ON THE

/2

BEST MEANS FOR PROMOTING

SCIENTIFIC EDUCATION IN SCHOOLS;

A REPORT

PRESENTED TO

THE GENERAL COMMITTEE

OF THE

BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE
AT DUNDEE, 1867.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1868.

ON

THE BEST MEANS FOR PROMOTING

SCIENTIFIC EDUCATION IN SCHOOLS.

ON THE

BEST MEANS FOR PROMOTING

SCIENTIFIC EDUCATION IN SCHOOLS;

A REPORT

PRESENTED TO

THE GENERAL COMMITTEE

OF THE

BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE
AT DUNDEE, 1867.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1868.

PREFACE.

THE importance of introducing Natural Science into the higher Schools of this country was brought before two Sections of the Meeting of the British Association at Nottingham, 1866, and a proposal to appoint a Committee for the purpose of considering the best method of extending Scientific Education in Schools was referred to the Council of the Association.

At a meeting of the Council, held on November 15, 1866, a Committee was appointed for the purpose of inquiring into the subject.

This Committee consisted of the General Officers of the Association, the Trustees, the Rev. F. W. Farrar, M.A., F.R.S., the Rev. T. N. Hutchinson, M.A., Professor Huxley, F.R.S., Mr. Joseph Payne, Professor Tyndall, F.R.S., and Mr. J. M. Wilson, M.A.

A Report drawn up by the Rev. F. W. Farrar, Mr. G. Griffith, Prof. Huxley, Prof. Tyndall, and Mr. J. M. Wilson, and revised by the Committee, was presented to the Council and received by them on March 9, 1867.

At a subsequent special meeting the Report was considered by the Council, and it was resolved to adopt the recommendations and to submit the Report to the General

Committee of the Association. At the Meeting at Dundee, September 1867, the Report was received by the General Committee, and the following Resolution was passed:—

That the President of the Association be requested to communicate the Report of the Committee appointed by the Council to consider the best means for promoting Scientific Education in Schools to the President of the Privy Council, and to the Parliamentary Committee, on the part of the Association, and that the General Officers be authorized to give publicity to the Report.

TABLE OF CONTENTS.

REPORT.

1. A DEMAND for the introduction of Science into the modern system of education has increased so steadily during the last few years, and has received the approval of so many men of the highest eminence in every rank and profession, and especially of those who have made the theory and practice of education their study, that it is impossible to doubt the existence of a general, and even a national desire to facilitate the acquisition of some scientific knowledge by boys at our Public and other Schools.

2. We would point out that there is already a *general* recognition of Science as an element in liberal education. It is encouraged, to a greater or less degree, by the English, Scotch, and Irish Universities, it is recognized as an optional study by the College of Preceptors, it forms one of the subjects in the Local Examinations of Oxford and Cambridge; and it has even been partially introduced into several Public Schools. We have added an appendix containing information on some of these points*; but the means at present adopted in our Schools and Universities for making this teaching effective, are, in our opinion, capable of great improvement.

3. That general education in Schools ought to include

* See Appendix A.

some training in Science is an opinion that has been strongly urged on the following grounds:—

As providing the best discipline in observation and collection of facts, in the combination of inductive with deductive reasoning, and in accuracy both of thought and language.

Because it is found in practice to remedy some of the defects of the ordinary school education. Many boys, on whom the ordinary school studies produce very slight effect, are stimulated and improved by instruction in science; and it is found to be a most valuable element in the education of those who show special aptitude for literary culture.

Because the methods and results of Science have so profoundly affected all the philosophical thought of the age, that an educated man is under a very great disadvantage if he is unacquainted with them.

Because very great intellectual pleasure is derived in after life from even a moderate acquaintance with Science.

On grounds of practical utility as materially affecting the present position and future progress of civilization.

This opinion is fully supported by the popular judgment. All who have much to do with the parents of boys in the upper classes of life are aware that, as a rule, they value education in Science on some or all of the grounds above stated.

4. There are difficulties in the way of introducing Science into schools, and we shall make some remarks on them; they will be found, we believe, to be by no means insuperable.

First among these difficulties is the necessary increase of expense; for if science is to be taught, at least one additional master must be appointed, and it will be necessary in some cases to provide him with additional school-rooms and a fund for the purchase of apparatus. It is obvious that the money which will be requisite for both the initial and current expenses must in general be obtained by increasing the school fees. This difficulty is a real but not a fatal one. In a wealthy country like England a slight increase in the cost of education will not be allowed (in cases where it is unavoidable) to stand in the way of what is generally looked on as an important educational reform; and parents will not be unwilling to pay a small additional fee if they are satisfied that the instruction in Science is to be made a reality.

