afforded by lessons on arithmetic, geometry, geography, and handwork to introduce the idea of measurement, to give practice in the use of simple measuring instruments—a valuable exercise in manipulation—and, lastly, to develop both readiness in the making of calculations and an appreciation of the degree of accuracy to which results may be stated.

50. (II) The next stage of instruction in science is one which presents special difficulties arising from the two systems of school organization to which we have referred in sections 10 and 13. We have to distinguish and to treat separately—

(a) The system which transfers a boy from a preparatory to a public school at 13½ or 14 without any continuity of curriculum in natural science.

(b) The system which provides a continuous course of instruction in one school from 12 to 16 or longer.

(a) The interruption of a boy's education which is brought about by his transference from a preparatory to a public school is specially detrimental to science work, because (1) most of the public schools pay no serious attention to a knowledge of science in selecting boys, either for entrance or for scholarships, and thereby discourage any teaching of the subject; (ii) many of the boys who come from preparatory schools, though they know no science, are placed at entrance high up in school because of their knowledge of other subjects. If science were taken in the lower forms, either these boys would have to omit the elementary stages of a systematic course or boys who begin in a lower form would have to take these stages over again. On this account it is considered impossible in some public schools to begin systematic work in science in the lower forms, with the result that there is not enough time left for a satisfactory course before the age of about 16½. * * *

The stage immediately after the age of 12 might begin with a course on the simpler parts of that branch of knowledge which Huxley called physiography. One of the advantages of this subject is that it gives opportunities for out-of-door observation, to which we attach great importance, not only at this stage but throughout the school course. It is unfortunate if pupils are left with the impression that physical principles operate only in a physical laboratory; it should be the object of the teacher to train the pupil to see illustrations of these principles in the experiences of everyday life. The course in physiography should include the simpler astronomical phenomena, which in the hands of a good teacher may be made an excellent training in reasoning and observation. At this early stage there should be practical work involving measurements of simple physical quantities, while a valuable introduction to some important branches of physics can be given if the manual training includes the making of some simple, practical instruments and machines, such as electric bells, small induction coils, telescopes, pumps, and so on. This plan has been tried at some of the central schools and has given very satisfactory results.

The introduction of practical work into the curriculum widens the opportunities of discovering ability which might otherwise be overlooked. One witness writes: "Often, very often, the dunce of the form when put on to practical work becomes brilliant." It is the function of any system of education to discover ability as well as to develop it, and under a system in which the curriculum is entirely bookish many able boys may be depressed and lose all interest in their work from want of success and of opportunity to reveal their ability.

(b) In schools provided with laboratories and having a continuous curriculum a course of elementary general science, including work of an introductory kind on hydrostatics, heat, and properties, both physical and chemical, of air and water is common at present; it serves as a satisfactory introduction to later work, but it is important, especially in town schools, that what we might call the physiographical aspect of these subjects, to which we have called attention in a preceding paragraph, should always be before the mind of the teacher.

51. The more systematic study of science begins about the age of 13; while we do not consider it desirable to suggest a detailed syllabus, we think it important to state what in our view are the principles on which it might be framed. For the sake of definiteness we will consider the case of a syllabus in physics: the principles, however, apply to chemistry and biology. In the first place, the object of such a course is not to train specialists in physics nor to give dexterity in making accurate measurements of physical constants; it should be designed to give as good a mental discipline as possible and to make the student acquainted with the principles involved in familiar physical phenomena. Even if, as we suggest, the time allotted to science teaching is increased, it will not be possible to study the various branches of physics, such as heat, light, sound, electricity, and magnetism, in as much detail as when only one or two are attempted. There must necessarily be great gaps in the students' knowledge of these branches, but in the general course we think these gaps should be distributed rather than that one or more of these branches

should escape consideration altogether. The problem the science master has to face is how to simplify the courses so as to be able to complete them in the time at his disposal. To make our meaning clear we give an example in some detail, showing how a course in heat might be arranged. The science master would first ask himself what are the most important physical phenomena and industrial applications for which a knowledge of heat is essential; let us suppose he decided that these were the domestic fire, the warmth of the sun, the heating of buildings, changes of state of water to ice or steam, the formation of rain, fog, clouds, snow, hail; the steam engine and internal-combustion engine. He would then build a course around these topics, in which attention was mainly directed to the subjects most closely connected with them, namely, the sources of heat, the expansion by heat of liquids, the changes of state of water, vapor pressure, the thermal effects due to compression, and the transformation of heat into mechanical work, the other parts of heat being only dealt with so far as they are necessary for the study of these subjects. He would then consider at what stages these subjects should be taken, for it is desirable that the study of heat, as of other branches of physics, should not all be done in one term, but resumed from time to time; this gives opportunity for revision and for postponing the more difficult parts until the students are more mature and have more mathematical knowledge at their disposal than at the beginning of the course.

It is essential that the parts on which it is decided to concentrate should be done very carefully and in detail, with much practical work in the laboratory. It is better to curtail the number of subjects discussed than to save time by slurring over difficulties.

We should like to lay stress on the fact that the conventional subdivision of physics into branches such as heat and light is apt to lead to neglect of very important parts of the subject, either because they are related to several of the branches—e. g., the conservation of energy, or because they lie outside the customary divisions. Few boys get in a school course any idea of subjects such as surface tension and diffusion through membranes, which are well within their comprehension and are of the greatest importance in biology.

It is very undesirable that the work of a form should be confined for a whole year to a single branch of physics; at least two of them should be taken. Further, the scheme of work should provide for the recurrence of the various branches of physics in the course, to afford opportunity not only for revision of what has been previously done but for extension of the ground covered.

The subjects included in the course might vary with the locality and type of the school. Thus, for example, in a town which is the seat of an important industry some phenomena might be matters of daily experience which would rarely come under observation in a different district. These would naturally be included in one case and not in the other.

52. In chemistry restriction of the field on the same principle is needed, but the problem of choice is easier because the field is less varied. It is essential that the work shall be brought as closely as possible into relation with the things of daily life. No attempt should be made to study in detail more than a small number of the chemical elements. A choice must be made which should include the most important elements, enough to illustrate the principles on which the elements may be classified. In discussing these elements opportunity should be taken to explain important points of general chemistry such as diffusion, the laws of combination, equivalence, solution, and electrolysis; no course can be considered satisfactory which does not lead up to the general laws of chemical combination and the explanation of them in terms of atoms and molecules. Quantitative experiments which take a long time can often be

replaced with advantage by simpler descriptive exercises not involving measurements but requiring some independent thinking. The description of manufacturing processes should not be neglected, although minute details would naturally not be introduced. Boys are always keen about large-scale work, and while such work is being described many opportunities will occur to the teacher of exemplifying principles which the boy will already have come across in his work in mechanics and physics. The sharp division which is at present made between inorganic and organic chemistry should disappear, and ideas such as fermentation, saponification, etc., should find a place in the course. The chemical processes in the life of a plant should not be omitted; for example, the way in which carbon dioxide is transformed into sugar, the utilization of atmospheric nitrogen by the leguminous plants, and the part played by nitrogen compounds in the food supply of plants could be pointed out while carbon and nitrogen were being studied. Similarly, the study of silica would naturally lead to a discussion of the part played by air and water in the weathering of rocks.

53. We have already laid stress on the point that some knowledge of the main facts of the life of plants and animals should form a regular part of the teaching in every secondary school. Systematic work in zoology, including dissection of animals and the use of the compound microscope, belongs to a later stage of school life, but the main facts as to the relation of plants and animals to their surroundings, the changes in material and in energy involved in their life and growth should form part of a well-balanced school course.

There is a considerable measure of agreement among our witnesses to the effect that the course might include the main anatomical features of the higher plants, the elementary physiology of plants, especially their relations to the soil and to the atmosphere, together with some quite general knowledge of animal metabolism. We think that in a boy's school career room could be found for this work by devoting to it part of the science time in the summer terms. Our object would not be attained by the establishment of courses of elementary biology at all analogous to those which are found at present in the higher forms of schools. Many of them are modeled on the first year's course for medical students at the universities, and contain an amount of morphological detail which would be altogether out of place in a general science course for middle forms. The kind of instruction which we have in view need not be in the hands of a teacher qualified only in biology and responsible only for that particular section of the science work. We realize that it is not easy at present to find teachers who can give adequate instruction in the various subjects which we should like to see represented in the curriculum, and that therefore only gradual development and improvement can be looked for. The separation of the biological sciences from the physical sciences at the universities has made it extremely difficult to find a competent biologist who can teach even the most elementary physics with the requisite accuracy and definiteness. The want of teachers with wider scientific qualifications is at present the real difficulty in the introduction of biology into school work.

54. *Girls' schools.*—There is some difference of opinion as to the science subjects which can be most usefully taught in girls' schools. For many years little beyond descriptive botany was attempted. Botany is still the chief subject, but it is becoming more and more common to treat the plant as a living and growing organism, rather than as a specimen to be classified in a herbarium; the physiology of the plant and its relation to its surroundings have become more important than the identification of wild flowers. But a study of plant physiology is impossible without some knowledge of physics and chemistry, and

partly for this reason these sciences have gained increased importance recently in girls' schools. Several witnesses emphasized the fact that the study of physics is still unduly neglected, especially in schools where a low standard in mathematics has become conventional. This has proved a serious obstacle to students who wish to enter the medical profession. It is most desirable that girls should have an opportunity of discovering whether they have a taste for physics or chemistry and of developing such a taste where it exists.

The main difficulty of the schools is to secure science mistresses who can undertake all the subjects which are required. This difficulty will tend to disappear as the recommendations made in our report bear fruit. It is to be hoped that ultimately a mathematical mistress will not be considered to be fully equipped unless she is at least capable of teaching the physics needed between the ages of 12 and 16.

Two special points deserve notice: It is important that hygiene should be well taught in girls' schools. We agree with the opinion of some of our witnesses that the subject should be taken as late as possible in the school course, preferably at the 16–18 stage, after a course of systematic work in the sciences on which it depends. Where this is impossible, definite teaching on the laws of health and on personal hygiene may well form part of the work of the lower forms, but it can not be properly considered as a part of the science course.

Similarly lessons on the everyday affairs of the household are obviously of practical importance, and they may form a part of scientific education if they are given by a teacher who has a real background of scientific knowledge. But much of the domestic science taught in schools has no claim to the name of science at all; it would be less pretentious and more accurate to call it housecraft, and find a place for it outside the hours allotted to science.

55. *Time.*—Teachers will very naturally ask how time is to be found for the extension of the range of science teaching which we propose. Some if it will have to come from time now given to other subjects. There are several possibilities in different parts of the curriculum. There can be little doubt that if a considerable part of the ordinary mathematical work were done by teachers who are also teaching science, much overlapping would be avoided and much loss of time prevented. Practical exercises in physics give better practice in rational arithmetic than the very unreal problems common in textbooks, and help to familiarize pupils with the metric system. The question as to the advantages and disadvantages of the metric system of weights and measures has many aspects which it is not within our province to discuss. As far, however, as education is concerned, the introduction of the metric system would be attended with great advantages. Arithmetic would be much simplified, and time saved which could be devoted to other subjects. Again, there is much overlapping between the subject matter of physical geography and of elementary science lessons; frequently a question such as the causes of the fall of rain is treated from one point of view in a physics lesson without much reference to the natural phenomenon, while this natural phenomenon is explained in a so-called popular manner in the geography lesson. There is a clear opportunity here for saving time. The time given to mechanics might come from the time allotted to mathematics; if we put this at one period per week and allot the equivalent of one period per week on the average to biology and two to chemistry there would remain, if our proposals are carried out, at least four periods per week for physical subjects, including mechanics. This suggestion is only intended to give an idea of the proportion of time to be assigned to each subject and should not be taken as a recommendation that a week's science work can be wisely broken up among so many subjects.

But we must indeed trust mainly to wiser, more economical, and more effective use of the hours spent in the laboratory, and this can only be attained by the constant care and attention of the teacher, and by careful planning of the practical work of the forms (see sec. 43). If the periods of practical work are too short, a disproportionate amount of time is lost in starting and stopping. In many schools time is wasted in making fair copies of laboratory notes instead of writing a concise description as the experiment proceeds and in making unnecessary sketches; nothing is more useful than a sketch of apparatus in describing an experiment, but it is a waste of time to take five minutes to draw a crucible with the aid of ruler and compasses.

56. *English.*—All through the science course the greatest care should be taken to insist on the accurate use of the English language, and the longer the time given to science the greater becomes the responsibility of the teacher in this matter. It is not always recognized that there are excellent opportunities for teaching clear writing in connection with everyday laboratory work. A boy may fail to write a good essay because his command of English is insufficient to express what he would like to say, or because he has little or nothing to say on the subject, but if he has been doing an experiment he should at least be able to describe what he did and what he saw in simple and comprehensible language, in the plain English of educated people. The conventional jargon of laboratories, which is far too common in much that is written on pure and on applied science, is quite out of place in schools. The science master can not be allowed to repudiate responsibility for the English in which the work of his class is written.

There is a tendency at present in some schools to discourage boys from reading anything about their science work except the notes which they take in class and in the laboratory. We consider that this policy is most pernicious. If a boy is interested in his subject he will naturally wish to read about it and should be encouraged to do so. A part of the time given to preparation, which is now often devoted to the mere transcription of laboratory notes, might be spent in this way, and boys should have access to good scientific books suitable to the stage of knowledge reached. The practice of discouraging private reading is responsible for the tendency, which has become more noticeable in recent years, for students of science at the universities to rely entirely on the instruction they get in lectures. Some of them seem to have lost any desire to read for themselves and from want of practice lack the ability to use books to any advantage. Boys who have acquired the habit of reading books on science when at school are more likely to keep alive in after life their knowledge and interest in the subject.

SCIENCE IN SECONDARY SCHOOLS, 16–18.

57. We have already recommended that there should be a general course in secondary schools up to the stage reached by boys of about 16 and marked by the first school examination; that the course should not be uniform for all schools or for all the pupils in a school, but that a substantial scheme of work in science should form an integral part of it. This general course should, in our opinion, be followed by a period of study covering about two years, in which attention is concentrated on a more limited range of subjects. In this connection we shall first refer to the age of transfer from the secondary school to the university. Hitherto it has been customary for many boys passing on to Oxford and Cambridge to remain at school till 19 or even later; on the other hand, those entering the modern universities have not infrequently done so at 17 or even earlier. In our view it is desirable on educational and other grounds

that boys who intend to pass on to a university should as a rule remain at the secondary school up to the age of 18, provided that the school is so organized as to furnish satisfactory courses in the various groups of subjects appropriate for them. Wherever this condition is fulfilled we consider that it will be for the advantage of the pupils, and not less advantageous to the schools and to the universities, that after the general course there should be a two years' period of advanced work at school. When the condition is not fulfilled, the right remedy lies in raising where possible the standard of the work undertaken by the secondary school. We recommend that 18 should be the normal age of entry from secondary schools to the universities; and in making this recommendation we are supported by all the witnesses who have given evidence to us on the subject.

58. We recommend further that the usual age limit for entrance scholarships for boys awarded by the colleges of Oxford and Cambridge should be 18 rather than 19, for it is not generally advantageous to a boy's intellectual development that he should remain subject to school conditions much after the age of 18. Further, university courses for science students will normally extend over a period of four years, and may often be usefully prolonged to a fifth year. The increasing requirements of professional study at the universities and elsewhere (especially in medicine and engineering) and the development of advanced courses in applied science, which presuppose a thorough knowledge of pure science, alike involve a lengthening of the period which intervenes between the end of a boy's school life and his entry into industry or professional practice; while under the conditions which are likely to obtain after the war young men will need to enter on their life work at an earlier age than has hitherto been customary. It follows that the age of leaving the secondary school should not be unduly postponed; and we do not consider that it can be wisely postponed much after the age of 18. We have already recommended that the age of entry into the public schools should be 13 rather than 14; we are not therefore suggesting any curtailment of the period spent in the secondary school.

59. It is generally agreed that the greater part of a boy's time between 16 and 18 should be devoted to the study of a group of subjects, the choice of which will depend upon the tastes and aptitudes he has developed and the career to which he looks forward. Specialization at this period is desirable because the imaginative and logical faculties can be best trained by the intensive study of a few subjects. Advanced work, too, is necessary to enable the learner to appreciate and attain a high standard of accuracy and thoroughness.

60. Under existing conditions the amount of time devoted to subjects other than those in which a boy is specializing is often extremely limited. The science specialist gives little time or attention to literary studies; he may, even though his main work is concerned with physics and chemistry, neglect mathematics. The specialist in classics or modern languages omits any study of science. Without wishing to lay down any hard and fast rule in the matter, we suggest that an apportionment of time by which a boy devotes not more than two-thirds nor less than half of the school week to work in his special subjects may be regarded as reasonable. Some literary study, including English, should have the first claim on the balance of the time of all science students. Further, just as the science specialist should, in the best interest of his education, widen his outlook and enlarge his interests by continuing some literary study, so the student of classics or modern languages should give time and attention to science work of an appropriate kind.

61. Those whose main subject is natural science will not all be candidates for entrance scholarships at a university; there will be boys who do not propose to proceed to a university at all, and will pass direct into industry or a pro-

fession; and others, again, who will enter universities with a view to taking pass degrees. All these will be specialists in the sense that their work will be limited to fewer subjects than those taken in the previous general course, and their interests can not be ignored.

62. The kind of work and teaching appropriate for the science specialist as such will consist, broadly speaking, in carrying forward to a higher stage the work in two or more of the sciences—physics, chemistry, biology—which have formed part of the general course, and will present to the schools only those difficulties with which many of them are familiar. It will usually be accompanied by further study of mathematics. Those who take biology should certainly continue the study of physics and chemistry, but we think it is not necessary to insist that they should do advanced work in mathematics.

63. The work we suggest as appropriate for boys who are not specializing in science differs altogether from this advanced work. It can not aim at the same measure of completeness even in a limited field, and there will not be time for extended laboratory teaching. There is at present little experience to guide us when we come to consider the character of the work in science suitable for such boys. The matter is, however, one of the first importance, and science masters could do no more useful service to the cause of science than to think out the problem for themselves and to make their own experiments.

The course or courses—for it is not desirable that there should be a uniform course—must satisfy certain necessary conditions. First, they should presuppose a general course in science including laboratory teaching up to 16 somewhat on the lines we have suggested. Second, they should be planned on a scale consistent with the comparatively small amount of time available for them, and not all of them need involve practical work in a laboratory. Third, their scope and character should be suitable for boys of 16–18 who are doing advanced work in other subjects. The last condition is vital. It implies that the teaching must, if it is to have any real value, be given by thoroughly competent teachers with a sound background of scientific knowledge and a wide outlook. It must not be merely discursive or disconnected or journalistic; it should deal with scientific questions of general interest and discuss them on a basis of definite knowledge. Above all, it must not aim too low. If it does not stretch the wits of the cleverer boys and give them something to think about, it will have failed.

64. The choice of the subjects must lie with the teacher. There is great wealth of material and a wide scope for teachers of varied gifts who know how to use their opportunities. We can not do more than make a few tentative suggestions, as follows:

A. (i) A course on the outlines of cosmical physics and astronomical principles of general interest, such as the measurement of time, the calendar, the size and mass of the earth and sun; the applications of spectroscopy to elucidate the composition of the stars, nebulæ, etc. (ii) A course on the general principles of geology, without too much technical detail, illustrated by local examples and the use of geological maps. (iii) A course on physiology and hygiene, which would include a discussion of the part played by bacteria and other lower organisms in fermentation and in the spread of disease. (iv) A course on physical meteorology; the composition and general circulation of the atmosphere, relation of wind to pressure, storm, clouds, rain, snow, thunderstorm, the aurora, weather mapping.

B. Courses on the history of science—e. g.: (i) The history of astronomy from the Greeks to Newton, including some account of the geocentric and heliocentric systems. (ii) The history of mechanics on the lines of the earlier portions of Mach's "Principles of Mechanics."

C. Courses on the development of scientific ideas—e. g.: The constitution of matter, the conservation of energy, the doctrine of evolution, heredity, immunity.

D. The lives and work of scientific men—e. g.: Leonardo da Vinci, Galileo, Newton, Lavoisier, Cavendish, Faraday, Clerk Maxwell, Kelvin, Pasteur, Darwin, Helmholtz.

F. The bearing of scientific inventions on industrial progress—e. g.: In connection with the history of farming or with other local industries; methods of transport by land, water, and air; means of communication, such as signaling, telegraphy, telephones; methods of lighting.

F. Courses of a more practical kind than those mentioned above on the particular applications of science—e. g.: On the internal-combustion engine or the dynamo. Such courses would appeal to boys of a mechanical turn of mind.

G. A course on the method and philosophy of science, historically treated, with special reference to the work of Aristotle and his predecessors, Archimedes, Galileo, and Bacon, and the later experimental philosophers.

It will be seen that many of these courses—and the list does not pretend to be exhaustive—give special opportunities to a teacher who combines some knowledge of history with his knowledge of science, and should appeal to boys with historical tastes. It is not, of course, suggested that they could all be profitably undertaken by any one teacher, or included in the work of any one school; they are quoted only as suggestions from which a selection might be made, depending on the teacher's own interests and the circumstances of the school. The fact that a teacher has quite rightly devoted himself during his university course to the special study of a few branches of science is no reason why he should limit himself in school to the teaching of these subjects. The courses indicated would be profitable also to science specialists, and would do much to counteract the narrowness of view which sometimes accompanies specialization.

Teachers will have their own views as to the methods by which such subjects can be most effectively presented. It may be assumed that the teaching will for the most part take the form of class teaching with illustrative experiments, diagrams, and specimens from the school museum; but every encouragement should be given to the pupils to supplement this by private reading. It is essential, in the interests of precision and accuracy, that the boys should be required to write about their work. Opportunity should be taken to set them questions of the essay type which would test their knowledge and powers of expression.

65. The pupils who are specializing in science will generally fall into one or more of the following groups: (1) Scholarship candidates and others who will give their attention to two or more of the subjects—physics, chemistry, and biology—with a view to an honors or pass degree in pure science; (2) those looking forward to entering the medical profession; (3) those who intend to enter the engineering profession or one of the industries; (4) those who will be connected in one way or another with the land.

The special needs of the last three groups are considered elsewhere; the needs of the first group are influenced by university entrance scholarship examinations, which are dealt with in a later part of this report. (See secs. 136–142.) For all of these it is important that, in addition to their science work, the school should provide appropriate courses of work in other subjects. The value of a knowledge of French and German at least sufficient to enable a student to use these languages as tools in his work is obvious, and there is no reason why anyone who has got beyond the elementary stages should not read a French or German textbook or use books of reference in these languages. The need for mathematics for the majority of science boys is no less urgent, and should not be difficult to meet if the recommendations which we make elsewhere as to the relation between the teaching of mathematics and science can be carried out. It is the study of English subjects which is at present most neglected in science forms. Just as we recommend that a special kind of appropriate science teaching should be provided for the nonscientific boys, so we think that the schools should grapple with the problem of helping mathematical and scientific boys in the study of subjects of a general education which will be of value to them in later years. It happens too often at present that the time which is not given to the pupil's special work is used in a haphazard manner without a definite plan.

THE SECOND SCHOOL EXAMINATION.

66. The board of education have made proposals for the establishment of a second school examination suitable for pupils of about 18.

Such an examination should, in our opinion, test the work in a few selected subjects which would include not only those in the group to which the candidate's main attention has been given, but some other subject or subjects as well. It should not be on the lines of the first school examination; for merely to test the subjects of a general course carried to a higher stage would be to throw away the intellectual opportunity offered by concentration on a more limited range.

67. We consider that, while there should be reasonable freedom of choice in regard to the subjects offered in the examination, a candidate whose main subject is natural science ought to offer at least one other subject, history or an ancient or modern language, or English literature. We should not consider the combination of science and mathematics without any literary subject as satisfactory. Conversely, a candidate whose main subject is a literary one should be expected to offer a branch of natural science or mathematics. We presume that the examination will always test the candidates' power of writing English. The standard set in the subjects offered should not, however, be so high as to preclude the possibility of giving time to other studies which might be considered appropriate at this stage of education. It is not, in our view, necessary or desirable that a boy should present for examination, least of all at this stage, all the subjects to which he is devoting school time. Art and music or a modern language might, for example, occupy some of his time, but there is no reason why they should be offered for examination. Lastly, it is essential that the regulations for this examination should be so framed as not to be inconsistent with the scheme for widening the basis of college entrance scholarship examinations which we recommend in section 140.

Sections 69, 70, and 71 deal with secondary scientific education in Wales, for which the observations made in regard to the position of science in English State-aided schools generally hold good.

TEACHERS OF SCIENCE IN SECONDARY SCHOOLS.

(1) Supply.

72. The first and indispensable condition for any real improvement in the teaching of science in schools of all kinds is that effective steps should be taken to secure an adequate supply of properly qualified teachers. The supply is inadequate for existing needs, quite apart from the abnormal conditions created by the war, and it will be still more deficient after the war.

We have suggested elsewhere that the time to be given to science should be augmented, that the subject should be taught in schools and parts of schools where it is omitted, and that advanced work should be further developed, especially in State-aided schools. If these suggestions are to be carried out it is clear that, quite apart from the demand entailed by the continued growth of secondary schools, which has been a striking feature of the educational history of this country in recent years, the supply of science teachers must be further increased. On the other hand, industry has already begun to compete for the services of those who in former times would have looked forward to science teaching as a profession, and the competition is likely to grow more severe in the future.

(ii) Salaries and Other Conditions of Work.

73. To secure the requisite supply of teachers it will be necessary to improve, and improve substantially, the salaries of teachers of both sexes and to provide a satisfactory national system of pensions and retiring allowances. * * * The teachers are, in fact, the key to the educational situation. Unless a sufficient supply of properly qualified men and women teachers can be secured, all our proposals will be futile.

Another committee has been appointed to consider the whole question of salaries. It will have at its disposal information that we have not, and it can concentrate on the consideration of principles and maybe on the determination of details outside the scope of our inquiry. But we should be faithless to our duties did we not assert as emphatically as possible that the conviction formed at an early stage of our proceedings that no suggestion we might make would be of avail to improve the position of science in education unless the salaries at present offered to teachers were considerably raised, has been strengthened at every step we have taken in our journey. It is not merely an improvement in the salaries that is needed, but a revolution in the attitude of the public toward them. Exceptional teachers will always join the profession for the love of the work it offers and the opportunity it presents of fulfilling themselves. These must be a minority, invaluable it is true, but not to be reckoned with as part of the normal supply. We have spoken of a revolution. What we mean is that present salaries should no longer be taken as the basis for a future arrangement. To add 10 or 20 per cent is useless; a much larger increase is necessary to attract the number of better qualified men and women that our proposals necessitate. The new basis for the calculation of salaries must be what the men or women of intelligence, education, and vigor might gain in any other profession. There are no doubt compensations in the life of a teacher—e. g., longer holidays—but there are counteracting disadvantages. Whilst term lasts the work is peculiarly exacting. The salary-earning life is shorter. In no profession is it more important that the members should have reasonable opportunities of foreign travel and the wherewithal to purchase books, but foreign travel and the purchase of books impose a heavy tax on scanty incomes.

But a scale of salaries—even a reasonably generous scale—will not be sufficient. We attach equal, if not greater, importance to the attractive value of posts carrying a salary and influence more considerable than any that can be recognized by an automatic scale. The annual increment and the fixed minimum must be tempered and vivified by better-paid posts. All schools should be enabled to offer to one or more of their masters as a reward for teaching gifts, as distinct from administrative ability or mere seniority, salaries not confined within a scale. The very existence of such prizes would serve as an encouragement and a stimulus to teachers to cultivate their abilities even in the middle years—the most dangerous years of their career.

74. It is also desirable that the conditions under which the teacher works should be such as will improve his efficiency. The preparation of successful experiments to illustrate lectures makes demands on the time of a science teacher and on the accommodation at his disposal which under present conditions are in many schools very difficult to meet. We think that this fact should receive recognition in the arrangement of secondary school time-tables, especially for those teachers primarily responsible for the organization of the science work. In some schools the teaching is handicapped by the fact that teachers are without the services of a laboratory assistant. This handicap will be increased when our proposals are adopted.

It has been pressed upon us that teachers in secondary schools should have opportunities for independent research. We are in general sympathy with this suggestion and think that much more might be done in the direction of establishing points of contact between the work of university teachers and investigators and that of teachers in secondary schools. But the number of teachers in secondary schools qualified to conduct scientific research, except of a quite unambitious kind, will probably never be large; and necessary school duties must remain, save in exceptional cases, a bar to any considerable development of this kind. There should in any case be room enough in a school laboratory for the masters to carry on experimental work of their own. It is beyond question that a great stimulus is given to the better boys where they see that a science master is engaged in independent investigation and can help him in operations incidental to it. A junior master who has had experience in a research laboratory could find in many of the sciences problems within the range of his resources. But, as his work must be intermittent, he must have some place where his apparatus can be left undisturbed. It is especially important to keep the need for this accommodation in mind in the designing of new laboratories. Facilities for independent work would increase the attractiveness of the career of a science master, and research would have a great effect in refreshing and stimulating his mind.

There is also work of the first importance to be done in the direction of improving the methods of science teaching—e. g., the devising of new experiments and the improvement of schemes of practical instruction. These, under the influence of textbooks and examinations, tend to get stereotyped. Such pioneering, which might be described as educational research, is badly needed and can only be done at the schools.

(iii) Qualifications.

75. We pass on to consider the qualifications of science teachers, both as they are and as they should be. In regard to the first point, science teaching in secondary schools is almost exclusively concentrated in the hands of those who have obtained a university degree in science. Science, unlike some other subjects, is seldom intrusted to a teacher who has no special knowledge of the subject he is required to teach. On the other hand it is only an insignificant minority of teachers who have received any training in the art of teaching their own subject, and the opportunities afforded to science teachers of seeing work in schools other than their own and profiting by the experience of their colleagues are extremely limited. We were indeed informed by the chief inspector of secondary schools that "there was need for science teachers with a wider outlook and a more developed skill in handling their subject."

With regard to the qualifications which science teachers should possess, it is clearly desirable that they should have taken a university course in science and should have come under the influence of inspiring university teachers. It is also desirable that future science teachers should, so far as possible, avail themselves of opportunities for experimental work of a research type, whether before or after taking their degree. But if science teaching in secondary schools is to follow the lines we propose and be something more than teaching adapted to the future science specialist, it is necessary that the teachers should have received a school and university education calculated to give them that wider outlook without which their teaching is only too likely to be wooden and uninspiring—an education which would enable them to deal with the relations of science to the progress of civilization, its influence on human thought, and the history of scientific discovery. It is probable that the pressure of examinations, the laudable desire to carry the school work in physics, chemistry, or botany up to a high standard, and an undue emphasis on practical work in and for itself are contributory causes which may account for that failure to deal with the wider aspects of science of which science teachers are themselves increasingly conscious.

76. It is one of the unfortunate results of the lack of teachers qualified in science that they are commonly under the necessity of devoting their whole teaching time to their own special subject and that alone. In many schools this is carried so far that a master will be engaged in teaching only a single science subject—e. g., physics or chemistry. There is no doubt room in the more highly organized schools for a certain number of teachers whose work is specialized in this way, but we certainly hope, in the interests alike of science and of those who are concerned to teach it, that they will be encouraged to devote a portion of their time and energies to teaching some subject other than the one in which they are specialists. In particular we agree, as we have already said, with the view expressed in one of the answers to a questionnaire which we sent to the mathematical association, that the best method of securing coordination of the work in mathematics and science is to assign the teaching of mathematics and physics largely to the same teachers. To do this it would be necessary to have a supply of teachers who had had sufficient training in both mathematics and physics to enable them to enter into the spirit of both subjects. * * * It would be well if those concerned with the appointment of teachers let it be known that they would give preference to candidates with qualifications of this kind. School science would gain if its teachers could take a share in some subjects other than mathematics. The abolition of water-tight compartments in which even closely allied subjects tend to be isolated would benefit both teachers and pupils. It has been suggested to us that science masters are at a disadvantage in obtaining head masterships; we think that any such disability will disappear when the importance of science is more fully recognized and when science masters undertake a wider range of school work.

We desire to express our agreement with the view that some knowledge of the history and philosophy of science[1] should form part of the intellectual equipment of every science teacher in a secondary school. The effectiveness of science teaching as an instrument of mental training would, in fact, be greatly enhanced if teachers were themselves more critical of loose reasoning and were better able to instill precise and accurate habits of thought.

[1] Such a knowledge as might be gained by the study of chapters of Mill's Logic; Jevons' Principles of Science; Merz's History of European Thought in the Nineteenth Century; Mach's Principles of Mechanics; Karl Pearson's Grammar of Science; Ward's Naturalism and Agnosticism; H. Poincaré's Science and Hypothesis (and his later works); J. Arthur Thomson's Introduction to Science, to mention only a few well-known works.

(iv) Training.

77. We have already pointed out that teachers, especially men, have so far availed themselves to a very slight extent of such opportunities as exist for professional training. This is due in part to doubts entertained in regard to its value and in part to the fact that, owing to the dearth of teachers, head masters and governing bodies have not been in the position to insist on training as a necessary qualification for appointment. We are ourselves convinced that a suitable course of training would add to the efficiency of science teachers, and that the doubts which are felt in some quarters are due to the unsuitability of existing schemes and to limited experience of their effects on teachers otherwise well qualified. For us the question is not whether teachers should continue to lack the guidance which a suitable form of training might provide, but what sort of training is likely to be most effective.

In regard to this, there was a remarkable consensus of opinion among our official and other witnesses. There was general agreement that training should be centered in the secondary school, and that it should consist mainly in practice under proper supervision in the art of teaching the subject or subjects with which the teacher is concerned. We think that a full year's training should be provided after the completion of a university course of study and before appointment to a permanent post in a school.

The first portion of this time should be spent in a secondary school and the second, which should not exceed a third of the whole, in some academic or other training center. In regard to the conditions of training at a secondary school, we suggest: (i) That not more than half the time should be devoted to actual teaching; (ii) that the teacher in training should be regarded for the time being as a regular member of the staff; (iii) that he should work under the full control of the head master and under the immediate guidance of an experienced member of the assistant staff qualified to assist him in his special work, but that the authorities of the academic or other training department should have full opportunities of cooperating with the school authorities and advising the teacher in training as to his course of study; (iv) that opportunity of seeing work in subjects other than his special subject should be given to the teacher in training; and (v) that board and lodging, or their equivalent, should be provided by the school. The second portion of the training should comprise attendance at courses of instruction in the technique of science teaching as well as other subjects, and we hope that such courses will be organized at the universities.

The adoption of a scheme of this kind should not prevent teachers who had attended an elementary training college or the elementary training department of a university from taking posts in secondary schools if suitably qualified. It will be noticed by those acquainted with present arrangements for the training of secondary teachers that the scheme we have proposed is a combination of the second and third types of training recognized by the board of education, and we think it may claim to have the advantages belonging to both.

Until salaries are considerably improved some arrangement must be made for giving further financial help to the teachers in training. The financial help might take the form of (*a*) direct payment by the school out of money contributed by the State in recognition of the fact that schools undertaking this work perform a national service, or (*b*) a loan from a fund administered by the university or college to which the teacher in training belonged. We wish to emphasize this point, for the fact that a teacher may begin his work immediately after he takes his degree and without further expenditure has had an important effect in attracting men and women to the profession.

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78. The one year's course of training proposed as the normal course for all secondary teachers in the future will need to be supplemented in various ways. As things are, teachers tend to be isolated in their work, especially in the smaller schools. Further, it is difficult for them to keep even tolerably well abreast of the progress of knowledge in a subject in which rapid advances are being made.

Something might be done to remedy these defects by encouraging teachers to visit other schools. Such visits are of little value unless they are of at least a week's duration, and their value is much increased if the teacher makes a record of this experience, of course only for his own benefit and that of his colleagues. Again, it is well worth considering whether some organization might not undertake the task of issuing a journal (not necessarily appearing at regular intervals) or a series of leaflets in which teachers who have devised new lecture or laboratory experiments or new methods of dealing with particular problems in connection with their work might bring them to the notice of their colleagues.

79. Apart from these expedients there is need for the establishment of short courses for teachers, which should be held preferably at university centers. These courses might be of the following kinds: (i) Courses consisting of lectures given by university teachers on recent advances of science. Opportunity might be afforded to the teachers attending such courses of working in a fully equipped laboratory and of obtaining instruction in laboratory arts. (ii) Courses given by those who had had experience of school teaching, on the methods of teaching the several sciences. These courses would normally include laboratory work, and no small part of their value would lie in the interchange of experience among those who attended them. they would enable teachers to acquaint themselves with new experiments and improved methods of overcoming difficulties in the school treatment of science. (iii) Courses adapted for teachers who wished to familiarize themselves with a subject in which they felt their knowledge deficient. Thus courses might be provided to help teachers of nature study in preparatory schools or the lower forms of secondary schools, courses in practical physics for teachers of mathematics, or in geology or astronomy for science masters who had not taken these subjects as part of their university studies. To many an additional attraction of a return to the university would be the possibility of access to a large library.

In existing circumstances there will be need for a somewhat extensive provision of courses of the third type to tide over temporary difficulties arising out of the dearth of properly qualified teachers. It is very important that the universities should regard it as a normal part of their duty to provide courses of the first two types to supplement the one year's course of training.

LABORATORY ACCOMMODATION, EQUIPMENT, AND LIBRARIES.

80. In the matter of laboratory accommodation and equipment it is necessary to distinguish between State-aided and other secondary schools. Those State-aided schools which date back to the days of the science and art department are well provided with laboratories and lecture rooms, while in the newer State-aided schools the Board of Education have always insisted on the provision of properly equipped laboratories.

The schools which do not receive grants are under no compulsion in the matter. We were, however, informed by witnesses representing the Public Schools Science Masters' Association that during the past 20 years there had been great improvement in the provision of laboratories. An analysis of the answers given by 55 Head Masters' Conference schools to our questionnaire shows that 30 of these schools have three and more laboratories, 21 have two laboratories, and only 4 schools (with less than 200 pupils) are limited to one. In certain schools the laboratory provision would appear to be either insufficient for the needs of those taking science or sufficient only because so many boys do not learn science. Thus five schools with more than 400 pupils have each only two laboratories; though in one of these schools substantial additions are under consideration.

In girls' secondary schools, including some which are State aided, the provision is less satisfactory. The Association of Science Teachers laid before us figures showing that out of 28 schools, with between 200 and 300 pupils, 20 had only one laboratory, and that 10 out of 13 larger schools were no better off. Even if we take into account the fact that a certain number of pupils in these schools have not arrived at an age at which science with practical work forms part of the course, the figures shew that the laboratory accommodation is quite insufficient. Our proposal for the increase of science teaching will make greater demands on laboratory accommodation. We would point out (i) that the number of the laboratories must be determined by the number of forms who have to do practical science simultaneously; (ii) that in planning new schools it is much more important to secure ample space than to provide elaborate and costly fittings. School laboratories are sometimes constructed complete in every detail because it is thought necessary to include as much as possible of the initial cost in the builder's contract; it would, as a rule, be better to supply at the outset only the absolutely necessary fittings and to hold over a portion of the intended expenditure for the numerous minor adjustments and additions which are best made after experience of actual work in the room.

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81. It is impossible to leave the subject of apparatus without pointing out that it is desirable on educational as well as on economic grounds to make the utmost use of the school workshop, the skill of its manual instructor, and the help of the boys. Wherever it could be afforded, it would be an advantage to have a mechanic sufficiently skilled to be able to repair instruments and to make simple pieces of apparatus for use in teaching. The services of such an assistant would tend to a great economy in time, and his wages would be to some extent recouped by the saving in the purchase of apparatus.

82. One of the most valuable things which a school can do for its pupils is to teach them how to make an intelligent use of books, but in many schools this need has not been sufficiently recognized for science students.

Two classes of books should be provided by the school:

(*a*) Books dealing with scientific subjects in a general way—e. g., biographies and books on the history of science and discovery; books of travel and well-written popular works on science and its applications. These books should form part of the general school library and be available for the whole school, some being selected as specially suitable for the younger boys.

(*b*) Advanced textbooks, works of reference, and some of the very useful reprints of classical scientific papers of all nations. This class of works is intended for the use of senior boys and of masters. Some of these books might be kept in the laboratory, so as to be readily available for immediate reference.

An adequate sum for the maintenance of the school library should in all cases be provided in the annual estimates. Such provision, where made, is often insufficient, especially in grant-earning schools.

But it is not enough to provide the books. The science masters should make it their business to encourage boys to read, and to direct their attention to the books which are most suitable for them. Lists of books appropriate for boys of different ages might be put up in the laboratory or lecture room.

Sections 83, 84, 85, and 86 deal with scientific education in the intermediate and secondary schools of Scotland. The observations made with regard to the position of science in English schools generally hold good in that country also.

SCIENCE IN ELEMENTARY SCHOOLS.

87. In secondary education we have recognized two stages—a period of general education and the stage of specialization. The elementary schools proper should, from their essential nature, never reach the second of these periods, which belongs to the schools of the secondary grade, to continuation classes, and to technical schools. The elementary school, however, serves as a preparation for these subsequent stages, and both in its own character as providing general education and also in its function as a preparatory school it should include in its curriculum the teaching of science in a simple and suitable form. This should normally include nature study, and should be supplemented by instruction in elementary practical work of the kind described in section 49, taken in connection with the teaching of arithmetic and handwork. With regard to the time to be allotted to this subject we should not wish to lay down any hard and fast rule, but we suggest that two periods a week would be appropriate.

88. The foregoing remarks apply to the ordinary elementary schools as at present constituted, from which exemption may, in too many cases, be obtained at 13 or even little more than 12. If, however, the minimum leaving age is raised without exception to 14, as seems probable, steps will have to be taken speedily to prevent the marking of time which even now occurs too frequently in the seventh and ex-seventh standards. In many schools provision will have to be made for more advanced work, and consequently instruction in science will have to be carried to a higher stage. From a number of syllabuses which have been submitted to us, it is evident that under existing conditions in some elementary schools, especially where many of the boys stay till 14, a master with exceptional character and qualifications can give an amount of science teaching which may be of great value. Where such teaching exists, it is generally found in close connection with the practical work in the school curriculum, such as gardening or manual instruction, and is sometimes related to a particular local industry. Work of this comparatively advanced nature is at present confined to some three or four hundred out of a total of about 24,000 elementary departments for children other than infants in England and Wales. Though some of these are definitely organized as higher elementary and central schools, where the children stay till 15, nevertheless given the same quality of teachers, a good deal of what is being done in such schools can be done in other schools if the children are retained in sufficient numbers till 14 and are trained according to the full measure of their abilities. Those who pass from the elementary to the secondary schools should, for the most part, have been transferred by the time they are 12 and do not come under our consideration in this section.

89. It is to the general education and training of the teachers that we would look for the necessary improvement of the teaching of nature study in elementary schools and for the development of a further course of science, which may prepare pupils for more advanced work in the continuation and technical schools. The preliminary education of teachers will now, to a very great extent, be given in grant-earning secondary schools, where the board of education require a four years' course in science and where almost all future teachers will have to spend five years. None of these should, therefore, be wholly ignorant of science, and many of them will in future, it is hoped, take science as one of their subjects at the training college. We consider that where candidates for the preliminary certificate examination for entrance to a training college can not produce evidence that they have taken a course of science in a secondary school they should be required to present science as one of their subjects in the examination. It is not easy to exaggerate the importance of some scientific knowledge for all teachers, for it enables them to link up their daily lessons with the facts with which all children, in town and country alike, are in natural and continual contact.

The necessity for obtaining new teachers for elementary schools from all available sources will, however, for some time to come prevent their previous education from being so uniform or so satisfactory as that to which we have referred. It will also be necessary to provide special instruction for those who have been country pupil-teachers in districts remote from secondary schools or pupil-teachers centers and for those who enter the profession merely by passing examinations in which science is not at present included.

In 1904 in all training colleges science became a compulsory subject for every student, and special grants were given for it. Every college was obliged to have a well-equipped laboratory, and in consequence of this regulation adequate laboratory accommodation is available. The theory of training in those days was that every student should be fitted to teach every subject in the ordinary curriculum of an elementary school. In 1913, however, at the request of the training colleges the regulations were altered so as to allow students to take fewer subjects and to carry those selected to a more advanced stage. It thus became possible for a student to omit science altogether.

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It is extremely desirable that there should be a much larger number of teachers in elementary schools qualified to give instruction in science, and that all possible steps should be taken to increase the supply.

90. In the general work of the training colleges there has been a great improvement during the last 10 years, but the evidence before us leads us to believe that the standard of acquirement in elementary science is at present very low, and that, in general, attention ought to be given to the subject of science. There are probably not many students passing out of the training colleges who, without further instruction in science, would be qualified to carry the teaching of the subject very much beyond what is now usually given in an elementary school; a considerable number of the teachers would not be capable of even this amount. With the existing teachers it is most undesirable that any uniform curriculum of science should be introduced into the schools. But a great deal of useful training can be effected by special classes and short courses, more especially at agricultural colleges, farm institutes (when developed), and universities. We may draw attention to the value of allowing lecturers who have conducted classes for teachers to follow up the results of their instruction by subsequent visits to the schools where their students are teaching. Improvement in the scientific qualifications of teachers generally is

of special importance, as we think it is highly desirable that the work in every school should, if possible, be in the hands of a member of the regular staff, and we strongly deprecate the employment of peripatetic teachers as anything but a temporary expedient.

91. A certain number of the council schools of the larger towns are provided with laboratories, but even where these have been built some of them have never been equipped, and the use of others is temporarily suspended, owing to staffing difficulties during the war.* We have, however, no doubt that it will be soon found necessary to add to their number.

In the smaller towns and in country districts a less ambitious provision will probably serve the needs of the elementary teacher. It is extremely desirable that in every school there should be a large room with flat tables and a supply of water (and, where possible, gas and electric light), which should be available for the general use of the school and not restricted to the daily instruction of one class. Such a room in rural schools can be, and often is, used for manual instruction and cookery. With these subjects simple science teaching can usefully be linked.