Another ground of hesitation is the fear that the teaching of Science will injure the teaching in classics. But we do not think that there need be the slightest apprehension that any one of the valuable results of a classical education will be diminished by the introduction of Science. It is a very general opinion, in which schoolmasters heartily concur, that much more knowledge and intellectual vigour might be obtained by most boys, during the many years they spend at school, than what they do, as a matter of fact, obtain. It should, we think, be frankly acknowledged, and indeed few are found who deny it, that an exclusively classical education, however well it may operate in the case of the very few who distinguish themselves in its curriculum, fails deplorably for the majority of minds. As a general rule the small proportion of boys who leave our schools for the Universities consists undeni-

ably of those who have advanced furthest in classical studies; and judging the existing system of education by these boys alone, we have to confess that it frequently ends in astonishing ignorance. This ignorance, often previously acknowledged and deplored, has been dwelt on with much emphasis, and brought into great prominence by the recent Royal Commission for Inquiry into our Public Schools. We need not fear that we shall do great damage by endeavouring to improve a system which has not been found to yield satisfactory results. And we believe, further, that the philological abilities of the very few who succeed in attaining to a satisfactory knowledge of classics will be rather stimulated than impeded by a more expansive training.

Lastly, it may be objected that an undue strain will be put upon the minds of boys by the introduction of the proposed subjects. We would reply that the same objections were made, and in some schools are still made, to the introduction of Mathematics and Modern Languages, and are found by general experience to have been untenable. A change of studies, involving the play of a new set of faculties, often produces a sense of positive relief; and at a time when it is thought necessary to devote to games so large a proportion of a boy's available time, the danger of a general over-pressure to the intellectual powers is very small, while any such danger in individual cases can always be obviated by special remissions. We do not wish to advocate any addition to the hours of work in schools where it is believed that they are already as numerous as is desirable; but in such schools some hours a week could still be given up to science, by a curtailment

of the vastly preponderant time at present devoted to classical studies, and especially to Greek and Latin Composition.

5. To the selection of the subjects that ought to be included in a programme of scientific instruction in public schools we have given our best attention; and we would make the following remarks on the principles by which we have been guided in the selection that we shall propose.

There is an important distinction between scientific *information* and scientific *training*; in other words, between general literary acquaintance with scientific facts and the knowledge of methods that may be gained by studying the facts at first hand under the guidance of a competent teacher. Both of these are valuable; it is very desirable, for example, that boys should have some general information about the ordinary phenomena of nature, such as the simple facts of Astronomy, of Geology, of Physical Geography, and of elementary Physiology. On the other hand, the scientific habit of mind, which is the principal benefit resulting from scientific training, and which is of incalculable value whatever be the pursuits of after life, can better be attained by a thorough knowledge of the facts and principles of one science than by a general acquaintance with what has been said or written about many. Both of these should coexist, we think, at any school which professes to offer the highest liberal education; and at *every* school it will be easy to provide at least for giving some scientific information.

I. The subjects that we recommend for scientific *information* as distinguished from training, should comprehend a general description of the solar system; of the form and

physical geography of the earth, and of such natural phenomena as tides, currents, winds, and the causes that influence climate; of the broad facts of Geology; of elementary Natural History, with especial reference to the useful plants and animals; and of the rudiments of Physiology. This is a kind of information which requires less preparation on the part of the teacher; and its effectiveness will depend on his knowledge, clearness, method, and sympathy with his pupils. Nothing will be gained by circumscribing these subjects by any general syllabus; they may safely be left to the discretion of the masters who teach them.

II. And for scientific *training* we are decidedly of opinion that the subjects which have paramount claims are Experimental Physics, Elementary Chemistry, and Botany.

i. The science of Experimental Physics deals with subjects which come within the range of every boy's experience; it embraces the phenomena and laws of light, heat, sound, electricity, and magnetism, the elements of mechanics, and the mechanical properties of liquids and gases. The thorough knowledge of these subjects includes the practical mastery of the apparatus employed in their investigation. The study of experimental physics involves the observation and colligation of facts, and the discovery and application of principles. It is both inductive and deductive. It exercises the attention and the memory, but makes both of them subservient to an intellectual discipline higher than either. The teacher can so present his facts as to make them suggest the principles which underlie them, while, once in possession of the principle, the learner may be stimulated to deduce from it results which lie

beyond the bounds of his experience. The subsequent verification of his deduction by experiment never fails to excite his interest and awaken his delight. The effects obtained in the classroom will be made the key to the explanation of natural phenomena,—of thunder and lightning, of rain and snow, of dew and hoar-frost, of winds and waves, of atmospheric refraction and reflexion, of the rainbow and the mirage, of meteorites, of terrestrial magnetism, of the pressure and buoyancy of water and of air. Thus the knowledge acquired by the study of experimental physics is, of itself, of the highest value, while the acquisition of that knowledge brings into healthful and vigorous play every faculty of the learner's mind. Not only are natural phenomena made the objects of intelligent observation, but they furnish material for thought to wrestle with and to overcome, the growth of intellectual strength being the sure concomitant of the enjoyment of intellectual victory. We do not entertain a doubt that the competent teacher who loves his subject and can sympathize with his pupils, will find in experimental physics a store of knowledge of the most fascinating kind, and an instrument of mental training of exceeding power.

ii. Chemistry is remarkable for the comprehensive character of the training which it affords. Not only does it exercise the memory and the reasoning powers, but it also teaches the student to gather by his own experiments and observations the facts upon which to reason.

It affords a corrective of each of the two extremes against which real educators of youth are constantly struggling. For on the one hand it leads even sluggish or uncultivated minds from simple and interesting obser-

vations to general ideas and conclusions, and gives them a taste of intellectual enjoyment and a desire for learning. On the other hand, it checks over-confidence in mere reasoning, and shows the way in which valid extensions of our ideas grow out of a series of more and more rational and accurate observations of external nature.

It must not, however, be supposed that all so-called teaching of chemistry produces results of this kind. Young men do occasionally come up to public examinations with a literary acquaintance with special facts and even principles of chemistry, sufficient to enable them to describe those facts from some one point of view and to enunciate the principles in fluent language, and who yet know nothing of the real meaning of the phrases which they have learnt. Such mere literary acquaintance with scientific facts is in chemistry an incalculable evil to the student if he be allowed to mistake it for science.

Whether the student is to learn much or little of chemistry his very first lessons must be samples of the science. He must see the chief phenomena which are described to him, so that the words of each description may afterwards call up in his mind an image of the thing; he must make simple experiments, and learn to describe accurately what he has done and what he has observed; he must learn to use the knowledge which he has acquired before proceeding to the acquisition of more; and he must rise gradually from well-examined facts to general laws and theories.

Among the commonest non-metallic elements and their simplest compounds the teacher in a school will find abundant scope for his chief exertions.

iii. Botany has also strong claims to be regarded as a subject for scientific training. It has been introduced into the regular school course at Rugby (where it is the first branch of Natural Science which is studied); and the voluntary pursuit of it is encouraged at Harrow and at some other schools with satisfactory results. It only requires observation, attention, and the acquisition of some new words; but it also evolves the powers of comparison and colligation of facts in a remarkable degree. Of all sciences it seems to offer the greatest facilities for observation in the fields and gardens; and to this must be added the fact that boys, from their familiarity with fruits, trees, and flowers, start with a considerable general knowledge of botanical facts. It admits therefore preeminently of being taught in the true scientific method. The teaching of Science is made really valuable by training the learner's mind to examine into his present knowledge, to arrange and criticise it, and to look for additional information. The science must be begun where it touches his past experience, and this experience must be converted into scientific knowledge. The discretion of the teacher will best determine the range of Botany at which it is desirable to aim.

6. The modes of giving instruction in the subjects which we have recommended are reducible to two. I. A compulsory system of instruction may be adopted, similar to that which exists at Rugby, where science has now for nearly three years been introduced on precisely the same footing as Mathematics and Modern Languages, and is necessarily taught to all boys. II. A voluntary system may be encouraged, as has been done for many years at

Harrow, where scientific instruction on such subjects as have been enumerated above is now given in a systematic series of lectures, on which the attendance of all boys who are interested in them is entirely optional.

Of these systems it is impossible not to feel that the compulsory system is the most complete and satisfactory. The experience of different schools will indicate how it may best be adopted, and what modifications of it may be made to suit the different school arrangements. It will often be very desirable to supplement it by the voluntary system, to enable the boys of higher scientific ability to study those parts of the course of Experimental Physics which will rarely, if ever, be included in the compulsory school system. Lectures may also be occasionally given by some non-resident lecturer with a view of stimulating the attention and interest of the boys. We add appendices containing details of these two systems as worked at Rugby and Harrow *, and we believe that a combination of the two would leave little or nothing to be desired.