So far as nature study is concerned, the school garden is an invaluable adjunct, and, great as the increase in the numbers of gardens has been even before the war, it is desirable that further provision should be made wherever competent teachers can be secured. Indeed, it is hardly possible to overestimate the extent to which the various forms of practical work now obtaining in the schools may be made to serve the ends of the teacher of science. Methods of measurement may be applied to, and elementary scientific conceptions derived from exercises in woodwork, simple metal work, gardening, and cookery; thus the science teaching, gardening, drawing, and other branches of handwork may help each other.

The hope now at last to be realized of giving a longer school life to many children in the elementary school increases the importance of securing teachers and conditions that will enable good and full use to be made of the time thus redeemed.

TECHNICAL EDUCATION.

92. The terms of our reference appear to us to indicate that while we should by no means neglect the important subject of technical education, at the same time we were not expected to institute any very prolonged or detailed inquiry into its present conditions or its immediate needs. Technical education in this country was first consolidated, and to a large extent organized, under the technical instruction act of 1889. Partly in consequence of this the term has come to be often used loosely, as including all the work in commercial and literary as well as scientific and industrial subjects that is done in technical institutes and evening schools throughout England and Wales. We are not concerned with technical education in this wider sense, but only with that part of it into which science enters. This will include work in pure science and in industrial subjects, such as engineering, mining, building, which depend on applied science; instruction in these subjects is given both in the technological departments of the universities and in technical schools aided under the regulations of the Board of Education.

93. By far the largest number of students receiving "technical education" of one kind or another are to be found as part-time students in evening and similar schools which provide instruction mainly for those engaged in some wage-earning occupation. The classes conducted in these schools "vary widely

in character and scope, for they range from the small and unambitious continuation classes of a rural school to the highly specialized work done in the best equipped of the technical colleges." The number of boys and men who attended evening schools at any time during the year 1912-13 was 467,240, of whom 162,001 were under 16 years of age and 305,239 were 16 and over. It is, however, not possible to determine what proportion of the total number attended classes in science and related subjects, and 54,800 classes in subjects into which ing, mining, building, which depend upon applied science. The statistics published by the board of education show that there were approximately 36,000 classes in science and related subjects, and 54,000 classes in subjects into which science does not enter. Unfortunately they do not show either the number or the age-range or the sex of the pupils who attended the classes in the several subjects enumerated in the returns. It should be observed, however, that in estimating the number of boys over 16 and men receiving instruction in science and technology a very considerable deduction must be made from the total number—305,239 quoted above—to allow for (i) those pupils who attended classes exclusively in commercial, literary, and other nonscientific subjects, and (ii) those who failed to attend for the minimum period of 14 hours in the year, which is necessary to qualify for grant. The statistics available do not permit of our making anything but a rough guess as to what deduction should be made in respect of the pupils falling under these heads; but we should not be surprised if it amounted to something like 40 per cent of the whole number. In 1911 the total male population of England and Wales between the ages of 16 and 24 was 2,500,000. If the estimate of 180,000 males of 16 years of age and over, taking science and related subjects in evening schools, is accepted, this means that only 7 per cent of the male population of these ages was receiving instruction of such character in these schools.

It must be remembered that attendance at evening classes is voluntary, and that many of the pupils concerned work for long hours in the daytime. But even if the numbers are unsatisfactory, there is no doubt that the instruction provided is of very great importance, both to the students who receive it and to the nation as a whole, since the courses in question furnish the only opportunities at present available to a considerable body of students, most of them wage earners, of receiving any instruction in science at all.

94. We pass on to deal with a special point of great importance in any consideration of technical education. It is sometimes supposed that technical education consists in the main of instruction in trade processes, and objection is raised to such instruction because it is thought to be directed exclusively toward increasing manipulative skill. It is worth remembering that the technical instruction act of 1889 specifically excluded teaching in the practice of any trade or industry, and defined technical instruction as "instruction in the principles of science and art applicable to industries." Although the act was formally repealed in 1902, its influence has been considerable in determining the character of the course provided in technical institutions which were established under the act and are still carried on by practically the same education authorities. It is true that certain of the courses in engineering providing trade instruction for apprentices and artisans in the special subjects of their trade (to quote a particular example), are intended "primarily to help workers to a more intelligent understanding of their craft," and that instruction in them is "based on the operations and processes with which the students are familiar, and is not directed primarily toward imparting broad general principles." But even these courses (a) presuppose a general preparation in mathematics, drawing, science,

and English; (b) are not limited to the processes and operations of the trade in which the student is engaged, but are supplemented by instruction in calculations and drawing and by practical work or demonstrations. Further, it is desired and is indeed to a large extent secured, that students who take a course of this kind will proceed to broader courses of study in which greater emphasis will be laid on the scientific bases of engineering. There can, we believe, be little doubt that the general trend of recent educational policy has been to emphasize two important ideas: (i) That vocational instruction must be based on a foundation of general education, (ii) that this vocational work should so far as possible include instruction in the scientific principles on which industrial processes are based.

95. Since this committee began to sit, two important documents have been issued, the first being the report of the departmental committee on juvenile education in relation to employment after the war, presided over by Mr. J. Herbert Lewis, while the second is the education bill introduced by Mr. H. A. L. Fisher in the House of Commons on the 14th of January, 1918, which proposes to carry into effect many of the recommendations contained in the above-mentioned report. If the bill becomes a law,[1] the age of compulsory whole-time attendance at school will be advanced to 14 without exception, and there will be further compulsory part-time attendance for 320 hours in the year up to the age of 18. It is in connection with the education of adolescents so far as this is given otherwise than in secondary schools that the effects of the new bill will be mainly felt. The two main features of the change will be that the substitution of compulsory attendance up to the age of 18 for voluntary attendance, and of day classes for evening classes. The voluntary attendance has frequently been neither regular nor sustained. Under existing conditions 100 hours is a fair record of attendances in the course of a year, whereas under the new conditions every student will have to put in at least 320 hours attendance, and this, not in the evening after a full working day, but between the hours of 8 a. m. and 7 p. m. It is obvious that the increased and regular attendance and the tranference of instruction from the evening to the daytime will facilitate the organization of better and more coherent courses of work. We have not gone into the question of industrial conditions and are not prepared to say what arrangement of hours may be best, but from the educational point of view we hope that ultimately it may be possible to extend the requirement of attendance to 480 hours a year, i. e., an average of 12 hours a week for 40 weeks. We recognize that even the proposals of the bill represent a step in advance and will permit of a great improvement in the position of science in the educational system. If they are adopted, there will ensue a wide recasting of arrangements for schools other than full-time elementary and secondary schools. We do not therefore think it necessary to consider existing types of school in detail. It is obvious that the amount of education given to pupils between the ages of 13 and 18 not only at elementary and continuation schools, but also at the existing central, higher elementary, trade, junior technical, and secondary schools will be greatly increased. Many new schools of these and probably of various other types will be created, many barriers will be broken down and the framework of our system will have to be kept very elastic and capable of efficient expansion. In connection with technical education the questions that press refer not so much to the place of science in the system of education as to the system itself. We want clear paths by which every grade and type of talent may pass to the appropriate grade and type of usefulness, and that each may have on the journey all the help that education can afford. We want also that in the course

[1] It became law on Aug. 8, 1918.

of the prescribed period of school training, every youth should have a real introduction to healthy interests other than those which are closely vocational.

We trust that one result of the revision of the educational system which is now contemplated will be to increase greatly the numbers of pupils in whole-time day schools providing education higher than elementary, and that in the curricula of such schools there will be a full measure of influences calculated to promote aptitude and liking for occupations in or related to industrial applications of science. With such a spirit in the work of day schools there would be a material increase in the supply of students qualified for higher study and investigation in pure science or for more advanced technical education, as provided in the higher technical institutions and in the scientific departments of universities. The standard and the results of the higher teaching of science in relation to its application in industries depend very largely upon the preparation and the numbers of students available for that stage of work. Accordingly, the crux of the situation is the nature and prevalence of education of secondary grade.

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96. We shall now deal with a number of points to which our attention has been specially directed in the course of our inquiry.

(I) *Teachers.*—(*a*) It is essential in technical as in other schools that there should be a considerable raising of the status and remuneration of whole-time teachers, and that this improvement should include a national scheme of adequate pensions. This is necessary, if only to increase the supply of educated and efficiently trained teachers of science and industrial subjects in technical schools, and the necessity is increased by the fact that the present teachers as a whole have no share in the supplementary grants made by Parliament to elementary and secondary schools. (*b*) It is clearly desirable that in technical institutions there should be a sufficient staff of teachers with time enough for the preparation of their work and the organization of the laboratory and for keeping up their knowledge of their subject in all its bearings. Principal and heads of departments will naturally need enough time for some teaching as well as administrative work and organization. (*c*) All teachers should receive from competent and adequately paid laboratory assistants as much help as they need. (*d*) Teachers who are suited for undertaking research should have time and facilities placed at their disposal. (*e*) With regard to the qualifications and training of teachers, it is to be noted that in junior technical schools it has been required that a reasonable proportion of the teaching staff should have had professional or practical trade experience of the occupations for which the school furnishes a preparation. It is most necessary that teachers of certain subjects should have had some works experience, which should be renewed under special arrangements from time to time, and, indeed, an increased closeness of relation between teachers and the workshops is much needed on both sides. (*f*) It is no less desirable that teachers in certain subjects, such as engineering and mining, should be allowed to undertake consultative work under reasonable but liberal limitations. (*g*) For teachers in technical institutions, as for all other teachers, short courses of training are certainly needed. (*h*) Lastly, we would note that the provision of an organized staff of competent teachers for technical schools is likely to be facilitated when, as the result of the requirements of the education bill, many teachers who are now confined to evening work will have an opportunity of taking classes in the daytime; for this will mean that the technical institutions will have at their disposal a full-time staff instead of having to rely so largely, as at present, on part-time teachers.

(II) *Coordination between grades of schools and institutions.*—It is desirable that in each educational area there should be effective personal conference between those responsible for arranging the curricula of different types of institutions; such personal intercourse between the heads of the local schools and colleges is essential to secure that students passing from one type of school to another may, on the one hand, find themselves adequately prepared, and may not, on the other, be compelled to lose time by traversing unnecessarily for a second time ground already covered. It will be necessary also to guard against work of a secondary grade, such as preparation for matriculation tests being undertaken by whole-time day colleges.

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(IV) *Length of session.*—A considerable amount of valuable time is at present lost by the traditional practice of closing technical schools about Easter and not reopening them until the autumn. It would be well to require the large institutes, at any rate, to provide some instruction for 40 weeks in each year, and there seems to be no reason why this requirement should not at once be introduced into the regulations of the board of education.

(V) *Buildings and equipment.*—In certain districts the existing accommodation in technical schools (even in some which ought to be "local colleges") is very inadequate and their equipment is unsatisfactory. If the new bill is passed and the system of compulsory continuation classes is established, there is no doubt that new buildings for such classes will ultimately have to be provided. Again, we may reasonably anticipate a great additional development of higher technical instruction as the result of the better preparation of pupils whose school education now ceases at or before 14. This will mean that in the not distant future new institutes will have to be built and many of the existing buildings enlarged and improved.

(VI) *Libraries.*—It is important that provision should be made for securing and maintaining small supplies of the more expensive books on technical subjects for lending to members of the advanced classes. Where the students of a technical school have access to a public library it would be an advantage if the authorities of the school could keep in communication with the selection committee of the library.

(VII) *Representation of industries.*—The trades, industries, and professions which particularly depend upon applied science have, or ought to have, the deepest concern in the organization and development of technical education. It is most essential therefore that the counsel both of employers and of representatives of labor should be available either on the governing bodies or on advisory committees or otherwise. For the larger institutes it would be very desirable to include representatives of the universities, and more particularly of their technological departments.

(VIII) *Pure science.*—It has been stated to us in a memorandum submitted by the Association of Teachers in Technical Institutions that, in their opinion, the amount of instruction in pure science given in technical schools diminished in recent years. Much, however, of the work which was formerly included under the heading of separate science subjects, and appeared as such in the board of education statistics, is now taken in the first year's course of one or other of the industrial subjects, so that the diminution in the amount of instruction in pure science is more apparent than real.

We have further been informed that there is little difficulty in arranging for instruction in pure science in full-time day technical institutions with a course extending over two or three years; but that in certain of the part-time courses difficulties have arisen owing to lack of time, to the insufficient previous knowledge of the students, and to the necessity for showing the immediate practical application of every bit of knowledge gained. For the removal of these defects we must look to the wide extension of education of a secondary grade and to the provision of a system of compulsory continued education, to which we have already referred.

We desire to add that the provision of adequate opportunities for instruction in pure science in technical institutions is of great importance, quite apart from the fact that such instruction is a necessary preliminary to more specialized technical work. It must be remembered that even in large towns the opportunities afforded by technical institutions are often the only opportunities available to a large section of the population for obtaining instruction in science.

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(X) *Junior technical schools.*—Junior technical schools do not at present play a very important part in our educational scheme. There were in 1914 only 49 in the whole of England. Most of these were in London, Lancashire, and Yorkshire; very few had more than 100 pupils. It is only now that Birmingham is making arrangement to open one.

The distinguishing features of these schools are:

(I) The schools are normally planned to provide for the education for two or three years, up to the age of about 16, of pupils leaving the elementary school at the age of 13 or 14.

(II) The parents of pupils have to give a certificate that the pupil is intending to enter into employment for which the school provides preparation. The recognition of a school will not be continued unless, as a rule, the pupils enter into the employment for which the school provides a preparation.

(III) A reasonable proportion of the staff must have had practical trade experience of occupations for which the school prepares.

(IV) Practical work is given a prominent place.

(V) Each course must be organized to cover not less than two and not more than three years.

(VI) No language other than English is approved unless for vocational purposes.

The object of these schools seems to be to bridge over the gap between the elementary schools and the practical work of a skilled trade; to give, in fact, some education to and develop the intelligence of those who might otherwise spend a year or two as errand boys. Instruction is provided in English, mathematics, science (mainly physics and mechanics), technical drawing (including practical geometry), and the use of various kinds of tools, so that when apprenticeship is entered on more rapid progress can be made and a more intelligent craftsman and a better citizen produced. The curriculum is devised for boys passing into the engineering and building, but not into other trades. The few technical schools for girls provide courses in trade dressmaking, laundry work, etc., and are more strictly trade schools.

It has been suggested by the committee appointed by the council of the Northeast Coast Institution of Engineers and Shipbuilders that much greater use should be made of junior technical schools in preapprenticeship education. They consider that junior day technical schools should be established to provide a two or three years' course for boys up to the age of apprenticeship. Prospective shipbuilding and engineering apprentices should be drafted from the ordinary classes of the public elementary schools into these schools for the three years' course.

In considering the future of junior technical schools the first difficulty that confronts us is that of the name. By it is suggested a school leading up to the senior technical schools. So far is this from being the case that the board of education consider that pupils should not be diverted to junior technical schols if they are intended ultimately to pass on to more advanced full-time technical courses. The reason given for this is that it is not possible to provide a curriculum that is suitable both for the boy who is passing directly to industry and for the boy who is to continue his education.

Another point is that the present regulations exclude from the school all boys proceeding to an industry that is not the local industry. This seems unnecessarily to limit the sphere of influence of such schools, especially in the smaller towns.

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It is unlikely that the general education offered by these schools will be satisfactory unless it is inspected by the inspectors who deal with the secondary schools and know what can be done there. In the same way, some of the science work of the secondary schools may gain by the inspectors being familiar with the more practical instruction of the junior technical schools. The present system of water-tight partitions between the two branches of the inspectorate seems to us undesirable.

We think, as we have already said, that there is room in our scheme of education for those between the age of 12 and 16 for schools where no foreign language should be compulsory and where a definite bias should be given toward practical education in connection with science and mathematics, but we see no reason why these schools should not be regarded as part of our secondary system, even when their practical work is organized with a view to the predominant industry of a neighborhod.

We recommend that junior technical schools should be strengthened and developed into such a form of secondary school, retaining some of their distinctive features, e. g., that a reasonable proportion of the staff must have had practical trade experience of occupations for which the school prepared. We must repeat our insistence on the need of making the teaching of English especially efficient where no foreign language is taught. In small towns where there is room for only one secondary school, opportunities for learning one foreign language should be provided.

97. In dealing with the education given in institutions other than elementary and secondary schools, we have endeavored to keep in mind the two functions which such institutions may be called upon to fulfill: (i) The provision of courses of instruction designed to encourage a more intelligent appreciation of the scientific bases of industry in its various forms, and so to promote industrial efficiency; (ii) the provision of part time continued education in the wider sense for those whose full time instruction ceased at 14 or 16. There is reason to think that the need for a wider diffusion of scientific and technical education is not sufficiently realized by many of those engaged in industry. We do not propose to argue the matter on general grounds, but we desire to refer in this connection to the Whitley report on joint standing industrial councils, a report which has been recently adopted by the Government and has an important bearing on the question. In paragraph 16 of this report it is stated that "among the questions with which it is suggested that the national councils should deal or allocate district councils or works committees, the following may be selected for special mention:

(vii) Technical education and training.

(viii) Industrial research and the full utilization of its results.

(ix) The provision of facilities for the full consideration and utilization of inventions and improvements designed by workpeople, and for the adequate safeguarding of the rights of the designers of such improvements.

(x) Improvements of processes, machinery, and organization and appropriate questions relating to management and the examination of industrial experiments, with special reference to cooperation in carrying new ideas into effect, and full consideration of the work-people's point of view in relation to them."

We submit that there can be no intelligent consideration of such matters in the national or district councils or in the works committees, by employers or employed, except on a basis of scientific and technical knowledge. Works' experience is valuable and, indeed, indispensable, but it is not by itself sufficient.

It is not to be expected that all those engaged in an industry, or even all those directly responsible for its management, should have received the training which is essential for scientific advisers and technical experts, but it is idle to suppose that questions concerning industrial research, the utilization of inventions or improvements in processes, machinery, and organization, which may vitally affect the well-being of an industry and the prosperity of those engaged in it, can usefully be discussed in the absence of some degree of scientific and technical knowledge.

If the intention is to bring about a fuller cooperation between employers and employed and to give the employees a voice in the management of industrial concerns, there must be on the part of both employers and employed a more general understanding of industrial problems in their scientific aspects, and this can only be obtained through a more effective system of technical as well as general education.

II.—PROFESSIONAL EDUCATION.

MEDICINE.

98. No profession is more affected by the way natural science is taught in schools than that of medicine; for medical science is directly based on a knowledge of chemistry, physics, and biology. We have, therefore, considered in some detail the steps by which a student enters the medical profession and the educational course he pursues up to the first professional examination, which admits him to the more directly vocational studies of human anatomy and physiology.

99. *Admission examinations.*—It is the business of the General Medical Council, through their education committee, to prepare a list of examining bodies whose examinations fulfill the conditions they have laid down for entrance into the medical profession.

The examinations which the council have accepted may be classed under the following headings: (1) Examinations for university degrees in arts and sciences; (2) examinations accepted by the universities for matriculation in arts, science, and medicine, such as the London matriculation, senior local examinations, etc.; (3) certain other examinations conducted by universities or other approved examining bodies; some of these are of a lower standard than those included in the first two groups.

Thus, roughly speaking, there are two standards for admission—a senior, which is equivalent at least to a university matriculation examination, and a junior, which is considerably lower. About 60 per cent of medical students register on certificates of senior standard and about 40 per cent on junior certificates.

So far as the senior examinations are concerned, they would be a satisfactory test for entrance into the medical profession if one or more natural science subjects were offered by the candidate, and if the teaching of natural science were materially improved in secondary schools.

Our concern is to find some substitute for the junior certificates which will make it certain that the pupil has passed through an educational course in the natural sciences. At present these junior certificates are taken by boys who either left school at about 16 for no very definite cause, or were too lazy or too ignorant to pass the higher examinations, or who, perhaps on account of poverty, do not aim at a university course in medicine.

These certificates demand no evidence of instruction in natural science; they demand no certificate of attendance at any educational course, whether at a secodary school or elsewhere. Trust is placed solely in an examination "which calls for four subjects—English, mathematics, Latin, and an additional language, classical or modern."

Now, it is obvious that any such method of entering the medical profession must suffer from two grave defects. Firstly, there is no guaranty that the candidate for registration has received any instruction in natural science, the bedrock of his future vocation. Secondly, there is no evidence to show that the candidate has gone through a coherent educational course in any of the subjects demanded; he may have been coached by some institution which exists to instruct persons by letter, or by cramming classes, how to pass examinations.

We believe that these defects will be avoided by the adoption of the scheme of a first school examination suitable for students of about 16 years of age. If the proposals we make elsewhere are adopted, they will secure that the pupil has passed through a course of instruction in science before he presents himself for his examination.

100. At present the General Medical Council profess not to register a student unless he takes Latin as one of the subjects in the linguistic group. But they accept for registration the matriculation examinations of the universities of London, Liverpool, Leeds, Sheffield, and Birmingham, although Latin is not a compulsory subject in any of them. Thus, a student at any of these universities may pass on to the highest medical qualifications without showing that he has ever learned a word of Latin. Moreover, a pupil in a grant-earning secondary school where Latin is not taught can enter the medical profession through any of these universities, but not by any other portal.

We consider that, after the door has already been opened in this way, it is too late to attempt to retain Latin as an obligatory subject in the examination for entrance to the medical profession.

The first school certificate should demand a knowledge of English, languages, mathematics, natural science (see sec. 35). Within these divisions the choice of subjects should be free. This will enable otherwise suitable pupils in secondary schools where Latin is not taught to enter the medical profession.

We are strongly of opinion that the first school examination, with the modification we have suggested, should be accepted as evidence of general education sufficient to admit a student to professional instruction, but something more than a simple pass should be required. When a candidate has only obtained a simple pass, we suggest that he should be allowed to enter on the study of medicine by passing the second school examination. The prospective student, who may never have entered for the first school examination, must be offered some such portal to the medical profession. Thus, boys or girls who through accident, laziness, or slow development have failed to reach an adequate standard in the first examination can retrieve their position by passing a higher examination. Exceptional cases—e. g., a boy educated abroad—must be met by special examination.

101. ***The science course and its relation to the first professional examination.***—The first professional examination passed by the medical student after entry at a university or medical school comprises chemistry, physics, and biology. Chemistry and physics are now included in the curricula of the great majority of secondary schools for boys, and in many secondary schools in which boys stay up to the age of 18 opportunities are afforded for comparatively advanced work in these subjects. This fact, together with the growth of technical institutions in no way affiliated to schools of medicine, led the College of Physicians to suggest that some part of this period should be counted as medical study, although it might have been spent at a secondary school or an equivalent institution. The General Medical Council now accept a certain proportion of the time spent in the study of the basic sciences at properly equipped and inspected schools as part of the medical course.

It is necessary for us to consider the bearing of such a policy on the teaching of natural science. The unanimous opinion of the witnesses who came before us was in favor of improving the facilities for instruction in chemistry and physics during the last two years spent in a secondary school. In the opinion of Dr. Norman Moore, who has visited over 70 schools as an inspector for the conjoint board of the Royal College of Physicians and Surgeons, chemistry, physics, and biology should be included in the secondary course taken by pupils intending to enter the medical profession; if a boy left school ignorant of the basic sciences, he could not find sufficient time to learn them thoroughly within the crowded curriculum of a medical student. In his experience as an inspector the quality of the science work and the character of the equipment varied in the different schools, but in the best schools it was excellent. His view was that the teaching and time given to the study of these sciences at the secondary school should be such as to make it unnecessary to devote any part of the time spent at the university or the medical school to the preliminary study of these basic sciences.

This was also emphasized by the lecturer on physiology at the London School of Medicine for Women, who pointed out that many women students crammed up the work for the first professional examination in one year, and had not acquired any real knowledge of chemistry, physics, or biology; moreover, the attempt to pass examinations in this manner placed a considerable strain on women students, particularly on those whose previous training in mathematics and physics had not reached a sufficient level.

Thus we are strongly of opinion that after the conclusion of the general course, physics, chemistry, and some systematic instruction in the nature of plant and animal life should form a serious part of the school curriculum of all candidates for the medical profession. We do not think it advisable that such pupils should be put into a class by themselves, as we believe that it would be possible so to improve the teaching of natural science in the last two years at a secondary school that candidates for the medical profession would enter on their vocational studies vastly better equipped than they are at present.

We are of opinion that boys who have taken physics and chemistry in their first school examination and then pass on to some biological study should carry on physics and chemistry to a still higher standard; we are strongly opposed to their marking time in these subjects. This additional knowledge will be of the greatest value when they enter on the study of physiology. Lack of such knowledge is one of the greatest difficulties to which the medical student and young practitioner are exposed in the higher grades of their professional work.

102. In some schools these preliminary subjects of the medical course are admirably taught. The pupil leaves school at about 18 with a good knowledge of chemistry and physics and sometimes even with a groundwork in biology. Now

the first professional examination usually consists of two groups of subjects (A, physics and chemistry, and B, biology), which may be passed separately. The evidence brought before us exhibits a sharp difference of opinion as to whether the pupil should be allowed to pass any part of this first professional examination before entering a medical school or university. The majority of the witnesses favored such a course. At some universities a medical student, however good his previous education in science may have been, is compelled to spend a year in the elementary study of the basic sciences. Other universities, including Cambridge, now permit a student to enter for the first professional examination, taking some or all of the subjects on beginning his studies. The regius professor of physics at Cambridge informed us that there had been a considerable rise of standard since the change was made. A boy who is aiming at medicine naturally pays special attention to science in his later years at school, and we see no reason why he should not be able to pass, at any rate, in chemistry and physics on entering his university or medical school. He could then settle down quietly to the study of anatomy and physiology without that feeling of hurry and insufficient preparation so often associated with the earlier years of professional study. Some of the teachers in the medical schools are of opinion that a medical bias should be given to the teaching of physics and chemistry from the outset. But such special arrangements would be unnecessary if students came to the medical school with a sound general knowledge of these sciences such as a secondary school should be able to give in its highest forms. With this basis to start from, the universities would be able to give their students, in the first year of medical study and in direct connection with their work in physiology, a more real insight into the numerous special applications of physics and chemistry to physiological problems than is possible at present.

103. *The future supply of medical students.*—So far there is no material difference in the problems connected with the early education of men and women medical students. But the question how to obtain in the future suitable candidates for the medical profession is governed by different conditions in the two sexes, and these must be considered independently.

With regard to the future supply of men students, Sir Donald MacAlister stated that although there would undoubtedly be a shortage in the number of practitioners added to the register in 1918 and 1919, he did not think this would be more than temporary.

It is, however, extremely difficult to discover the present sources of this supply, as far, at any rate, as England is concerned. In Scotland it is common for boys of ability who have passed with credit through a secondary school to enter the medical profession. In England, though their school education would fit them to do so, very few boys enter as medical students from grant-earning secondary schools. * * *

We believe that several causes led to this preponderance of the schools which do not receive a grant. The first is the expense of medical education; however able a boy may be, his parents, if without capital, often prefer to train him for some occupation where he will be securely provided for on graduation. The boy in a grant-earning school, though he might make an excellent practitioner of medicine, has often no one to guide him through the difficulties which surround his entry to the medical profession. If he enters one of the universities with a scholarship, he may turn to medicine as the natural corollary to his biological studies; but he tends to be deterred by the cost and length of the education.

Since war broke out there has been a great influx of women into the medical schools. It does not seem likely that this great rush will be maintained under peace conditions, but all the evidence brought before us shows that the multiplication of posts for women practitioners and the probable further increase of such opportunities will attract a much larger number of women into the profession than before the war.

The vast majority of women students come from the proprietary schools, the schools of the girls' public day school trust, or similar organizations. A number of these are inspected and receive grants. The majority of the prospective students of medicine from these schools enter by taking a matriculation examination or one of the equivalent Oxford and Cambridge examinations. Now the way to some of these schools is open to any girl of sufficient ability to win a county council scholarship, and once a pupil is in one of these secondary schools she can pass in the natural course of education to any profession. But, as a matter of fact, it would appear that in England very few girls who have held a county council scholarship finally pass into medicine. They are repelled by the cost of a medical education which, apart from living expenses, will certainly reach £250. There are many women who would make excellent members of the medical profession, though they can not face the expenses of a medical education. A clever girl who has already shown her ability by passing the examinations in science at her local university may not be able to persuade her parents to go to the further expense of a medical training; they prefer her to begin earning her living at once. * * *

PHARMACY.

104. We are indebted to the Pharmaceutical Society for a memorandum dealing with the course of training for pharmacists.

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The society makes the suggestions—

(*a*) "That in place of the multiplicity of certificates from various examining bodies now recognized as evidence of general education, a State-conducted or State-controlled examination should be instituted for which scholars at secondary schools should present themselves at the age of about 16."

The adoption of the first school examination (see sec. 35) and of the certificate of general education which it will provide would, we consider, meet the society's requirements.

(*b*) "That candidates for the qualifying examination should be required to undergo a systematic course of study in pure and applied science at an institution or institutions properly equipped as regards both teachers and facilities."

With regard to (*b*), we see no reason why the society should not make it a condition of entry for the qualifying examination which they conduct that candidates must have attended schools or institutions approved for the purpose. For those pupils who began their apprenticeship before the age of 18 and without completing a full secondary school course or presenting themselves for the second school examination it will be necessary to arrange that they should receive instruction both in pure and in applied science during and after their appreticeship. There is a very considerable number of technical schools at which suitable courses in pure science are already available, and any deficiency that may exist in particular localities should be brought to the notice of the education authorities concerned. We suggest further that, when intending pharmacists who have passed the first school examination obtain further instruction in the pure sciences by remaining for the period 16–18 at a secondary school, assuming it is suitably staffed and equipped, and pass in these sciences in the second school examination, this should be accepted as satisfactory evidence of the knowledge of these subjects required in the qualifying examination. These pupils would begin their apprenticeship at 18, and would in the course of it obtain the necessary instruction in applied science at approved technical or other institutions providing classes in pharmaceutical subjects. We understand that the number of technical schools providing full-time or part-time instruction in pharmaceutical science could without much difficulty be increased to 20 or more.

ENGINEERING.

105. We now have to consider the character of the secondary school curriculum which will be suitable from 16-18 for boys who intend to become engineers, whether they have a college course in view or not.

As to this there is general agreement among the engineers whom we consulted. It is common ground that up to 16 there should be no differentiation of the curriculum for intending engineers, but that boys of 16–18 who propose to pass on to a college or university course should devote special attention to mathematics, mechanics, mechanical drawing, physics, and to a less degree chemistry. These subjects are regarded as essential to the later work in engineering science which will be done at the college or university, and if the work in them is not carried to a fairly high standard (mathematics, for example, should certainly include the calculus) the student will inevitably be handicapped in his university course. Our witnesses further agree that from 16–18 the education of the future engineer should not be confined to mathematics and science. They lay great stress on the importance of English and the desirability of securing a working knowledge of one or two modern languages.

106. With these suggestions we are in accord. In particular we would emphasize the importance of keeping up the general education of the future engineer. Boys at this stage are naturally and properly attracted by those subjects which appear to them likely to be most useful later; there is the more need for laying stress on the parts of the work which seem to them to stand outside their professional needs. The absorbing nature of the work that lies before a young engineer when he first enters on his profession and the long hours which he may have to spend in workshop or drawing office make it difficult for him to devote much time to general reading. Moreover a liberal education is the more necessary for those who throughout their professional careers will continually be called upon to deal not only with machinery but with men. The last years at school are therefore of more moment for their general education than they are for people in many other walks of life; the greatest care should be taken to use them to advantage. Even from the professional point of view it is essential that English should be cultivated, for an engineer will be frequently called upon to explain to the layman the merits of any proposed undertaking, and it is essential that he should be able to do so in clear and intelligible language. Further, engineering is a world-wide occupation, and an engineer can not afford to neglect the engineering literature of other countries. There are, therefore, very obvious advantages in keeping up the study of modern languages at school.

107. We would further point out that the broad foundations in mathematics and science on which later professional training must be based can best be laid during the years 16–18. A secondary school course which in the supposed interests of technical and vocational study neglects these foundations in order to find room for the more specialized training which it is the proper function of the engineering college to provide, may be positively detrimental to the best interests of the pupils. As things are, the universities are compelled to provide first-year courses in mathematics and science, owing to the insufficient preparation of many of the students who enter from schools, with the result that time available for engineering science proper is unduly restricted.

We do not think that it is necessary or even desirable to separate engineering boys for all their work from the rest of the senior boys who are specializing in science with other aims in view. Some modifications of their curriculum will be desirable, e. g., more time for mechanical drawing and a somewhat different kind of work in mechanics; but the common ground is wide, and the boys could be taught together in most of their subjects with great advantage. The work in engineering forms tends to be narrow and empirical; in advanced science forms it is often too abstract and theoretical; each kind of teaching would gain by contact with the other.

108. The question is often asked whether it is necessary or desirable to include workshop instruction for future engineers at secondary schools. The matter is one of great importance to school governors responsible for providing the necessary buildings and equipment. In the questionnaire which we addressed to schools on the head masters' conference we inquired specifically what special facilities were available for boys who intended to take up engineering. The answers showed that only a very small number of schools have fully equipped workshops with machine tools; a larger number, perhaps a quarter of those who replied, provide facilities for metal work as a part of the manual instruction which is not restricted to engineering boys. In some schools part or all of this practical work is done out of school hours. Where there are no engineering workshops there is often some modification of the curriculum in science and mathematics—e. g., the inclusion of mechanical drawing and graphic statics such as we have recommended in the preceding paragraph. Some schools disapprove in principle of providing workshop instruction specially for future engineers, and quote the opinion of the Institution of Civil Engineers and of the Society of Engineers in support of their attitude. Several of the leaders of the engineering profession whom we consulted hold the same view. * * *

We think this answer goes to the root of the matter. We do not consider that workshop practice is required in the special interest of engineering education at the school stage; the demand for it does not come from the engineering profession. Certainly time should not be given to it at the expense of subjects such as mathematics, mechanics, physics, and chemistry, which are fundamental for the engineer. We are, however, strongly impressed by the importance of manual instruction as a school subject. Provision for more advanced instruction may well be made, and without conceding all that has been claimed for manual instruction by its advocates, we think its possibilities have been too little explored in many of our leading schools.

109. When boys leave school at about 18 to go into works, usually as premium pupils, the course which we have sketched out may want some modification. It would be a temporary advantage to such a boy at the beginning of his work in the shops to have had more practice in handwork than is necessary for others, and he should use whatever facilities and whatever time the school can give him to acquire this experience. It must be remembered, however, that the great defect of the pupil system in engineering works is that as a rule no one is responsible for the necessary theoretical training; it is often left to chance; a sound foundation at school is therefore of the utmost importance.

SCIENCE IN RELATION TO AGRICULTURE.

110. We have thought it convenient to deal in this section with the position of of science in the education and training of those who are to take part in or direct agricultural pursuits or industries of all grades. We have been much assisted in reaching conclusions in this matter by replies which were furnished to questions addressed by us to heads of agricultural colleges, professors of agri-

culture, and other persons who have had a wide experience in the administration of agricultural education, and we are much indebted to them for their assistance. (See Appendix D.)

Before proceeding to our immediate subject, it may perhaps be well to review the classes of the community for whom our agricultural educational system must be designated. These are—

(1) The sons of landowners who will in their turn own considerable estates and may desire to take a much more active and informed part in their management than has been customary of recent years.

(2) The sons of large farmers, who intend to follow farming as a profession and will have a reasonable amount of capital at command.

(3) Students who intend to become land agents, who will be required to direct large estates and sometimes to manage considerable farming enterprises.

(4) Students who intend to become teachers in the agricultural colleges, officials connected with agriculture, scientific experts and advisers either at home or abroad.

(5) Sons of small farmers occupying from 50 to 300 acres who expect to take up similar businesses.

(6) Small holders, farm bailiffs, and farm laborers, who will start life with no particular capital at their disposal, and who will at least begin by working directly upon the land.

The first four classes will as a rule pass through the ordinary public or secondary school and then proceed either to the university or to an agricultural college of corresponding rank, receiving as a rule some further professional training before they embark upon their career. The fifth group, the smaller farmers' sons, may expect to receive their education in the country grammar schools, followed by a technical training at one of the farm institutes. The last class will receive an education at the elementary schools and at the continuation schools, which we confidently hope will become a necessary part of the national system of education in the near future.

In making this rough classification we do not for a moment wish to put out of sight the necessity of establishing the educational ladder whereby a boy of parts may obtain his opportunity, from whatever rank of society he starts. We must, however, lay stress on the fact that as agriculture is a business which can not be embarked upon without capital, much less use can be made of the educational ladder in farming than in many other professions. The brilliant boy who is picked out from the elementary school and eventually reaches the university or the agricultural college has, with the present organization of British agriculture, but little opportunity of taking part himself in farming or the management of land; almost his only outlet lies in teaching or in official or expert work. It is more important therefore to make each stage in agricultural education really preparatory to the normal vocation of those passing through it, than to adjust them all as successive steps toward the highest form of education.

111. Seven of the agricultural colleges, of which there are 13 in England and Wales (2 suspended because of the war) and 3 in Scotland, give a three or four-year course of instruction leading to a degree at one or other of the universities with which they are affiliated. The Universities of Durham, London, Wales, Manchester, Leeds grant a B.Sc. degree in agriculture; at Oxford and Cambridge a student can only obtain a diploma in agriculture, which counts for some portion of a pass degree. These degree courses agree in requiring a preliminary examination in pure science, generally taken at the end of the

first year's study and not greatly differing from the preliminary scientific examination required from medical students. The course embraces the elements of inorganic and organic chemistry, in botany a general outline of morphology and physiology, in zoology a similar descriptive sketch of the animal kingdom with special reference to certain orders of importance in agriculture. At most of the colleges these subjects are taught in the laboratory as well as the lecture room, though the examination may not include any practical tests. Certain other sciences are generally taught in the first year's course—e. g., geology, some physics and mechanics, though they may not be included in the examination syllabus. Though these courses are so slightly specialized, and are to such a large degree identical with the courses in pure science followed by students for the preliminary stages of the medical or scientific degrees, it has been found desirable, where the school is large enough, to provide separate instruction for the agricultural student. Apart from the agricultural bias by way of selection and illustration that may be given to the most elementary and general course—e. g., in chemistry—it has been found by experience that the agricultural student did not flourish as one of a small minority in a general course of science. Very often his preliminary preparation for the study of science had been even more scanty than that of his fellows, science to him was difficult and against the grain because as yet he had little feeling for the relation it bore to his real subject of agriculture. It has been said that all pure science is alike at this stage in education and that the future doctors or engineers or farmers can, under existing conditions, all share in one unspecialized course. A university course, however, does become specialized, in chemistry for the future chemist, in botany for the future botanist, because the teacher in pure science follows his own bent and gives a professional type of instruction, designated to train men of science. For example, the chemist finds the valency of nitrogen more interesting than the part the element plays in the nutrition of the plant, but the student of agriculture rarely possesses the detachment of mind or the disinterested love of learning that permits of much attention to such questions. Hence it has been found, if only as a matter of self-interest, that in its efforts to enforce a reasonable standard of knowledge in pure science the agricultural department of a university needs to appoint its own teachers for the elementary pure science required for the preliminary degree examination. Doubtless this necessity would not arise if the university or the agricultural college were able to count upon a reasonable knowledge of science on the part of the students when they enter. But the course of instruction at an agricultural college has at present to be based on the hypothesis of complete ignorance of all the sciences on the part of its entering students; the greater part of the first year has to be spent in hurriedly putting the student through these rudiments, which have often to be selected and peptonized to an uneducational degree because of the limitations of time. Nor does the evil end with the first year; the student is always being hampered by his hasty and ad hoc instruction in pure science. For example, he is as a rule called upon to carry out certain analyses of fertilizers, etc., in his final course; very rarely are these more than pieces of unintelligent routine, because time has not allowed him to pass through the appropriate preliminary drill in quantitative chemical work.

Lack of school training in science causes not merely a loss of time at the university or agricultural college in acquiring the elementary instead of the special training appropriate to that stage of education, but it induces a certain stiffness of mind and slowness of apprehension that is a great handicap to the technical student approaching science for the first time. Elementary chemical facts and conceptions that are easily absorbed at the age of 14 or 15 become real difficulties at 18 or 19 to the same type of student intent on agriculture.

It is often said by university teachers that they prefer students who have learned no science at school. This probably means no more than that they prefer the boy of all-round ability who for that very reason has remained on the classical side at school to the sort of boy who gets drafted across to science; for the type of boy intended for practical life the absence of a school training in the elements of science means a definite loss of time and opportunity in his technical training.

112. This is perhaps hardly the place to discuss in any detail the curriculum for an agricultural degree. The difficulties lie in the number of sciences with which agriculture is in contact and the temptation upon the body framing the course is to insist on some acquaintance with each of these sciences. Chemistry, botany, geology, bacteriology, entomology, meteorology, and many others find each their applications in agriculture; each again possesses teachers insistent on their rights to a share in the agricultural student before he can be regarded as qualified. The danger would be less if the subsequent examination were not conducted from the specialist point of view. The result is that too many of the degree courses in agriculture are overloaded with science and with sciences the value of which in the educational scheme has never been weighed, to the comparative neglect of agriculture itself and particularly of its economical and quantitative sides. For it must always be remembered that the agricultural course ending in a degree though mainly occupied with science subjects, does not produce men of science for the service of agriculture. The young man who has only learned his chemistry as an agricultural student is not fitly prepared for the career of teacher of agricultural chemistry, expert adviser or analyst, because he has not been properly grounded in pure science. The future teacher or expert should graduate in a school of pure science and acquire his agricultural special knowledge as a postgraduate and research student. From the point of view therefore both of the farmer and the expert, the current degree courses in agriculture might well be revised with a view to shedding a good deal of matter which is of interest only to the professional student of science and thus leaving room for more instruction on the economic, historical, and social aspects of agriculture.

In the foregoing discussion attention has been concentrated upon the degree course, but the number of the students in agricultural colleges attempting the degree course is always small in comparison with those who take instead a more limited course, generally of two years' duration, leading to a diploma or a certificate. This course is similar to the degree course as regards the agricultural instruction, but is weaker on the scientific side, especially as regards the preliminary introduction to pure science. In fact it is not unfair to describe the diploma or certificate courses as degree courses watered down to meet the weakness of students coming to the college without a preliminary acquaintance with science and insufficiently persuaded of the value of a technical training to pursue it with due thoroughness. Under present conditions these courses must be regarded as necessary. Even this limited course is not completed by the majority of the students, who content themselves with some portion of it and leave without obtaining any qualification. This result must in the main be set down to the insufficient education, especially on the scientific side, of the students before entry. They think they have come to learn agriculture only; from the want of any preliminary acquaintance with the matter they are daunted by the scientific subjects; they demand to be taught the results without undergoing the training which is needed to make the results vital. Those responsible for education in the agricultural colleges are engaged in a constant struggle against their students' demand for short cuts to knowledge.

113. The agricultural college or university department of agriculture can at best provide for the education of a minority of the future occupiers of land—the landowners and their agents, the large farmers, the teachers, and experts; the bulk require a training that is less ambitious and that runs less risk of divorcing the recipient from the soil. It is the function of the farm institutes to provide this training for the sons of the smaller farmers, bailiffs, etc. The farm institute is a comparatively recent conception in English education and it can not be said to have crystallized as yet into a definite type. Two forms exist, one of which may be described as a farm school, the other as a winter school of agriculture. The farm school takes whole time residential students, generally about the age of 16, for a year's course, partly spent in the classroom, partly in manual work upon the farm. It is a mixture of apprenticeship and education, and the time allowed is too short for either. The classroom teaching is greatly handicapped by the general lack of previous scientific instruction in the pupils, as also by the want of educational outlook on the part of the teachers, so that the course often represents an attempt to compress the whole college course within the narrower limits of time. But whatever these faults of conception, such farm schools do make for enlightenment in their own district; they may teach often the wrong sort of things and teach them badly, but they do introduce their boys to the applications of thought and intelligence to their industrial life, they induce the feeling that knowledge exists and can be put into practice, they provide indeed stimulus at an impressionable age. From the educational point of view the winter school of agriculture is the preferable organization. This provides a course of instruction lasting for 10 to 16 weeks during the winter at some center with residential facilities for young men of the age of 18 or upward, who come from the farm at the slack season of the year and go back to it in due course. The course of instruction, however practical, can omit much of the information about processes generally regarded as necessary and everything in the nature of manual teaching; the pupils come off the farm and are already acquainted with its routine. The instruction can concentrate on the scientific and economical principles on which the practice hangs. When fully organized a winter school should have two or three courses succeeding to one another and making up a whole, and the student who had qualified by attendance in three successive winters should be entitled to some sort of diploma.

At this early stage in their development it is difficult to say anything of the scientific training that should be preliminary to the winter schools. They will be receiving pupils who have either been to a country grammar school or secondary school, or often only to an elementary or a private school. In the future it may be hoped that the bulk of their pupils will have passed through three or four years of continuation school training, and will have acquired a basis of knowledge of chemistry and botany. Until there is this basis, farm institute teaching besides losing time in endeavors to repair the omission, must always remain unsound; many mysteries will be pronounced upon with authority and accepted with faith, many blessed words will hide the lack of knowledge; both learners and teachers will lack the spirit of criticism and inquiry.

114. We may now proceed to consider what science should be taught in secondary schools to boys who intend to proceed to a university or an agri-

cultural college, to boys in fact who belong to the first four of the categories indicated above. All our informants take the view in which we agree that agriculture or agricultural science should not form part of a secondary school course. All emphasize the point that the best preparation for an agricultural course at an institution of university rank is a good general education up to the age of 16, and they desire as an essential part of this education a generalized acquaintance with the whole field of the physical and natural sciences.

While we agree with this view we feel it necessary, in the light of the evidence that we have received, to make it clear that even this generalized acquaintance with science must be made subservient to and built upon a sound foundation in English and mathematics. Students intending to proceed to agricultural colleges, who remain at secondary schools until 18 or so, should continue a general science course rather than specialize in agriculture. The biological sciences treated from the physiological side should be added to chemistry and physics, and the general education the boys are continuing might well include some introduction, by way of stimulus, to such subjects as economics and industrial history. Particularly at the public schools, through which are passing the future landowners of the country, is this introduction important. It is necessary to kindle the boy's mind to an appreciation of the responsibilities and the opportunities attached to the ownership of land, and this can be well and educationally done by somewhat informal courses dealing with such questions as the development of the English land system and the history of the English agricultural community. In these courses the aim should be stimulus rather than instruction.

The teachers of science in the secondary schools might, however, well be reminded to keep agriculture in view in their treatment of the pure sciences. For example, the facts that nitrogen compounds are essential to vegetable growth, and that plants build up proteins and the other complex compounds of nitrogen from nitrates and ammonia, are just as germane in an account of nitrogen as the part which that element plays in the constitution of explosives, though the latter only will usually be found in the textbooks. Again, the provision in the school grounds of a few plats showing the specific action of fertilizers containing nitrogen, phosphoric acid, and potash may be considered as part of the essential experimental equipment of a chemistry course, to be regarded not as a lesson in manuring, but as a demonstration of pure science. Similarly there are many outdoor experiments with seeds, plants, and trees which should be treated as normal botany, apart from their bearings upon horticulture or farming.

The boy who intends to become a farmer or to follow one of the professions connected with agriculture should be encouraged to gain some practical experience by spending his summer holidays at work upon a farm.

For boys included in our fifth category, who intend to become working farmers, a normal secondary school course up to 16 forms the best preparation for that attendance at a course at the farm institute or winter school of agriculture, which should constitute the technical training they will require. There is nothing to differentiate in kind between the secondary school course required by such students and that which we have indicated as suitable to the boy who intends to proceed to the university. The secondary school course should not attempt to include agriculture or agricultural sciences, but should provide a sound groundwork of physics, chemistry, and physiological botany, with of course mathematics and English. Whether such a student should proceed straight to the farm institute from the secondary school or go back for a time to his father's farm is a matter upon which no hard and fast rule can be laid down, but an early acquaintance with the routine work of a farm and an actual apprenticeship to its chief manual operations are of the utmost importance.

115. We have given some consideration to the question whether a secondary school with a rural bias is likely to perform useful work either as an alternative to a farm institute or in preparation for it. We think there may be a place for insitutions of this kind if they are carefully organized and are established where conditions are favorable. Only in a few districts are the majority of the pupils at even a country secondary school going back to the land, so that the whole trend of the institution can not be directed to the end of training farmers. Such schools can not be satisfactory alternatives to a farm institute, though they may form a good preparation for it. It is of very little use to create an agricultural side in such a school and to segregate at the top of the school a certain group of boys who are occupied with definitely agricultural subjects. Unless the whole bias of the school in its upper stages can be made rural, it will be better for country grammar schools to aim at giving their boys a good general education in common. Fair success does seem to have been attained by a few of the rural secondary schools which have attempted this form of education, but this appears in the main to have been due to the enthusiasm of the headmaster and to his power of directing the interest and intelligence of his pupils toward rural life, rather than to the practical benefits of the actual instruction given. The chief difficulty about such schools will always be to find a headmaster who combines the necessary experience in teaching and organization with such an appreciation of the work of the farm as will show him what matters of agricultural experience and routine can, educationally considered, be included within the school course. It is not necessary that the headmaster should himself have any experience of the practical working of a farm, but he must have a sufficient sympathy with its methods and objects to be able to steer between purely academic instruction and the giving of practical tips or scraps of agricultural information.

116. The education of the farmer, however good the secondary school may be, will be seriously deficient until there is a well-equipped and well-attended farm institute in each considerable agricultural center. The setting up of these institutes has been urged by the board of agriculture for some years, and it is full time that rapid progress were made in developing them.

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It is to the provisions of the education bill with regard to continuation schooling that we look for the improvement of the education and outlook of the future farm laborer or small holder. We are aware of the special difficulties in rural districts of organizing classes which are to cover as much as 320 hours in each of the four years from 14 to 18, but we believe that these difficulties can gradually be overcome, and that nothing would tend more to make country life what it should be than their successful solution. The provision of good teachers will be a difficulty which will be felt everywhere and especially in the country. Money will be well spent both by the State and the local authorities in providing facilities for their training.

The question has often been raised whether instruction in rural subjects ought not to be more generally included in the curriculum of the training colleges. The main difficulty lies in the fact that most of the students at the training colleges are not expecting to take service in the country schools, and that such a course would only be wanted by a minority. Better results would be attained by a system of studentships whereby the younger teachers already established in the country schools could go for a time to the agricultural departments of the universities for courses specially organized for their benefit. This system should hold both for teachers in the elementary and the continuation schools in country districts.

117. The course of instruction in the continuation school in rural districts should not aim at agriculture nor attempt to anticipate the technical instruction of the winter schools of agriculture. Its aim should be to keep the boy's mind growing, so that he may become interested in and receptive of the opportunities for special training that will come later. Rural subjects should be used as means of education, not as ends in themselves. We may instance as valuable subjects when treated in this spirit—

(1) Mensuration and applied arithmetic leading up to the taking out of quantities; land measurement with a chain; leveling for drainage operations.

(2) The elements of chemistry and botany.

(3) The elements of animal physiology and hygiene as bearing upon the feeding and care of live stock.

(4) Elementary mechanical principles as illustrated in machines.

Direct instruction in crafts like hedging, dairy work, etc., finds no place in such a course, though the gardening instruction given in the elementary school may be continued.

The elementary school.—It is generally agreed that no direct teaching of agriculture should be attempted at this stage. The elementary science of plants and animals that may be labeled as nature study should, however, be taught in every rural elementary school. Every rural school should have a garden large enough to provide a plat for every child or pair of children in their last year at school. The school garden provides useful educational training, and a knowledge of gardening is necessary to every man who is going to live in the country, whether as farm servant, railway porter, or shop assistant and very useful to the women who become their wives.

THE CHEMICAL INDUSTRIES.

118. It did not seem to us to be possible to institute inquiries as to the sufficiency of the training provided by schools and technical institutions for the special needs of all the various industries which depend on a knowledge of science. But in view of recent developments in applied chemistry we invited a number of chemical manufacturers to reply to the questions set forth in the appendix. We also consulted witnesses, selected by the conjoint board of scientific societies as able to speak with authority as to the scientific professions, to give us their opinion on the present condition of the teaching of chemistry in schools and universities, and to make suggestions for reform.

Sixteen firms, including some of the largest in the country and representing the main subdivisions of the industry, sent valuable replies. It was very satisfactory to find that in a large number of answers special stress is laid on the value of general chemical education rather than on the possession of detailed knowledge of the particular processes of the factory. "The increasing subdivision of the industry and the rapid development taking place in all the branches "reduce the value of the mere acquisition of knowledge but increase the value of the personal qualities of judgment, accuracy, understanding, and insight." The opposite view was formerly very common, and it is not extinct; thus the opinion is expressed that "previous chemical training, though indispensable, is of too general a character to be of much commercial value"; and, again, that "men ought to be trained specially for this line of business"; apparently the beginner is not to be allowed to go into the water until he has learned to swim.

But the prevailing opinion is that special training is best given at the works and that the time needed before a man becomes of use to his employer will be shortened by thorough general chemical training. The employees in chemical works who receive any systematic training in chemistry may be classified as (a) junior assistants, (b) works chemists and analysts, (c) research chemists, (d) works managers. Junior assistants are recruited from the technical schools and to a small extent from secondary schools; the technical colleges provide a supply of process chemists and analysts which was adequate before the war; the research chemists get their early training as a rule at a university or local college, and a course of physics and chemistry which leads up to research work, even of a modest type, is said to fit them for their duties. But the evidence seems to show that the duties which some of our correspondents have in mind are of a restricted kind and that a greater development of the research side of chemical industry than they contemplate is needed. The real difficulty is to get competent works managers with enough knowledge of science, enough appreciation of the point of view of the engineer, and enough power of thinking quantitatively on questions of energy. Our correspondents do not make many definite suggestions for the education of such men before they enter the works, except to recommend training in drawing, and the establishment of laboratories at the technical colleges where processes can be conducted with appliances more like those of the factory than those of the ordinary laboratory. The science work of a secondary school boy who means to proceed to a university or technical college with a view to entering the chemical industry need not differ from that of the boys who make the physical sciences their chief subject; but instruction in technical drawing would be of special value to him.

Continued education of employees.—In almost all the works some facilities are given for attending evening classes, and sometimes attendance is a condition of employment up to the age of 17 or even 19; but there is evidently room for much more cooperation between the works and the technical schools of the district.

ARMY AND NAVY.

119. *Science and military education.*—The normal avenues to commissioned rank in the army are through the Royal Military College, Sandhurst, for cavalry, infantry, and the Indian Army; through the Royal Military Academy, Woolwich, for royal artillery and royal engineers. The competitive examinations for Sandhurst and Woolwich are held concurrently. The age limit for the former was 17–19; for the latter, 16½–18½. The length of the course at Woolwich and Sandhurst has varied from time to time, but the ideal—seldom attained in the case of Sandhurst—has been a course of two years. The obligatory subjects for Woolwich are English, history, and geography, French or German, mathematics I and II, science. In each of the obligatory subjects a qualifying minimum mark of 33 per cent must be obtained. One more subject may be selected from mathematics III, German or French, Latin, Greek; freehand drawing may also be taken. For Sandhurst the obligatory subjects, also with a qualifying minimum, are English, history, and geography, French or German, elementary mathematics; any two of the other Woolwich subjects may be taken. By science is meant physics and chemistry, but it is noticeable that the minimum qualifying mark may be gained by knowledge of one of these subjects. Though much of course depends on the skill with which papers are set, we have no definite criticism to make as to the subjects for Woolwich—they may be regarded as forming a sound school education for boys with a

bent toward science and mathematics. It is hoped, however, that changes will be made in the type of science papers to bring them into harmony with the general course in this subject that we have elsewhere suggested.

120. At present an officer passing through Sandhurst may have had no instruction whatever in science before he enters. He will receive no science teaching while there or after leaving. It is hard to see the justification for intrusting the lives and welfare of men to officers who have had no opportunity of getting a secure hold of the knowledge of the simpler laws that govern weather, food, personal hygiene, the applications of electricity and optics and innumerable other factors that affect the daily life and work of a soldier. Yet it was stated to us by a witness speaking on behalf of the General Staff that "hitherto the General Staff had been of opinion that infantry officers did not require to have a knowledge of science. The General Staff had to think of the good of the service as a whole, and their view had been that the military efficiency of the officers had not suffered from lack of science. It was impossible to say what the view of the General Staff would be after the war." A knowledge of science seems to us to be so necessary for an officer that we consider that it is essential that it should be transferred from the optional to the obligatory subjects for Sandhurst. As a corollary to this change, time should be found in a course lasting from one and one-half to two years to carry on the education of the cadets in this subject. It is no less urgent that officers of all ranks should have a keen appreciation of the scientific problems involved in methods of modern warfare by land or air and their relation to one another.

At Woolwich, though science is a compulsory part of the course and adequate time seems to be given to it, the results are disappointing, especially in view of the ability of the successful candidates. It seems a pity that greater efforts are not made to give science a more important place in the course. The equipment is inferior to that of Dartmouth and the system by which the chief instructor, who is a military officer, holds this appointment only for a short time does not make for continuity, and renders it difficult for him to observe the effects of the changes he may have introduced. In fact it seems, in spite of some obvious advantages, to sacrifice educational efficiency to less important considerations.

For many years a large number of the ablest boys in the public schools have passed into Woolwich, and very few have secured a cadetship at all without possessing some ability or an unusual capacity for hard work; but owing to the absence of any attempt to make graded subdivisions in science among the cadets who enter together, due no doubt to insufficient accommodation and staff, the best are often retarded, the weaker are dragged along, to the detriment of both.

It is evident that cadets who possess high scientific abilities are not given sufficient opportunities for developing them at Woolwich and, when they leave, little encouragement is given them to improve their scientific qualifications for the benefit of the country. We were told by a witness: "Practically all the abler cadets got into the engineers, but, broadly speaking, the fact that a man had high scientific abilities gave him no advantages in his military career. Such men were allowed to apply for the ordinary billets that were available for engineer officers, with the result that they did not pursue their scientific studies."

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122. *Science and naval education.*—The committee had the advantage of hearing expert evidence on the education given at Osborne and Dartmouth.

In both these colleges great attention is paid to science, and though English subjects and a modern language are taught, it is on the teaching of science and mathematics and engineering that most stress is laid. At present science is not one of the subjects for the entrance examination for Osborne. We hope that it will be included on the lines suggested by us for entrance to public schools.

From the evidence it appears that the cadets make very satisfactory progress and take their work more seriously than boys of the same age at the public schools. This is to be ascribed to the fact that from the first the boy knows that all his work seems part of and counts toward his professional career; to the possibility of dropping a boy whose progress is considered unsatisfactory, and thus closing his career in the Navy; to the salaries offered that attract to the college specially efficient masters, and to the teaching of science and mathematics being kept in close touch with practical applications. The cadets are so prepared as to have their knowledge at their finger-ends—to be able to make a practical use of it rather than to carry it forward on theoretical lines. The generous expenditure on laboratories of all kinds contributes something to the result, but makes these schools less valuable as examples of method for others. The aims are more uniform and much more definite than those of a public school. There can consequently be more concentration on the subjects which are considered to be of special value for naval purposes.

The higher training of selected naval officers is carried out at the Royal Naval College, Greenwich, followed by courses at other special schools; but the weakness, perhaps inevitable, of this arrangement is the long gap that elapses between leaving Dartmouth and entering Greenwich.

123. *Scientific research for the services.*—The experience of the war must surely have taught us that the scientific problems suggested by the needs of the services are so important and so complex that a special permanent organization is needed to deal with them. Whether this need can best be met by developing existing establishments or by setting up a new institution to be shared by the Army, the Navy, and the Air Service it is not for us to determine; but we are convinced of the urgent need of such an organization. An establishment of this kind would afford ample scope for those officers of talent who show special aptitude for research and whose scientific ability might otherwise be allowed to run to waste. In the direction and control of its work officers of naval or military training and experience should be associated with men of high scientific standing who had proved their activity and initiative in scientific or industrial research not necessarily related to the applications of science in warfare.

On the subject of the relation of science training to home and India civil service, the committee made the following recommendations:

1. That all candidates for the competition examination for these services should supply evidence for continuous course of training in science extending over several years (secs. 125–128).

2. That to insure sufficient catholicity in questions propounded in the viva voce examination, these examiners should include some representative of science (sec. 127).

3. That the age limits of the India civil service and the university entrance scholarship examinations should coincide so far as possible (sec. 129).

4. That if science be not required, as urged in recommendations for the India civil service, it be a necessary supplementary subject to either the classics or the modern languages as the main subject (sec. 129).

5. That many permanent posts can best be filled by men selected not by the ordinary competition examination, but at a riper age on the ground of high scientific qualifications and professional experience (sec. 128).

6. That an inquiry should be made as to the best methods of securing the services of scientific men for the purposes of the State in permanent posts and otherwise, such as certain of those in the Home Office, the Board of Agriculture, the Post Office, the Government Laboratory, the natural history department of the British Museum, the Geological Survey, the Science Museum, the Meteorological Office, the Royal observatories, and the Patent Office (sec. 131).

III.—UNIVERSITY EDUCATION.

INTRODUCTION.

132. It can not be necessary to lay stress on the enormous importance of the contribution to education that is and should be made by the universities. The teaching in the schools must be barren unless there is passing from the universities to the schools a fertilizing stream of teachers. The outlook of the schools must be narrow unless the universities are setting before them ideals of accuracy in knowledge and enterprise in discovery. Territory can never be won from ignorance unless there are working at the universities, the true homes of research, many who can inspire enthusiasm as teachers, many who can themselves do pioneer work as explorers and some even who, like Browning's grammarian "with a great end to pursue, die ere they know it."

We hope that when our suggestions as to secondary education have been carried out the universities will be freed from most of the elementary teaching that has up to now tended to distract their attention from their proper province.

In this part of our report we propose to confine ourselves to those university questions which are specifically concerned with the teaching or study of science; we did not consider that under our terms of reference we were expected to deal with the wider questions of university government and finance.

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We addressed to the universities of England, Scotland, and Wales a questionnaire on the subjects which seemed to us of special importance and interest in connection with the study of science at the universities, and we are greatly indebted to the authorities of these universities for the full and careful answers they made to the questions and for the assistance they have given us.

As a royal commission has been appointed to consider university education in Wales, we have not thought it necessary to deal separately with the position of science in the University of Wales.

ADMISSION TO THE UNIVERSITIES.

133. Nearly all the universities hold examinations to test the fitness of candidates to enter on the courses of academic study which they provide. Most of these examinations test the general education of the candidate, rather than his

particular fitness for the work which he wishes to undertake. It is becoming more and more common for a university to accept as alternative to a part or the whole of its own tests the corresponding examinations of other universities and other examinations such as the Oxford and Cambridge school examinations taken in secondary schools; sometimes the number of such alternatives is very large (at Oxford there are nearly 50 alternatives to responsions), but there is little system in the arrangements, and, as we have already pointed out, the want of system is distracting both to the candidates and to the schools which educate them. We have welcomed the proposals for the first school examination because it adapts itself to the general education given in the schools. The attainment of a sufficient standard in this examination would provide a guaranty that the student has carried his general education far enough to profit by a university course.

In our opinion the universities should adopt such an examination as the normal test for entrance with such limitations or amplifications as they may find necessary, retaining the power of admitting after special examination or other test those candidates who may not have passed through a normal course of education. We recommend that except for such candidates special matriculation examinations, including responsions and the previous examination, should be abolished.

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COMPULSORY GREEK AT OXFORD AND CAMBRIDGE.

134. All the witnesses we have examined who have expressed any opinion on the subject have been unanimous in condemning the retention of Greek as a necessary subject for a degree at Oxford and Cambridge, and with this condemnation we are fully in accord. We consider that the requirement of a compulsory minimum knowledge of this language serves the interests of neither letters nor science, that it is a real and irritating hindrance to the study of science at these universities, and that it should be removed at the earliest possible moment. If a classical language is required, we think Greek should be an alternative to Latin.

As a rule after obtaining an entrance scholarship in science at one of the colleges of Oxford or Cambridge, a boy begins to cram enough Greek to enable him to pass responsions or the previous examination. The last term at school before entering the university ought, if wisely employed, to play an important part in a boy's intellectual development, for he then has the time to widen his outlook by independent thought and study, and thus correct some of the limitations of his reading which are almost inevitable in the time during which he has to prepare for a scholarship competition. This opportunity is, however, nullified if he has to take up the superficial study of Greek and to revert to work of a lower standard and more elementary grade than any that he has touched during the later years of his school life. The process by which he hastily gets up this knowledge may exercise the memory, but by no stretch of the imagination can it be conceived to train him in literature or in any other way to educate his mind. Even greater harm is done to a boy who though not up to scholarship standard is perfectly capable of making good use of the opportunities for the study of science at the university.

We are keenly alive to the necessity for developing the literary training of the student of science. This object is certainly not attained by causing him to learn by heart a translation of a set book and a portion of Greek grammar.

ADMISSION OF OVER-AGE CANDIDATES.

135. It happens not infrequently that in consequence of some change of plans candidates wish to enter a university long after they have left school, perhaps

after a period of occupation in some kind of technical work. It seems unreasonable to expect such candidates to show the same knowledge of the subjects of a secondary school course as may fairly be required of schoolboys. We therefore recommend that the universities should not require them to pass the ordinary matriculation examination, but should make special arrangements to test their fitness to enter on university work. We have ascertained that most of the universities would favor such a change. The number is not likely to be so large that a special test of each individual candidate would present serious difficulties. It would, however, be desirable to limit this exceptional mode of admission to candidates over 23 years of age.

ENTRANCE SCHOLARSHIPS AT THE UNIVERSITIES.

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136. At the outset we think it desirable to lay down two general principles which should in our opinion govern the award of scholarships; firstly, scholarships should be definitely associated with the idea of distinction conferred in recognition of intellectual merit and promise; secondly, they should be of a nominal value (say £20), to be supplemented if and so far as scholars require further assistance.

137. From the evidence before us we are convinced that there is need even now for larger expenditure on scholarships, and that this need will be greater in the future as the waste of talent due to imperfections in the present system of education is diminished. In this connection we would draw attention to the evidence of Prof. Farmer, who stated that "the national value of the royal scholarships was admitted by all who were conversant with the facts," and added that "if more scholarships were available a largely increased supply of qualified students would be obtainable from secondary and evening schools. At present there was a wastage of brain power due to insufficient scholarship provision. There was no difficulty whatever in finding employment for those who passed through the Imperial College. The demand was greater than the supply."

That there is need for further financial help is, in our opinion, especially true as regards students of science, particularly in the modern universities, and for students not resident in the university towns. The need in the modern universities is not due to there being fewer scholarships available for students of science than for students of other subjects, but to an absolute deficiency of scholarships in all subjects. The special need of scholarships for women has been referred to elsewhere in this report.

We are all well aware that some students to whom science scholarships have been awarded have failed by their subsequent performance to justify the award. We do not think that this can be taken as evidence of a deficiency of students of scholarship caliber in secondary and elementary schools. It arises from a variety of causes which we have dealt with elsewhere, and which result in many of the ablest boys never presenting themselves for the scholarship competition. Until these causes are removed, the problem of securing an increased supply of science students at the universities can not be solved merely by adding to the number and value of the scholarships available for students proceeding from secondary and technical schools to the universities.

138. With regard to the value of the scholarships, we think it is essential (i) that, subject to need being proved in each individual case, the assistance given should cover the whole cost of education and maintenance, this cost not to be assessed on a niggardly scale; the full benefit of a university education will not be gained if scholars are restricted in every direction by their pecuniary circumstances; (ii) that there should be no restrictions of a financial or other kind

imposed to prevent a scholar going to the particular university which is willing to award him a scholarship and which provides the teaching and teachers that meet his needs.

With regard to the duration of a scholarship, we think that this should never be less than three years, subject to attendance, good conduct, and satisfactory reports on the scholar's work. It should be capable of extension to a fourth year, and even in some cases to a fifth year, provided that this extension was approved by the responsible teachers.

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139. It is clear that the cost can not be met out of existing endowments, and for the most part it must form a charge on national funds. We do not propose to enter further into this matter, but we desire to express our agreement with the view of the consultative committee that even though the State provides the funds "the proper body to test the qualifications of candidates for scholarships to be held at a university is the university at which the scholarships, or the chief part of them, are to be held."

140. *Method of award of scholarships.*—We consider that the present method of awarding scholarships at the Oxford and Cambridge colleges for proficiency in a single subject—e. g., classics, English, modern languages, history, mathematics, natural science—is unsatisfactory and leads to overspecialization in the schools. On this point there was universal agreement among all the witnesses who gave evidence on the subject; a representative of the Assistant Masters' Association stated for example that in the later stages of his school career a boy might spend as much as three-quarters, or even nine-tenths, of his time on his science subjects in preparation for a scholarship examination; and the chief inspector of secondary schools observed that "so long as university entrance scholarships were given for proficiency in a single subject—e. g., mathematics or science—it was very difficult to keep specialization at school within proper limits."

We think it desirable to broaden the basis of these examinations by encouraging candidates to take a second subject, to which substantial credit should be assigned, even though the range covered is considerably less than that expected from those who make it their primary subject. By "substantial credit" we mean such an amount of credit as would make it difficult for a candidate to obtain a scholarship if he confined himself to one subject only. No attempt should be made to prescribe a hard and fast grouping of subjects. Complete freedom should be allowed to candidates offering science in the choice of their second subject, e. g., history, a language, or mathematics. In connection with all the subjects, great weight should be attached to evidence of a candidate's ability to express himself in clear and intelligible English. This result is not necessarily secured by the inclusion of an English essay as a compulsory subject in the examination. We are in sympathy with the suggestion that in addition to the practical examination there should be a viva voce examination for all science candidates.

The essential features of the proposals we have made are (1) that a science candidate should be required to present himself for examination in natural science and in another subject; (ii) that there should be freedom of choice in regard to the second subject. These proposals might with advantage be adopted not only at Oxford and Cambridge but by the universities generally.

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141. *Age limits for entrance scholarships.*—We recommend that the usual age limit for entrance scholarships awarded by the colleges of Oxford and Cambridge should be 18 rather than 19. This recommendation is in accordance

with our general view that 18 rather than 19 should be the normal age for boys passing on from secondary schools to the universities. The interval between the date of the scholarship examination and the time of coming up into residence is too long, and we recommend that the examinations should be held not earlier than March 1.

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142. We have received ample evidence that even now there are in the technical colleges, senior technical schools, and evening schools many students of great ability who are prevented by want of means from receiving the benefits of a university education, and that for lack of scholarships open to them their abilities are not developed to the full, and the interests of the country suffer in consequence. We think that the provision of scholarships open to such students is urgently needed; the consultative committee, as we have already stated, suggested that a considerable sum should be devoted to this purpose. The regulations for these scholarships should, in our opinion, differ materially from those we have suggested for candidates from secondary schools. In the first place, it is undesirable to have an age limit for these candidates; and, secondly, they can not be expected, at any rate for the present, to reach the same standard of literary training which it is fair to demand from candidates who have been studying continuously up to their entrance at the university. It would be well for the universities to bear in mind the importance of helping them during their university course to get into contact with literature and other subjects which have hitherto lain outside their opportunities. Greater specialization is permissible for these candidates who from the deficiencies of our present educational system or for other reasons have not had the time for covering a very wide field of knowledge and have been obliged to concentrate on such subjects as engineering, mining, metallurgy. In fact, evidence of real ability in their own subject should in this case be sufficient ground for the award of the scholarship.

All scholars should have reasonable freedom of choice in regard to the courses of study which they propose to pursue at the university.

UNIVERSITY FEES.

143. In the section of our report which deals with the supply of trained scientific workers we give reasons for believing that a large increase in the number of students passing through our universities is a matter of great national importance, and that steps should be taken to bring a university training within the reach of every one of sufficient ability to profit by it. Much would be effected by a generous extension of the system of scholarships, but this will require to be supplemented by a substantial reduction in the scale of fees charged. There should also be an equalization in the fees charged for approved courses in the different faculties, as at present students of science and technology are handicapped by the higher fees in these faculties. A large number of scholarships will be required in any case, because there are many parents who could not afford to maintain their children as students, even if fees were entirely abolished. Many parents are, however, deterred from sending their sons to the university by the present scale of fees, especially in large towns where there is a university which students could attend while living at home. We recommend that there should be made to the universities from national sources a grant large enough to enable them to make a substantial reduction in their fees and also to provide for the education of the larger number of students to whom such a reduction would open the door. * * * We are convinced that if fees were lowered great waste of intellect would be prevented, and that the

increase in the number of educated men and women able to help in developing our resources and in increasing the output of our industries would be worth the expenditure of a much larger sum, if we regard only the material aspect of this change.

The award of scholarships is not the only method by which assistance can be given to students. In the later stages of professional education when a student is approaching the time when he will be able to earn money, much help can be given without great expenditure by the establishment of loan funds. These would necessarily be administered by the university or other institution at which the candidate was studying, as no other body would be in as good a position to judge of the propriety of a loan. The system has been tried in several of the women's colleges. In the London School of Medicine for Women it has proved very helpful and there have been few cases of default.

PASS DEGREES IN SCIENCE AT OXFORD AND CAMBRIDGE.

144. In most of the universities a student can aim either at a pass degree or at an honors degree in the main subjects of study. In the modern universities the work for a pass degree includes more subjects than are required for an honors degree, but the two kinds of work are on the same lines and have much in common in their earlier stages; subjects can be chosen so that the study of each helps the rest.

But it can not be said that the Universities of Oxford and Cambridge provide satisfactory courses of work for pass men whose interest lies in the natural sciences. At both universities the choice of subjects is limited by regulations which do not secure, or may even prevent, the selection of subjects which stand in close relation to each other; e. g., at Cambridge a pass man can not combine agriculture with either chemistry, botany, zoology, physics, geology, or physiology, nor can he take physics with engineering, while at Oxford he is obliged to do more work in the classical languages than is required of an honors man in any subject except classics.

In consequence of this want of continuity many students aim at an honors degree in science who would get a better education from a simpler course if one were open to them. Others who would gain by carrying on the scientific training they have received at school find that they have no opportunity of doing so in the pass courses of the university.

The provision of continuous courses in science for pass men seems to us to deserve the serious consideration of the two universities.

COURSES IN GENERAL LECTURES.

145. The increase of specialization in all branches of knowledge at the universities has brought it about that students of one branch of knowledge have little opportunity of hearing anything about other subjects. It is therefore very desirable that there should be given at the universities courses of lectures of a general character on philosophy, history, literature, science, and economics. We believe that such lectures have been given with much success at more than one university.

DEGREE COURSES.

146. We asked the universities whether the present degree courses in pure science sufficiently meet the needs of those students who will later seek employment in scientific posts connected with industry. The answers to the question generally indicate that these degree courses are satisfactory so far as they

go, but that for students who will enter scientific industries there is need for further specialized study for at least one year. We have found no evidence of any strong feeling on the part of the universities generally in favor of a change in the character of the courses taken for their degrees in science.

There is less unanimity in the answers to our further question—whether any new combinations are desirable in the possible courses for a degree (e. g., chemistry and engineering)? Some universities and colleges state that sufficient options exist or that no combinations of the kind are desirable. Others take the opposite view and advocate combined courses in chemistry and engineering, or state that proposals in this direction are under consideration. There is a general view, with which we agree, that students of technical chemistry should have an opportunity of acquainting themselves with the appliances used in chemical processes on a large scale. Experienced correspondents agree that cooperation between the chemist and the engineer is most necessary in modern work. It is only very exceptional men who can be fully qualified both in chemistry and engineering, and it is therefore doubtful whether the universities should attempt a course of training giving anything like full professional qualifications in the two subjects within the time limits of an ordinary degree course.

147. Before leaving the subject of degree courses we desire to add that in our view it is most important that the courses in question should be so arranged that students who come well prepared from secondary schools should not be put back to do elementary work which they have done already. This does not mean that there should be no elementary lectures. Such lectures will be necessary to meet the needs of students who have not pursued a full course of science at a secondary school and may sometimes be attended with advantage by those who have; but attendance should not be compulsory and there should be nothing in the university arrangements to prevent well-prepared students from proceeding to the more advanced studies which it is the special function of the university to foster. In no case should the period spent at the university be shortened; the student should be able to spend three years of uninterrupted study on the more advanced parts of his subject.

148. One method of securing this end would be to allow the intermediate examinations for the bachelor of science degree to be taken direct from school. This raises the question at what point in the course of a student's scientific training does the province of the secondary school end and that of the university begin. We have asked the universities for their views on this point. The answers disclose conflict of opinion.

It may be asked, in the first place, what is the aim of the intermediate examination for the bachelor of science degree? To this question three different answers have been given. Some maintain that the examination aims at finding out whether the undergraduate possesses the general and elementary knowledge of science needed as a foundation for the more advanced and specialized part of the degree course, and assume that secondary schools are not so equipped with teachers and laboratories as to be able to impart that fundamental knowledge of science which is needed as an introduction to advanced university teaching. This assumption is already antiquated as a general statement.

Others urge that the examination is designed to show whether the undergraduate has followed with intelligence the course of instruction given to him during his first year at the university under conditions freer and more stimulating than those which can possibly prevail at a school. This view takes it for granted that the lectures and laboratory instruction given in a university in preparation for the intermediate bachelor of science examination are in the hands of the most brilliant and experienced professors under whose inspiring leadership the young student is privileged to make his entrance into the university of science. This assumption is not always justified by the facts.

A third group regard the intermediate course (tested by an examination) as a year of probation during which the university teachers watch the student's abilities and judge his promise for further work. This view assumes that the intermediate course at a university is a sort of shunting ground, in which each student according to the ability which he shows is put upon the line of rails which will carry him forward into the course of advanced study most fitted to his powers. This assumption does not correspond with usual university practice.

A majority of our university witnesses, however, reply that the intermediate examination for the bachelor of science degree should be allowed to be taken from school. This privilege is already granted in one university to all students and in several others to students who enter for an honors course in science. The principle, therefore, has already been conceded. In view of the facts (1) that the work of the last two years in a secondary school well organized for science teaching does usually include the necessary subject matter of the intermediate bachelor of science examination, (2) that actually the ground covered by the first year's work at the university is much the same as the higher work of schools, (3) that school methods for most students are more suitable for those beginning a subject, and (4) that two years are insufficient for an honors course at the university, we recommend the universities to allow candidates to take these examinations direct from such schools.

But a still more helpful arrangement would be that candidates in a second school examination (see sec. 66) who do satisfactory work in any of the subjects required for the intermediate examination should be exempted from further examination in these subjects. It is not desirable that the work of pupils between 16 and 18 should be disturbed by their having to prepare for an examination not primarily designed to meet school needs.

THE PLACE OF ORIGINAL RESEARCH IN UNIVERSITY EDUCATION.

149. The training afforded by the study of natural science will be incomplete unless the student undertakes some piece of research, in which, relying as far as possible on his own resources, he applies his knowledge of science and of the methods of scientific investigation to the solution of some scientific problem. The effect of a year's work of this kind on the general mental development of the student is most striking. He gains independence of thought, maturity of judgment, self-reliance; his critical powers are strengthened, and his enthusiasm for science increased; in fine, he is carried from mental adolescence to manhood. We think that whenever possible a year spent mainly on research should form part of the course at the university of those whose work in life will be concerned with the industrial applications of science, as well as those who will devote themselves to research and teaching. It is important, however, that at this stage the teachers at the universities should regard research mainly from the point of view of its value as an educational training and not as a means of getting within the year as many new scientific results as possible. The student should be encouraged to overcome his difficulties by his own efforts, and the assistance given by the teacher should not be more than is necessary to keep him from being disheartened by failure and to prevent the work from getting on lines which can not lead to success. Work of this kind should in general be taken after qualifying for the bachelor's degree, and should be recognised by the grant of some additional distinction.

We think that original work should not be required for the first degree in science. The period, usually three years, spent in preparation for this degree is none too long for wide reading in all branches of a student's main subject and in those branches of other subjects which have an intimate connection with it. We regard it as of the utmost importance for the student's future success that he should not confine his studies to some particular branch, say, of physics or chemistry, but should gain a general knowledge of the conception and results of the whole range of his subject. Such knowledge is most easily acquired at this stage, and experience shows that, unless this opportunity is seized, the student's knowledge throughout life is specialized to an extent which is unfavorable to the highest success. It must be remembered that research work to be useful demands a great deal of time and great concentration of mind on the subject under investigation and would curtail to a serious extent the time available for general reading.

For the sake of widening the outlook of students of natural science as well as for increasing their equipment for successful investigation it is of especial importance that opportunities should be given for combining the study of mathematics with that of natural science, and we welcome the efforts which most universities have made and are still making to effect this object.

DEGREES FOR RESEARCH WORK.

150. The universities have not adopted a common policy in regard to research degrees. As a rule the degree of bachelor of science marks the end of an undergraduate course and in many universities the degree of doctor of science is given a few years later for a specific piece of work, often undertaken with a definite view to the degree. Other universities give a degree of master of science under conditions which vary so much that the precise meaning of the degree in different universities is obscured, and reserve the degree of doctor of science for still more senior candidates. If the object of granting a degree is to encourage research, there seems to be little reason for postponing the grant of it to a period so late that the hope of obtaining the degree is not likely to be a serious stimulus. If the number of students who come to this country for advanced work increases, the need for a uniform and comprehensible system of research degrees will become even greater than it is at present.

We are in general agreement with the following resolutions which were passed at the universities' conference held on May 18, 1917:

That, for the wider promotion of research in this country, as well as to encourage the attendance of graduate students from the British dominions and foreign universities, a degree of doctor shall be attainable after not less than two years' advanced study and research.

That the existing doctorates shall, if possible, be retained without lowering their standard.

That the title of the degree shall be the same for all faculties.

That it is highly important that the same title for this degree be adopted by all universities.

That the title of the doctor should be "Doctor of philosophy" (Ph. D.).

That it is essential that the period of two years contemplated should be a period of whole-time study or its equivalent.

POSTGRADUATE RESEARCH SCHOLARSHIPS.

151. It is a matter of great importance for the advancement both of pure science and of technology that students who have shown capacity for research should be able to remain at their university, in order to continue their studies and to acquire experience in a research laboratory under competent guidance; but there are often serious financial difficulties; a student who has been able

to support himself for the three years of an ordinary degree course by means of scholarships is often at the end of his resources and is compelled to take up some remunerative work at once. If he does this the chance that he will ever be able to return to research is small. Thus the critical time when such students are most in need of the help which a scholarship can give is at the end of the undergraduate course. * * *

We are convinced by the evidence that has been placed before us that no expenditure of public money on scholarships holds out more prospects of valuable returns.

It has been pointed out to us as a serious difficulty that the tenure of scholarships given by local authorities is often shorter and less easily prolonged than that of other scholarships, so that the holder of such a scholarship may find his income diminished just at the time when he begins to get the greatest benefit from a university education. It has also been pointed out that there is a special want of senior scholarships for women. Both these defects ought to be remedied.

Even where the tenure of a scholarship can be prolonged, another difficulty may arise. It can not be expected that all the universities should provide equal facilities for the study of all subjects; in particular the elaborate special appliances needed for higher work in some branches of technical science may exist only in one or two institutions in the country, so that it becomes necessary for students to migrate from one university to another. The universities have expressed very definitely the view that such migrations should not be encouraged during a three-year undergraduate course except under special conditions, on account of the dislocation of the general scheme of the student's work which would result; but they almost all approve of the migration of graduates and have made arrangements to facilitate it. The conditions of tenure of scholarships should be sufficiently elastic to permit of such migration.

Some laboratories can provide their senior students with opportunities for research by employing them as demonstrators for part of their time, on condition that the rest of their time is given to research; this arrangement is warmly advocated by those who have experience of it, as it provides the student with two different kinds of training and experience, each of which has its special value. But the number of students who can be helped in this way is necessarily small.

RELATION BETWEEN THE DEPARTMENTS OF PURE AND APPLIED SCIENCE.

152. In all universities there are departments for the study of medicine and engineering; in many of the modern universities there are also departments for the study of the applied sciences which are of special importance in the district. We consider that these departments promote not only the particular industry or profession with which they are connected, but also the study of pure science and the interests of the university as a whole. They promote the industry by giving to those who enter it the opportunities of getting the broader outlook and wider interests which life at a great university affords. Association with other departments of the university promotes and facilitates the application of science to industry, as it gives opportunities for intercourse between those who are proficient in the sciences on which the industry is based and those who are conversant with its practical needs. The purely scientific departments gain because more students pass through their classes and there is consequently a wider field from which to select those who show outstanding

ability in pure science. There are, for example, not a few eminent physiologists who began the study of their subject as part of a medical course, and who might not have devoted themselves to pure science but for the existence of a medical department. The technical department strengthens the university by bringing it into close touch with the life of the district and by increasing both the scale of its operations and the number of its students.

153. We consulted the universities as to a number of plans which have been suggested for bringing their departments of applied science into closer relation with the industries. The universities which have had experience in the matter are unanimous in thinking that the head of every technological department should be allowed and encouraged to take part in private professional practice, so far as it is consistent with the discharge of his university duties, in order that he may keep abreast with the developments of the industry which he is serving by his researches and for which he is training students. There is some difference of opinion as to the value of advisory committees consisting of representatives of the university and of the industries for which students are trained, but the universities which have instituted such committees are convinced of their usefulness, provided that their functions are clearly defined and are advisory, not executive. Much of the research work needed for the industries can only be done with advantage at the works where the problems arise. But frequently questions of a more general kind present themselves which need not, or can not, be dealt with in the works laboratory, but could be investigated at a university or technical institution. Two plans have been adopted to utilize university laboratories for such work. In one the university merely allows an investigator appointed by the firm to use its laboratories for his work; in the other the head of the university department undertakes some responsibility for the general supervision of the work done by investigators sent from the works laboratory, who are sometimes assisted by senior students; this method has been tried and found advantageous in several of the largest chemical laboratories in this country.

PROVISION FOR ORIGINAL RESEARCH.

154. The importance of research in pure science, the life blood of applied science, is recognized on all hands, and there is general agreement that it ought to receive more encouragement from the nation than it has done in the past. It is as difficult, however, to organize the production of the highest type of research in pure science as it would be to organize a method of producing great poems. The greatest advances in pure science are often the outcome of investigations which, until they are justified by success, appear fantastic and unpromising, and meet with little approval from orthodox scientific opinion, and it is often too a long time before any tangible results are obtained; for this reason they are not of a kind which could be expected from workers in a great institution supported by public funds. Such an institution would naturally be expected to furnish year by year a report of progress, but in research on entirely new lines a year may easily go by without any definite results being obtained, and the investigator would be in the invidious position of having little to show that he had earned his salary. There would thus be a strong inducement for him to pursue a lower type of work on more conventional lines in which he could feel assured of a fairly continuous progress. One can not hope to get great discoveries simply by paying for them; those in the past have for the most part been made in the laboratories of the universities and, we think, will continue to be so. The most hopeful way of promoting discoveries of this kind is to insure that these

laboratories are as efficient as possible, and that the professors and other teachers who work in them have enough free time for original research.

As science progresses, the instruments necessary for research become more and more numerous and more costly, and to equip and maintain the laboratories in the most efficient state is beyond the resources of most of our universities. One of the best methods of advancing pure science would be to insure the efficient equipment of the laboratories in our universities. The answers of the universities to our questions show that they consider their present resources insufficient to provide all that is needed.

Apart from more general questions of expansion, an increase of research work would require increase of staff and improvement of equipment. It is extremely undesirable that research should be confined to the larger universities, but in the smaller institutions where a science may be represented by only one professor the amount of routine and organizing work which falls to him may be so large that he can not give enough time to research students. In the early stages such students need much assistance and advice; there is consequently often a definite need for some arrangement to relieve the professor of some part of his routine work, and leave him more time for the organization and supervision of research.

With regard to the equipment, the needs vary so much from place to place that it is difficult to say more than that the universities consider them very urgent, and it is clear that they can only be met by further financial assistance.

PROVISION FOR STAFF, BUILDINGS, AND EQUIPMENT.

155. In this connection we can not do better than to quote certain of the answers we received to the question: "Are larger subsidies from the treasury now required (a) for the adequate development of the work of the university in pure and applied science; (b) for the general purposes of the university? Is it desirable that the Government should make building and equipment grants for the provision of new laboratories in the English universities?"

(I) "Immensely larger subsidies are required for all these purposes."

(II) "To all questions in this section the answer is emphatically in the affirmative. For its buildings and development this college has hitherto depended mainly upon private munificence. Private munificence alone can not, in our opinion, be expected to provide in the future, and especially immediately after the war, the whole of the funds for salaries, building, equipment, and upkeep that the university institutions of the country require. It is, however, of the utmost importance that, if the State subsidizes the universities, it should in no way restrict or interfere with their freedom of development."

(III) "(a) Yes; for both purposes, provided that the autonomy of the universities is preserved. (b) Yes; on the same condition."

(IV) "The university * * * has in the past depended mainly upon the generosity of corporate bodies and individuals for the endowment of fresh posts and for the erection and equipment of laboratories and other university buildings. The resources of the university do not enable it either to make adequate provision for the upkeep and full equipment of the existing institutions, or to provide the staff and the buildings that are necessary for teaching and research in new and rapidly developing branches of science. It is feared that after the war the financial position will be still more difficult."

156. The principles which in our opinion should be maintained are well set out in the following reply with which we are in complete agreement:

"The answer is in the affirmative, but I would couple with this answer the observation that however much the amount of Government assistance may grow to be, it is of vital importance that the universities should retain full independence. The State obviously, if it finds the money, has the right to know how the money is spent, and the right also to inspect the institution under all reasonable conditions; but the whole future of English university work and efficiency depends on the universities being left free as societies to do their work upon their own impulse and not upon the dictation or suggestion of a department of State. The principle involved here goes to the very root of university well-being, and no financial gain could ever compensate for its sacrifice." * * *

STIPENDS OF UNIVERSITY TEACHERS.

157. The universities and university colleges which receive exchequer grant spend a large proportion—over 51 per cent—of their income on the salaries of the teaching staff; more than half of the amount goes to professors and heads of departments.

There is widespread and serious discontent with the salaries and prospects of the junior staff in the scientific departments. The initial salaries for such posts are so low as to be out of all relation to the capital expended on the education of the holders, and there are many competent men doing responsible work at salaries far below what they could have earned in other walks of life. It must be remembered, however, that there are compensations in the opportunities for further study and research, and there is a strong feeling that the inducements to junior demonstrators to remain long in their posts should not be made too great. It is in the interest of the department that there should be opportunities of testing the capacity of students for teaching and research at as early a stage as possible; in the interests of the man that he should not remain too long in a post where, unless he is of peculiar ability, his horizon is necessarily limited; and in the interests of the teaching profession and of applied science that there should be a supply of men who have had experience of work in a research laboratory.

We think that, on the whole, the best way of improving the position of the junior staff is to decrease the time required for their official duties rather than to make large increases in their salaries. At present the tendency is to require so much teaching work from them that they have few opportunities for research, and so are at a disadvantage when competing for posts for which distinction in research is an essential qualification; and in addition to this the progress of science is retarded as many of those best qualified for original investigation are debarred from pursuing it. We are of opinion that the official duties of the junior scientific staff should be confined to at most four days per week, so that they may have at their disposal a considerable amount of time for original research. This plan is already in force in some laboratories, and we have reason to believe that the results have been satisfactory.

There will, however, always be men whose best work can be done in laboratory teaching and organization, and it is desirable that the universities should be in a position to retain them by providing for senior men a small number of permanent posts of substantial value; at present this is seldom possible.

RELATION OF UNIVERSITIES TO SECONDARY SCHOOLS.

158. The relations between the universities and the secondary schools need careful adjustment, more especially at such times of transition as the present day, and it is desirable to provide at each university regular opportunities of discussion and negotiation with the representatives of secondary education. For the most part such facilities have been provided by occasional, but not infrequent, conferences held chiefly between the representatives of the universities and those of the various teachers' associations, but there appear to us to be considerable advantages in the establishment of a more regular and systematic machinery organized on a broader basis for this purpose, such as has recently been set up by the University of Durham and the representatives of education in the adjacent counties.

THE SCOTTISH UNIVERSITIES.

Sections 159–164 state that steps should be taken to remove the limitations which confine a large proportion of the old established bursaries to the faculty of arts.

ADULT EDUCATION.

165. For the most part we have hitherto been considering education organized and systematized in schools and universities, and we have been dealing with students as yet youthful and immature. There is, however, a class of learners who are at last making their demands felt, and justly insisting that they should receive, however late in life, the educational opportunities which are due to them. These are largely men and women who have reached maturity without receiving any education which they regard as adequate and who are eager to make good their deficiencies in knowledge. We are glad to see that a subcommittee has been set up by the reconstruction committee to consider the needs of these adult students.

The movement is not a new one. In a certain sense it began a hundred years ago with the foundation of mechanics' institutes and the work of Dr. Birkbeck, when elementary and technical education were less generally diffused than now. Forty years ago the university extension system began to provide a considerable amount of extra-mural teaching for students who could neither come into residence nor take a full university course, and though the greater part of the science teaching originally so organized has passed into the hands of local education authorities, it is directly from university extension that the late tutorial classes and study circles have been developed. It is only in the last few years that there has been a considerable growth of adult classes, and it was not until 1904 that the Workers' Educational Association was founded. This latter organization has created, or at any rate focused, a remarkable demand for adult education, but up to the present that demand has been chiefly for knowledge of economic, social, and historical subjects.

At present, so far as we can learn, the little instruction which is given in science to adults, apart from that provided in technical schools and universities, is conveyed chiefly through the agency of field clubs, natural history societies, and mechanics' institutes. If this movement for adult education is to take the important part in the national life which seems to be opening up before it, it is essential that the education which it provides should be wide and liberal, and should give opportunities for study not confined to a limited range of intellectual interests. If it is to fulfill this requirement it must assign an adequate place in its scheme to the teaching of natural science. No modern intellectual system can afford to neglect the realm of natural knowledge; to be ignorant of its influences and lessons is to belong to the past and to distrust the future.

166. We are aware that those responsible for the Workers' Educational Association recognize in their program for educational reconstruction the position of science as "a staple part of an education of the traditional secondary type," and that they recommend that the technical schools should include in their curriculum "the study of the sciences upon which different industries are based." These few words are, however, the only explicit references to science in the program and its exposition; partly it would seem from a fear lest scientific teaching should be devoted wholly to increasing the manual efficiency of artisans, the subject has been to a certain extent discredited, and is not even yet appreciated as an integral part of a liberal education. There has, in fact, been no serious demand for instruction in science from the students who compose the classes organized by the association. To this statement one exception must, however, be made. In the neighborhood of Leeds the tutorial classes in biology have aroused considerable enthusiasm in working-class circles over a period of several years. Mr. Walker, the tutor responsible for conducting these classes, wrote to us in reply to an inquiry: "Last night I met a class of 21 adults, men and women, chiefly factory workers, all in their second year of attendance. They walked varying distances up to 8 miles to meet in class, and during our 10 meetings since the commencement of the session only two absent marks are recorded in the register." Though this is a solitary instance, it shows what can be done when the teaching is of the right kind, and we desire to emphasize the importance of developing tutorial classes in science along with other subjects. In this connection it may be of interest to quote the following observations which we have received from Mr. H. Wager, F. R. S., acting professor of botany at Leeds University, who speaks with knowledge of the classes referred to above:

"The success of science classes for adult students depends in a special degree on the character of the teaching and the personality of the teacher. It is more difficult to secure the right sort of teaching for adult students in science than in such a subject as economics. The teaching of science to adults may fail either because it is too elementary and does not deal with scientific matters of general interest—it is unreasonable to expect grown-up people to be profoundly interested in the textbook accounts of the properties of oxygen and hydrogen—or because it is too technical and specialized. It is not easy to get a teacher who will be successful in avoiding both these pitfalls. On the other hand, it is a profound mistake to suppose that workingmen are naturally lacking in interest in scientific matters. They are fully alive to really good teaching of science by a teacher who knows how to bring out their powers of reflection and judgment. If they can not get this kind of intellectual stimulus in science they can as a rule get it in such a subject as economics, simply because they are themselves more or less acquainted with the facts upon which the problems of economics are based."

167. If, as has been suggested, adult education is to become a recognized department of the extra-mural teaching of the universities a serious responsibility devolves on these bodies to include science in this work.

Popular lectures on science will no doubt play an important part in calling the attention of large audiences to the interest and importance of the subject. This work has for more than a century been carried on by the lectures at the Royal Institution, and from time to time brilliant speakers like Huxley have done much to create an interest in the methods and results of science. The work of such an organization as the Gilchrist Educational Trust has been and will continue to be of great service. But if even the best popular lectures are to have any permanent effect they must lead on to more serious work involving individual effort, to courses and to circles where systematic study will be carried on.

Again, there is a wider audience who are out of reach of popular lectures and who can not attend university extension and tutorial classes—those who depend for their education on books. There is a real need for well-written books and other publications in which the main results of recent scientific research and the achievements of science in the past are set forth in a manner which will appeal to intelligent men and women who have made a special study of science. It is one of the unfortunate results of the increasing specialization of scientific work that the original papers, reports, and treatises recording or summarizing the results of research are beyond the comprehension of those who do not possess a considerable amount of scientific and mathematical knowledge. Science needs its skilled interpreters as well as its active pioneers.

We are by no means sure that the popular interest in science is as great to-day as it was 30 years ago. Until this general interest in science is extended and increased, and the deficiencies of adult education in this respect are made good, an important piece of work in national education remains to be done.

IV.—SUPPLY OF TRAINED SCIENTIFIC WORKERS FOR INDUSTRIAL AND OTHER PURPOSES.

168. The need for a great increase in the supply of trained scientific workers of all grades is a matter of the utmost gravity and urgency. It is agreed on all sides that it is absolutely necessary for the prosperity and safety of the country after the war that the development of the resources of the Empire and the production of our industries must be on a scale greatly in excess of anything we have hitherto achieved. Schemes of reconstruction and development are being prepared and discussed; each one of them requires a supply of trained workers and the proposals will be futile unless a large army of these is forthcoming. We shall not get these workers in anything like sufficient numbers unless we have great changes in our educational system, and, above all, unless a much more eager desire for secondary education is created in the minds of a great mass of our citizens. We must multiply the number of students passing through our universities and technical schools, and this will involve a great increase in the number of boys and girls who complete a course of secondary education. It is true that since the act of 1902 a large number of new secondary schools have been established, and that in the last three years not only these but also the older schools have been filled to their limits. Nevertheless it is still necessary to increase the flow from the elementary to the secondary schools of children capable of profiting from the best education these schools can give. It is of no less importance to diminish the leakage, amounting now to more than 60 per cent, which occurs in the secondary schools before even the general course is completed.

We must by means of scholarships and maintenance allowances put a complete course of training within the reach of every boy or girl of sufficient ability to profit by it.

But this is not sufficient. We must not only provide the opportunities, we must make our citizens eager to avail themselves of them, we must strive to make parents anxious to secure secondary education for their children. This is the most vital and difficult part of the whole question.

The want of appreciation by parents of the benefits of secondary education prevents a full utilization of the resources in the way of scholarships which are even now available, and this will continue until a more lively appreciation of secondary education is spread throughout the country. Much as we may regret it there is no doubt that appeals for secondary education for its own sake appear far-fetched to the majority of parents and leave them untouched.

We are convinced that to make the country eager and willing to avail itself of the opportunities for secondary education the benefits it confers must be put in a very tangible and material form. This we think could be done by emphasizing the advantages conferred by the possession of the first school certificate or its equivalent, which attests the completion of a continuous course of instruction at a secondary school. The universities should be asked to require this as an integral part of their normal entrance examination, professional bodies as a condition for entering their profession, and great commercial institutions as a normal requirement for entering the higher grades of their service. The State itself should set the example in this respect and expect all who enter its service above a certain grade to possess this certificate.

We think, too, that steps should be taken to put before parents in as clear and simple a way as possible the careers open to those who complete a course of secondary education, the opportunities offered by such careers, the steps to be taken to enter them, the nature and cost of the training, and the assistance diligent students might expect from scholarships.

169. In the preceding sections of this report we have dealt with the position of natural science in different parts of the educational system. We have now to inquire how far the system considered as a whole is capable of giving us the number of men with specialized scientific training who will be needed after the war for the management and conduct of scientific industries and for carrying on the researches in pure and applied science on which the maintenance and development of these industries so largely depend.

In raising this question we are not forgetting that the study of science is to be desired quite apart from any utilitarian and material ends which it may directly or indirectly subserve. We have already pressed for the fuller recognition of science in schools because we regard it both by reason of its subject matter and of the mental discipline which its study affords as an essential element in a liberal education; and we desire, in the interests of the advancement of natural knowledge, to see every encouragement given to the higher study of science at the universities.

But it would have been necessary also to consider the needs of the trades and industries which depend upon applied science, even if we had not been specifically required to do so by our terms of reference. The needs of our civilization are increasing, the nation has already been deprived of the services of many of its ablest and most vigorous members. Our producing power can only be increased by well directed research, better training and the more skillful use of scientific methods of manufacture and distribution. Unless the resources of the country are sufficiently developed, neither the nation as a ~~whole nor~~ any of the classes in it can look for efficiency or prosperity or can afford to carry on the education of its constituent members to any advanced point.

170. It is necessary for the purpose of our inquiry that we should, on the one hand, realize the demand for scientifically trained workers which the industries will make, and, on the other hand, survey the extent and sources of the possible supply. As to the first point it is not possible to arrive at

even a rough numerical estimate of the needs of any particular industry, much less of industry as a whole. The national trade policy, the relations of capital and labor, the future of national establishments first organized for the production of munitions, and a thousand other complications deter those who know the situation best from venturing on more than the most general prophecy. But it may be worth while to set down certain facts and observations which have been brought to our notice.

Even before the war there was a growing demand from the industries for men who had pursued scientific studies at the universities. Thus we were informed by the secretary of the Cambridge University appointments board that, out of 110 men who had taken chemistry in Part II of the Natural Science Tripos since 1900, 80 had gone into the chemical industry; while in the period 1911-1914, 40 firms had accepted men as chemists, metallurgists, geologists, etc., as against 21 firms in the longer period of 1906-1910. We have further been informed that the demand for qualified students at the Manchester Municipal School of Technology was such that students were often engaged for posts before their courses of study were completed. As an immediate result of the war the need for increasing output is being realized and the necessary conditions to that end explored. Rule of thumb methods are seen to be inadequate if industry in this country is to hold its own. The individualism which has hitherto characterized British industry is gradually giving way before serious efforts toward combination. With all this there is a growing consciousness of the need for organized research into processes of manufacture. Lastly, the community has come to realize as never before that the development of industry is the concern not only of individual employers or groups of employees, but of the nation as a whole.

171. The Government took an important step when on July 28, 1915, they established a committee of the privy council for scientific and industrial research and associated with it an advisory council composed of men of the highest scientific standing. In the report of the advisory for 1915-16 it is stated "a largely increased supply of competent researchers is the first condition which must be secured if the object for which the committee of council was established is to be attained." The report goes on: "It is in our view certain that the number of trained research workers who will be available at the end of the war will not suffice for the demand which we hope will then exist." But it is not only the scientific pioneers who will then be needed. Sir George Beilby, chairman of the fuel research board, informed us that in the chemical industries there was need for a much larger supply of professionally trained chemists as works managers and process conductors; men who had received for four or five years the kind of training given, for example, at the Royal Technical College, Glasgow. A similar point is made in the report from which we have just quoted: "Effective research particularly in its industrial application calls increasingly for the support and impetus that come from the systematized delving of a corps of sappers working intelligently but under orders. We have not yet learned how to make the most of mediocre ability * * * yet without the scientific rank and file it will be as impossible to staff the industrial research laboratories, which are coming, as to fight a European war with seven divisions." The report significantly adds that "the responsibility for dealing with the grave situation which we anticipate rests with the education departments of the United Kingdom."

We asked Sir George Beilby whether he could give us any estimate of the number of chemists and engineers who would be needed for the work which the recently established fuel research board had in contemplation—work which is of great importance not only to industry but to the country at large.

He was unwilling to commit himself to any figures but pointed out that from one-fifth to one-half of the £100,000,000 sterling which represents the national bill for raw coal is being wastefully expended and might be saved, and that the saving can only be effected by the cooperation of a large body of trained fuel experts to carry out the necessary research work and to introduce and supervise improved methods in all works where fuel is consumed in large quantities.

We think there are good grounds for supposing that the need for a large number of men trained in science will be realized by industrial firms and will lead to an increased demand for such men in the near future. To take a single example, we were informed by Sir Gerard Muntz that before the war there were not more than half a dozen firms in the nonferrous trades which had metallurgical laboratories of their own, but in the near future it was likely there would be 50. It was difficult, however, to find young men suitable for filling positions in such laboratories, the supply being entirely inadequate. Again, the Government fund of £1,000,000 sterling to be administered by the department of scientific and industrial research has led to an extensive movement toward the formation of research associations. Some 27 industries have already taken up the question, and several of these, including the important cotton, wool, iron, photographic, and scientific instrument industries, are likely to inaugurate their associations in the near future. This department is also aiding out of its annual vote investigation into the manufacture of glass at the University of Sheffield, into technical optics at the Imperial College of Science and Technology, and into hard porcelain at the Central School of Science and Technology at Stoke on Trent, as well as a number of researches and preparatory surveys in connection with the metallurgical and other industries. We may reasonably hope that the movement in the direction of research will spread to other industries and bring with it a more scientific study of manufacturing processes and a greater demand for well-qualified men as works managers and technical experts. If further we may look forward on the return of peace to an increased and more economic production of iron and steel, to the maintenance for civil purposes of factories which have been enlarged or newly established for the making of munitions, to the development of chemical works for the manufacture of products formerly obtained abroad,[1] to a more scientific treatment of the problem of food production, the demand for professionally trained metallurgists, engineers, chemists, and agriculturists will be greatly increased. To this demand there must be added the normal requirement for the medical profession and the increased demand for science teachers to which we have already drawn attention.

172. So far we have spoken of the indubitable need for men with a scientific training and the probable demand that the industries will make for their services. We have now to deal with the question of supply. How did we stand in this matter before the war?

In the years 1910–1914 the number of men taking first and second class honors in Part I of the natural science tripos at Cambridge and in the final school of natural science at Oxford averaged 146 annually. The figures for the modern universities are not strictly comparable with these or with one another, but the total annual output of the first and second class honors men in science and engineering for all the English universities may be put at about 500.

[1] The works in question include those concerned in the manufacture of drugs, dyes, fine chemicals, incandescent gas mantles, synthetic ammonia, and other nitrogen compounds, liquid chlorine, tungsten, spelter—products which were formerly obtainable only or largely from Germany.

Not all these students pursue scientific avocations and of those who do some become teachers or doctors. It is clear that this supply of men with honors qualifications in science is quite inadequate, even for the particular needs of the scientific industries. The total number of full-time men students who entered the universities and university colleges of England and Wales (excluding the medical schools) in the year 1913-14 was no more than about 4,400, and of these some hundreds were foreign students who return to their own countries. It is probable that a certain number of men who would enter other faculties might be diverted to science and technology; but we can not look in this direction for any large addition to the number of science students. We must look rather to measures directed to securing an increase in the entries into the universities. It is impossible to regard the number of men who entered the universities year by year before the war as anything but an inadequate proportion of the number of young men in this country capable of making good use of the training which the universities give.

Although women workers trained in scientific methods have hitherto been few in numbers, their success in the last two years has given this country good reason to hope much from their help in future. But even though this contingent may be much increased, it will be long before we are likely to obtain as many as we shall require, for it can not be expected that after the war there will be the same opening as there has been in the time of stress for willing workers with merely an improvised training.

Special measures are in our opinion necessary to increase the supply of science students because the deficiency is marked and the need is urgent, but this problem is part of the wider problem of increasing the number of university trained students in general, and can not be solved by measures conceived in the special interests of science or by reforms which affect one part of the educational system, while leaving the other parts untouched.

The deficiency of recruits for the scientific professions and industries is so great that there is no available source of supply which we can afford to leave untapped.

173. The chief direct sources of supply at the present time are (i) the secondary schools and (ii) evening and other similar schools educating pupils below the university age. So far as the latter group of schools is concerned, the number of students passing on to the universities and technical colleges could be largely increased. But to make this possible (i) there must be a generous provision of scholarships awarded on the result of examinations specially adapted to the needs of the students in question; (ii) the industries should be organized so far as to give facilities for suitable men to pass from the works to the university with the prospect of securing better paid posts on their return to employment.

The supply obtainable from secondary schools of all kinds has next to be considered. With regard to the group of public schools which receive no grants from the State, the answers given to our questionnaire show that the number of boys annually leaving these schools was before the war about 5,800, of whom approximately 5,200 were 16 or over when they left. We estimate that from 25 per cent to 30 per cent of all those who left passed on to the universities. If we take the higher figure this gives an annual entry from these schools of 1,740 for the honors and pass schools in all subjects. No doubt the number of boys taking science as their subject of university study could be increased. The inclusion of a substantial course of science as part of the general education of all boys in these schools should result in the discovery of tastes and aptitudes for science among those to whom this opportunity has hitherto been denied. But when all possibilities have been taken into account there is an obvious limit to the number of science students obtainable from the public schools.

So far as numbers go, the possibilities are greater in the State-aided secondary schools, provided that appropriate measures are taken to develop the potential supply. The number of boys over 12 years of age who left these schools in England and Wales in the year ending July 31, 1913, was nearly 25,000; but of these about two-thirds left before the age of 16, the number leaving at 16 years of age or over being approximately 8,800. Of these 8,800 it is only a minority—probably from 12 to 15 per cent—who pass on to any university.

The main point to be noticed about these figures is that while the absolute number of boys entering State-aided secondary schools is quite considerable, the number who stay beyond the age of 16 and thus come within sight of a university education is far too small.

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175. If the number of boys who remain at school for the second stage of secondary education (16 to 18) is to be increased and the potential supply of university students from this source enlarged, it is necessary to stop the serious leakage which now goes on before the first stage is completed. As things are we have no security that it is the abler boys who remain for a full secondary school course. On the contrary, it is precisely the sharp boy who is most likely to be sought after by an employer and to enter on a wage-earning occupation at 15. The remedy for this state of things is only partly in the hands of the educational authorities. A great improvement would be effected if it became the general practice of employers (including engineering firms) to recruit their employees from secondary schools at either 16 or 18 i. e., at ages corresponding to the two stages of the secondary school course.

Again, if the possession of a certificate showing that a pupil had passed the first school examination after taking an approved course at a school of secondary grade were a passport to employment at 16 or 18, the advantages of a secondary education would be more widely impressed upon parents. It might then become the exception and not the rule for boys to leave school before the age of 16; and the too prevalent practice by which boys are sent to these schools for a year or two "to finish" would meet with the discouragement it deserves.

The temptation to seize opportunities for early employment would be further diminished by the provision on a more generous scale of (i) maintenance allowances for those who pay no fees, increasing in value as the pupils get older, and (ii) internal scholarships for fee-paying pupils.

Further, there is need for closer and more effective cooperation between education authorities and head masters of secondary and elementary schools, so that the advantages of a secondary education may be brought to the notice of the parents of all the abler boys in the elementary schools. Despite what has already been done in this direction, there is still a large number of able boys in elementary schools who for various reasons never have the chance of getting the higher education which the secondary school can provide. Want of knowledge on the part of parents and the natural but mistaken desire of some head teachers to retain their ablest boys may defeat the best-intentioned schemes of scholarship provision. There is, in fact, a great waste of ability, sometimes of a higher order.

Very clear evidence of the existence of this ability is afforded by the admiralty scheme of training dockyard apprentices. In the dockyard schools recruited from elementary or municipal secondary schools, to which boys are admitted by open competition and while serving as apprentices, the standard is kept up by annual rejection on the results of an examination. From these schools have come many holders of Royal and Whitworth scholarships, many distinguished naval architects and engineers and a large proportion of the directors of naval construction.

176. It is of the first importance that ability should not be wasted, and if it is not to be wasted measures must, as we have said, be taken to insure (i) that no pupil capable of profiting by a full secondary education should miss the opportunity of receiving it, and (ii) that the leakage from the schools should be, so far as possible, stopped. We have drawn attention to these matters in this section of our report on the principle that if there is no milk there can be no cream.

177. We have next to consider by what means a larger number of the able boys can be induced to remain at secondary schools for the period from 16 to 18 and afterwards to pass on to the universities or technical colleges.

The first essential is that there should be sufficient and attractive careers open to such students. Briefly, if industry wants men of scientific ability who have taken a college course extending over four or five years, it must be prepared to pay for them. To offer salaries of £100 to £150 a year with very indefinite prospects of future advancement is useless. The salaries and prospects of advancement must be such as to induce able young men to continue their education up to the age of 22 or 23 and to persuade poor parents to bear the additional burden involved.

Secondly. The existence of posts carrying sufficient salaries and prospects must be made known. Hitherto there has been a widespread ignorance on the matter. It is essential but it is not sufficient that there should be appointments boards at the universities and that industrial firms should keep in close touch with university professors and the teachers in technical colleges. The work of the appointments boards should be made known to every head master in the country, and the possibilities of scientific careers in connection with industry should be brought to the knowledge of parents.

Thirdly. Steps should be taken to secure that the head masters of secondary schools shall be fully informed as to the different courses of further study which are suitable for young men who desire to enter one or other of the scientific professions or industries. The head masters are called upon to advise parents in matters affecting the future of their boys and through no fault of their own they are not always in the best position to do so. It is quite unsafe to assume that the varied opportunities for higher scientific and technology instruction which the universities and technical colleges provide are everywhere realized by head masters. The remedy lies with the institutions for higher education. They must establish closer relations with the secondary schools, not excluding those outside their immediate neighborhood.

Fourthly. The nation must see to it that there is a generous supply of (i) maintenance allowances for secondary school pupils who have passed the first school examination, enabling them to remain at school up to 18, and (ii) entrance scholarships at the universities sufficient to cover the cost of education. The education authorities must on the other hand do their part in strengthening and developing the work of the upper forms so that so far as possible there shall be within reach of every boy at least one secondary school suitably staffed and equipped for the purpose of providing advanced instruction in science.

Lastly, if the universities are to discharge their responsibilities toward the science students who are coming and to maintain their position as homes of scientific learning and research they must receive a measure of financial support much more considerable than any they have received hitherto.

178. We have stated in outline the reforms which must, in our opinion, be effected if the supply of trained scientific workers is to be increased. But it is useless to speak of particular reforms unless the need for reform is recognized. That scientific research and the scientific study and direction of industrial processes are necessary for the development of our industries and even for their maintenance, in the face of foreign competition, is a proposition which in educated circles will not in these days be denied. But as one of our correspondents writes: "Scientific research on industrial problems is of no use whatever to an uneducated trade. Such a trade can neither state its needs with definiteness or accuracy, nor can it interpret into practice and utilize the results of research. Indeed, it does not feel the need for research, and can not therefore make a demand for it. * * * In some trades it will be necessary to wait for the full development of research schemes until we have a generation of leaders qualified to demand and make use of industrial research."

With these remarks we agree, and they have in truth a wider application. It is not only those engaged in industry for whom a better scientific education is required. If science is to come by its own the nation as a whole must be brought to recognize the fundamental importance of the facts and principles of science to the right ordering of our national life. The more closely the work of our legislators touches the life of the people the more intimately it is concerned with questions of food supply, housing, transport, the utilization of natural resources, and the conditions which make for bodily health, the more dependent it becomes on the skilled advice and assistance of those who can bring their knowledge of science to bear on social and economic problems.

Certainly we must provide the requisite training and opportunities for those who are capable of advancing natural knowledge or acting as scientific experts. But it is no less important that we should secure for all who are of an age to receive it an education which will enable them to realize the vital need of a knowledge of science both for the individual and national well-being.

The reforms we have suggested are such as might without difficulty be carried out by employers, teachers, and education authorities working in cooperation. We should hope that they will have behind them the driving force of public opinion, stirred by the circumstances of the times to recognize the extent of our national deficiencies and the need for a national effort.

SUMMARY OF PRINCIPAL CONCLUSIONS.

GENERAL.

1. That natural science should be included in the general course of education of all up to the age of about 16. **§ 81**

2. That the tests of such a course, recommended in the report, should, with necessary modifications, be accepted as the normal qualification for entrance to the universities and professions. **§§ 34–40, 100, 188**

3. That real progress in education depends on a revolution in the public attitude toward the salaries of teachers and the importance of their training. **§§ 73, 77, 96**

4. That a large increase in the number of scholarships at all stages of education is necessary. **§§ 96 (ix), 137, 139, 142, 173, 177**

5. That periodical inspection should be compulsory on all schools and that this inspection should be under the direction of the State. **§ 33**

SECONDARY SCHOOLS.

6. That steps should be taken to secure for all pupils in State-aided secondary schools a school life beginning not later than 12 and extending at least up to 16. § 12

7. That science should be included in the general course of education for all pupils in public and other secondary schools up to the age of about 16, and that this general course should be followed by more specialized study, whether in science or in other subjects. § 31

8. That in all secondary schools for boys the time given to science should be not less than four periods in the first year of the course from 12 to 16 and not less than six periods in the three succeeding years. § 31

9. That increased attention should be given to the teaching of science in girls' schools. § 30

10. That in girls' schools with a 24-hour school week not less than 3 hours per week should be devoted to science in the period 12–16. § 25

11. That a larger number of State-aided schools should be encouraged to provide advanced instruction in science and that those which undertake advanced work should be staffed on a more generous scale. § 12

12. That in suitable localities there should be some school or schools where less time should be given to languages and additional time to English, science, mathematics, manual instruction, and drawing. § 12

13. That in the curricula of all preparatory schools provision should be made for the teaching of the elements of natural science as defined in section 22. § 22

14. That the usual age of entry into the public schools should be lowered to 13 and that this should be the maximum age for entrance scholarship examinations. § 13

15. That the elements of natural science should be a necessary subject in the entrance examination of public schools and that due weight should be given to this subject in the entrance scholarship examinations to public schools. § 22

16. That general education would be benefited by there being no division of schools into sides at the 12 to 16 stage. § 32

SCIENCE COURSE 12 TO 16.

17. That the science work for pupils under 16 should be planned as a self-contained course and should include, besides physics and chemistry, some study of plant and animal life. §§ 42, 53

18. That more attention should be directed to those aspects of the sciences which bear directly on the objects and experiences of everyday life. §§ 47, 48

19. That there should be as close correlation as possible between the teaching of mathematics and science at all stages in school work. § 45

20. That the present chaos of English weights and measures causes waste of time and confusion of thought and that there are strong educational reasons for the adoption of the metric system. § 55

21. That all through the science course stress should be laid on the accurate use of the English language. § 56

SCIENCE COURSE 16 TO 18.

22. That the amount of time devoted from 16 to 18 to the subject or subjects in which a pupil is specializing should be not less than one-half or more than two-thirds of the school week. § 60

23. That those specializing in science should continue some literary study and those specializing in literary subjects should give some time to science work of an appropriate kind. § 60

24. That courses in science of the kind suggested in section 64 should be provided for those specializing in subjects other than science. § 64

25. That pupils who do advanced work in science should be enabled to acquire a reading knowledge of French and German. § 65

26. That 18 should be the normal age of entry from secondary schools to the universities, and that the age limit for entrance scholarships at Oxford and Cambridge should be reduced to 18. §§ 57, 58

EXAMINATIONS.

27. That in the first school examination all candidates should be required to satisfy the examiners both in mathematics and in natural science. § 35

28. That in this examination there should be cooperation between the teachers and examiners, and weight should be attached to the pupil's school record. § 37

29. That the examinations in science for the leaving certificate of the Scottish education department should include a written test. § 86

TEACHERS IN SECONDARY SCHOOLS.

30. That it is essential that salaries and prospects of teachers in secondary schools should be substantially improved and a national pension scheme provided. § 73

31. That a full year's training shared between school and university is necessary for all teachers in secondary schools. § 77

32. That grants for teachers in training should be available for all suitable inspected secondary schools. § 77

33. That short courses of training of various types should be provided for teachers. § 79

LABORATORIES.

34. That the teachers in State-aided schools should be given freedom and responsibility in the selection and purchase of laboratory appliances up to a fixed annual amount. § 81

ELEMENTARY SCHOOLS.

35. That increased attention should be given to the provision of suitable instruction in science in the upper standards of elementary schools. § 88

36. That a larger number of students in training colleges should be encouraged to take advanced courses in science. § 89

37. That there should be in every elementary school a room in addition to the ordinary classroom accommodation available for work in science and other practical subjects. § 91

TECHNICAL EDUCATION.

38. That greater efforts should be made to develop and increase the provision of instruction in pure and in applied science in technical schools and institutions of all grades. That arrangements should be made for consultation between the various institutions giving secondary and technical instruction within any area. § 96

39. That many more scholarships are needed to enable technical students to pass on to the universities, and also to enable boys from junior technical schools (or their equivalent) and from evening schools to enter senior technical schools. § 96

40. That the position of junior technical schools in the educational system should be reconsidered. § 96

41. That it is essential that the salaries and prospects of teachers in technical schools should be substantially improved, and a national pension scheme provided for whole-time teachers. § 96

42. That in the proposed continuation classes provision should be made for instruction in science both in its general aspects and in its bearing on industry. § 95

MEDICINE.

43. That the first school examination should be recognized by the General Medical Council as qualifying for entrance into the medical profession. § 100

44. That students should be allowed to take the first professional examination in (a) chemistry and physics and (b) biology before entering the university or medical school. § 102

45. That more scholarships should be provided for candidates of both sexes tenable throughout the medical course. § 103

ENGINEERING.

46. That a thorough and practical training in mathematics and science is essential to the school education of engineers; it can not be replaced and need not be supplemented at school by practice in an engineering workshop. §§ 105–107

AGRICULTURE.

47. That specific instruction in agriculture or agricultural science should not be given in elementary or secondary schools, though under favorable circumstances a rural bias may be given to the work of a secondary school. §§ 114, 115, 117

48. That all county education authorities acting either singly or in cooperation should provide well-equipped farm institutes for their areas. § 116

ARMY.

49. That science should be an obligatory subject in the examination for entrance into the Royal Military College, Sandhurst, and should be included in the course of instruction in the college. § 120

50. That steps should be taken to improve the efficiency of the instruction in science at the Royal Military Academy, Woolwich. § 120

51. That more encouragement should be given to officers at later stages of their career to improve their scientific qualifications. §§ 120, 121, 123

HOME AND INDIA CIVIL SERVICE.

52. That an inquiry should be made as to the best methods of securing the services of scientific men for the purposes of the State in permanent posts and otherwise. § 131

53. That many permanent posts can best be filled by men selected not by the ordinary competitive examination, but at a riper age on the ground of high scientific qualifications and professional experience. § 128

54. That all candidates for the competitive examination for these services should supply evidence of a continuous course of training in science extending over several years. §§ 125–128

55. That, to insure sufficient catholicity in questions propounded in the viva voce examination, these examiners should include some representative of science. § 127

56. That if science be not required, as urged in recommendation No. 50 for the India civil service, it be a necessary supplementary subject for those who take either classics or modern languages as their main subject. § 129

57. That the age limits of the India civil service and the university entrance scholarship examinations should coincide so far as possible. § 129

UNIVERSITY EDUCATION.

58. That the universities should adopt the first school examination as the normal examination for admission and should abolish special matriculation examinations for candidates from schools. § 133

59. That Greek should not be retained as a necessary subject in responsions at Oxford or the previous examination at Cambridge. § 134

60. That the universities should make special arrangements to test the fitness for entrance of candidates who are over 23 years of age. § 135

DEGREE COURSES IN SCIENCE AT THE UNIVERSITIES.

61. That the universities of Oxford and Cambridge should arrange to provide more suitable courses in science for candidates who do not aim at an honors degree. § 144

62. That candidates for the university intermediate examinations should be allowed to take the examinations from school. § 148

63. That the universities should recognize the second school examination as alternative to the whole or part of their intermediate examinations. § 148

64. That it is desirable that a year spent mainly on research should form part of the work of university students preparing for careers concerned with science and its applications; but this should follow the course for a first degree in science. § 149

65. That scholarships are needed to enable a young graduate to spend a year or more in research, at his own or at another university. § 151

STATE AID TO THE UNIVERSITIES.

66. That large expenditure of public money is necessary to equip the universities for their work in pure and in applied science. §§ 151

67. That grants from public funds to the universities should be increased to allow the universities to make a substantial reduction in their fees. § 143

UNIVERSITY TEACHERS.

68. That the duties of junior demonstrators should be limited so that they can spend a considerable amount of time on research. § 157

69. That there should be posts of substantial value in university departments for senior men whose best work lies in teaching. § 157

70. That the heads of technological departments should be allowed to undertake private professional practice. § 153

SCOTTISH UNIVERSITIES.

71. That steps should be taken to remove the limitations which confine a large proportion of the old established bursaries to the faculty of arts. § 163

SCHOLARSHIPS AT SCHOOLS AND UNIVERSITIES.

72. That scholarships should be considered as distinctions awarded in recognition of intellectual merit and promise. § 136

73. That all scholarships should be of nominal value, to be supplemented according to need. §§ 23, 136

74. That where necessary the whole cost of a scholar's education and maintenance should be defrayed. §§ 23, 138

75. That scholarships at the universities should be tenable for at least three years, with a possibility of extension. § 138

76. That scholarships awarded by local education authorities should not be restricted to particular universities. § 138

77. That scholarships at the universities should be awarded on a wider range of subjects than at present. § 140

78. That the age limit for scholarships at Oxford and Cambridge should be 18 rather than 19. § 141

79. That scholarships should not be awarded on work done in large pass examinations for schools. § 140

80. That scholarships to the universities for candidates from technical and evening schools should be awarded without an age limit, and for the present on a limited range of subjects. § 142

81. That the number of scholarships at the women's colleges should be increased. § 29

82. That loan funds should be established to enable senior students to obtain professional training. §§ 103, 143

SUPPLY OF TRAINED SCIENTIFIC WORKERS.

83. That concerted efforts should be made by employers, teachers, local education authorities, and the State to increase the flow of capable students to the universities and higher technical institutions with a view to securing the larger supply of trained scientific workers required for industrial and other purposes. §§ 168–177

APPENDIX.

A. QUESTIONNAIRE ADDRESSED TO PUBLIC SCHOOLS.

The schools represented on the Headmasters' Conference which are not in receipt of Government grant were asked to supply information as to the position of natural science in their curricula and as to their arrangements for giving instruction in it. On account of the want of published information as to these schools, it was thought desirable to send to them a long and elaborate questionnaire dealing with the details of school organization. The main points with which the questions were concerned were the following:

(*a*) *Previous education of boys* at preparatory schools or in junior departments; examinations for admission.

(*b*) *General school organization.*—Statistics as to the numbers of boys leaving after the age of 16; division of the school into sides and arrangements for the transfer from one side to another; classification of boys into sets for science, or for mathematics, or for both subjects.

(*c*) *Curricula.*—Subjects taught and time allotted to them in the various parts of the school; the position of science in the curriculum for all boys and for boys who wish to devote a large amount of time to it; arrangements made for boys who pass on to medicine or to engineering or to agriculture, and for boys who work for university intermediate examinations at school.

(*d*) *Scholarships awarded by the school.*—(1) At entrance, (2) to boys already at the school, (3) to boys passing on to universities or higher technical institutions; distribution of these scholarships to different studies.

(*e*) *Scholarships gained after leaving school.*—(1) By school-entrance scholars, (2) by other boys in the various subjects. Admissions to the Royal Military Academy, Woolwich.

(*f*) *Staff.*—Statistics as to the numbers of masters teaching science only, or mathematics only, or both subjects; other subjects taught by science masters; supervision of science teaching by a special master responsible for organizing it.

(*g*) *Laboratories and equipment.*—Number and nature of existing laboratories; their adequacy if more science teaching were undertaken; the provision of laboratory assistants; special fees for laboratory work.

B. QUESTIONNAIRE TO CHEMICAL MANUFACTURERS.

1. Into what grades or classes would you divide your chemically trained employees?

2. At what age do you prefer these classes to enter the works, and from what educational institutions—secondary schools, technical colleges, universities—are they drawn?

3. How far do you find their previous chemical training of use to them? What modifications in their scientific training would you suggest in order to make them more useful?

4. How far do you consider that some previous knowledge of engineering would be of advantage to them?

5. What rates of pay in normal times would you consider adequate (i) for a boy entering at 16; (ii) for a young man after a college career; (iii) for a man after having done a year or more of research work?

6. Do you consider that some previous scientific knowledge and training is desirable for those employees who are engaged in the buying and selling departments of your business, as distinguished from those engaged in work directly related to processes of manufacture? If so, in what would this training consist?

7. What facilities, if any, are provided for the continued education in science, whether in works schools or elsewhere, of your employees after they enter your service? Are the courses in science provided in the day or evening classes which your employees attend such as to give them further scientific education which is of direct value to them in their work?

8. Have you any difficulty in obtaining suitably trained men in all grades?

9. How far would you consider it possible or advantageous that there should be cooperation in research work between chemical works and laboratories of educational institutions?

C. QUESTIONNAIRE TO ENGINEERING FIRMS.

1. Having in view the character of the work they are called upon to undertake, what are the different grades or classes in which your employees are placed when they enter the service of your firm?

2. At what ages do you prefer these classs to enter?

3. Do lads or young men who have spent more time than usual on their education find any difficulty in entering your employment?

4. From what educational institutions are they drawn—elementary, secondary, or technical schools, university colleges?

5. Do you hold an entrance examination, or is any paper qualification necessary or desirable for admission to any grade?

6. What modification, if any, in their previous education would you suggest in order to make them more useful?

7. Do you think that all your employees who have been at school until 16 should have received, besides a general education including elementary mathematics and drawing, training in the principles of physics and chemistry?

8. Have you any definite system of joint training in the works and technical school or university (such as attending the technical schools for two afternoons a week, or a sandwich system for longer periods)? If so, are the results reasonably satisfactory and in what directions might improvements be made?

9. To what extent do the facilities offered at the local technical schools supply the need for part-time education?

10. Has any lack of such facilities caused you difficulty in selecting foremen and men in other responsible positions from among your own employees?

11. Do you make any periodical assessment of the progress of apprentices, both in the shops and in their theoretical training? And is any means afforded of promotion of apprentices from one grade to another?

12. Before the war had you any difficulty in obtaining suitably trained apprentices in any grade?

13. Any additional observations or suggestions bearing on the following passage in the Committee's terms of reference: "To advise what measures are needed to promote the study of science, regard being had to . . . the interests of the trades, industries, and professions which particularly depend upon applied science.

D. QUESTIONNAIRE ADDRESSED TO REPRESENTATIVES OF AGRICULTURE.

1. *Preparation for the agricultural college.*—What preliminary training in science, if any, do you consider desirable in the secondary schools for boys who are going to enter an agricultural college or department? Should this training consist of specific instruction in chemistry, physics, botany, or zoology, or would you prefer a more generalized acquaintance with the whole field of the physical and natural sciences? Would you wish that the school course should embrace any instruction in agriculture or agricultural science?

2. *Preparation of boys who will attend farm institutes for short technical courses of agriculture, and who intend to become working farmers or bailiffs.*—If these boys attend a country secondary school up to the age of 16 or thereabouts before coming to the farm institute, what science teaching should they receive at school as a preparation for the later technical instruction?

3. Have you any experience of secondary schools with a rural bias? Do you consider that the country grammar school can profitably develop an agricultural side or bias, either as an alternative to the farm institute or in preparation for it, the end being the training of the working farmer, who will not usually go to the agricultural college?

4. How do you consider scientific or technical instruction can best be given to the future small holder or agricultural laborer? Have you any experience of continuation schools, which carry on the boy's education after he has left the primary school and while he is at work on the farm? What form of instruction, agricultural or scientific, do you consider can best be given under these conditions?

5. Have you any suggestions to make concerning the training of the teachers who will be required for the above purposes?

The committee will welcome any further suggestions with regard to the character or extent of the scientific training of any of the classes who will be engaged in the working, management, or administration of land.

E. QUESTIONNAIRE ADDRESSED TO UNIVERSITIES AND UNIVERSITY COLLEGES IN GREAT BRITAIN.

1. To what extent is it desirable that a somewhat prolonged elementary training in science, with laboratory work, should have been an obligatory part of the secondary school education of all students at some time previous to their entering the university, and does this apply to the needs of all faculties?

2. In view of the development of more advanced scientific teaching in the highest classes of secondary schools, is it now desirable to make arrangements which will relieve students from being required, on their entrance to the university, to repeat work which they have already done at school, e. g.:

(a) Should the intermediate examination for the B. Sc. degree and the first M. B. examination be allowed to be taken from school? If so, on what security as to adequate teaching and laboratory work in the school course?

(b) Is it desirable that on entering the university every student of science and of medicine should go through one year's course in pure science (beginning at the level already reached at school) preparatory to more specialized study?

(c) Would it be desirable to allow well-prepared candidates to take the first part of their degree examination at an earlier stage than at present?

3. With special regard to the requirements of science, is there need for further financial assistance from public funds for entrance scholarships which

would encourage and enable an increased number of students to undertake a course of study for a degree or diploma at the university?

What should be the value of such scholarships; their length of tenure; what extension of tenure should be possible in approved cases; how, and by which authority, should the scholarships be awarded; should the scholarships, if awarded by open competitive examination, be of small money value, to be supplemented according to the needs or circumstances of the candidate after confidential inquiry?

4. Is it desirable to give to the winners of entrance scholarships, and of major county scholarships, freedom of choice between the various degree courses offered by the university? Should students be required to take special subjects in the examinations for entrance scholarships and for county major scholarships according to the degree course which they intend to pursue at the university?

5. Is the present matriculation examination satisfactory for older students, say, of over 21 years of age, in whose career there has been a long interval between the close of their school course and their decision to seek admission to the university?

6. Are the present degree courses in science found to encourage in the students something of the research spirit? Should some research work be required as part of the course for students seeking honors in science?

7. Is it desirable to provide a degree course which combines more fully mathematics and some branch of science?

8. Do the present degree courses in pure science sufficiently meet the needs of those students who will later seek employment in scientific posts connected with industry?

9. It has been suggested that there are some students whose needs would best be met by the study of subjects which do not constitute a recognized group provided for in the regulations for any one degree examination; and that arrangements should be made so that a satisfactory aggregate of work in such subjects should qualify for a degree. Do you approve of this suggestion?

Are any new combinations desirable among the courses for a degree in science, e. g., of chemistry and engineering in preparation for certain industrial posts?

10. Is it desirable that further encouragement should be given to students of applied science to study during their university course—(a) modern language? (b) economics?

11. Is further provision necessary for the encouragement of advanced courses of study and research on the part of men and women who have already graduated, e. g.:

(a) By extension of laboratories;

(b) By the establishment of new professorships or lectureships;

(c) By the offer of a new degree, common to all faculties, to be obtained after two years' advanced study, including independent investigation;

(d) By the provision of additional fellowships or graduate scholarships;

(e) By facilities for the publication of the results of research?

12. Would the university be in favor of increased facilities for students, graduate and undergraduate, to pass from one university to another for the study of special subjects?

13.—(a) In the older universities would the interests of the study of pure science be furthered by increased facilities for the study of applied science?

(b) In some universities of more recent foundation is it desirable to strengthen the facilities for research in pure science in the interests of the study of applied science?

(c) Is it desirable that new chairs or other teaching or research posts in pure or applied science should be established, and that other increased facilities for the study of these subjects should be provided?

14. Are the salaries and the prospects of promotion offered within the university or available elsewhere for junior members of the scientific staffs of universities adequate to secure effective service and the new recruits required?

15. What means have been found most effective in securing cooperation between the various industries and those scientific and other departments of the university which are most closely connected with their respective needs, e. g.:

(a) Establishment of advisory committees: their composition and duties;
(b) Allowance of private professional practice on the part of professors and other members of the university staff;
(c) Industrial research studentships in the university laboratories;
(d) Provision of special facilities in the university laboratories for research conducted under conditions of privacy on behalf of private firms or combinations of firms;
(e) Establishment of appointments committee;
(f) Facilities by which students of applied science may have a period of experience in factories, etc.?

16. What form of preparation in the practice of teaching is offered to students intending to become science masters or mistresses in schools? At what stage or stages should such a course be taken? Are there sufficient scholarships for students taking such a course? Are special courses of lectures and laboratory work open at the university to those who are already working as teachers of science in secondary schools? If so, what is the best time of year for such courses, and what should be the duration of the course?

17. Do the conditions laid down by the committee of the privy council for scientific and industrial research enable full use to be made of the scientific resources of the university in the prosecution of research?

18. Are larger subsidies from the treasury now required (a) for the adequate development of the work of the university in pure and applied science; (b) for the general purposes of the university?

Is it desirable that the Government should make building and equipment grants for the provision of new laboratories in the English universities?

19. Are steps taken to secure interchange of views and experience between the members of the university staff and the headmasters and headmistresses of secondary schools and the teaching staffs of technical colleges on educational matters, including the careers open to students?

20. Has there been collaboration in teaching or research between members of the scientific staffs of the university, of the technical schools, and of the secondary schools?

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