The thorough teaching of the Physical Sciences at schools will not, however, be possible unless there is a general improvement in the knowledge of Arithmetic. At present many boys of thirteen and fourteen are sent to the Public Schools almost totally ignorant of the elements of Arithmetic, and in such cases they gain only the most limited and meagre knowledge of it; and the great majority enter ill-taught. It is a serious and lasting injury to boys so to neglect Arithmetic in their early education; it arises partly from the desire of the masters of preparatory schools to send up their boys fitted to take a good place in the

* See Appendices B and C.

classical school, and from the indifference of the public schools themselves to the evil that has resulted.

7. With a view to the furtherance of this scheme, we make the following suggestions:—

i. That in all schools Natural Science be one of the subjects to be taught, and that in every Public School at least one Natural Science master be appointed for the purpose.

ii. That at least three hours a week be devoted to such scientific instruction.

iii. That Natural Science should be placed on an equal footing with Mathematics and Modern Languages in affecting promotions, and in winning honours and prizes.

iv. That some knowledge of Arithmetic should be required for admission into all Public Schools.

v. That the Universities and Colleges be invited to assist in the introduction of scientific education, by making Natural Science a subject of examination, either at Matriculation, or at an early period of a University career.

vi. That the importance of appointing Lecturers in Science, and offering Entrance Scholarships, Exhibitions, and Fellowships for the encouragement of scientific attainments be represented to the authorities of the Colleges.

With reference to the last two recommendations, we would observe that, without the cooperation of the Universities, Science can never be effectively introduced into School education. Although not more than 35 per cent., even of the boys at our great Public Schools, proceed to

the University, and at the majority of schools a still smaller proportion, yet the curriculum of a public school course is almost exclusively prepared with reference to the requirements of the Universities and the rewards for proficiency that they offer. No more decisive proof could be furnished of the fact that the Universities and Colleges have it in their power to alter and improve the whole higher education of England.

APPENDIX A.

I. Oxford.

The Natural-Science School at Oxford was established in the year 1853. By recent changes the University allows those who have gained a first, second, or third class in this school to graduate without passing the classical school, provided they have obtained honours, or have passed in three books at least, at the second classical examination, viz. moderations (which is usually passed in the second year of residence): honours in this school are thus placed on an equality with classical honours. The first classical examination, "responsions," is generally passed in the first term of residence. Arithmetic and two books of Euclid, or algebra up to simple equations, are a necessary part of this examination.

The University offers ample opportunities for the study of physics, chemistry, physiology, and other branches of natural science. At present only a few of the Colleges have lectures on this subject; while for classics and mathematics every College professes to have an adequate staff of teachers. At Christ Church, however, a very complete chemical laboratory has been lately opened.

A junior studentship at Christ Church and a demyship at Magdalen College, tenable for five years, are, by the statutes of those Colleges, awarded annually for proficiency in natural science. A scholarship, tenable for three years, lately founded by Miss Brackenbury at Balliol College for the promotion of the study of Natural Science, will be given away every two years. With the exception of Merton College, where a scholarship is to be shortly given for proficiency in natural science, no College has hitherto assigned any scholarships to natural science. The number of scholarships at the Colleges is stated to be about 400, varying in annual value from £100 to £60. With these should be reckoned College exhibitions *, to the number of at least 220, which range in annual value from £145 to £20, and exhibitions awarded at school, many of which are of considerable value.

The two Burdett-Coutts geological scholarships, tenable for two years, and of the annual value of £75, are open to all members of the University who have passed the examination for the B.A. degree, and have not exceeded the 27th term from their matriculation. Every year a fellowship of £200 a year, tenable for three years (half of which time must be spent on the Continent) on Dr. Radcliffe's foundation, is at present competed for by candidates who, having taken a first class in the school of natural science, propose to enter the medical profession.

At Christ Church two of the senior studentships (fellow-

* At Magdalen College there will be twenty exhibitions tenable for five years, and of the value of £75 a year, to be held by persons in need of support at the University; in the election to these, "the subjects of examination, for one exhibition at least in each year, shall be mathematics and physical science alternately."

ships) are awarded for proficiency in natural science: at the examination for one of these, chemistry is the principal subject, and for the other physiology.

At Magdalen College it is provided that, for twenty years from the year 1857, every fifth fellowship is assigned to mathematics and physical science alternately. In the statutes of this and of every College in Oxford (except Corpus, Exeter, and Lincoln*) the following clause occurs:—"The system of examinations shall always be such as shall render fellowships accessible, from time to time, to excellence in every branch of knowledge for the time being recognized in the schools of the University." This clause, so far as it relates to the study of natural science, has been acted on only by Queen's College and at Merton College, where a natural-science fellowship will be filled up during the course of the present year.

At Pembroke College one of the two Sheppard fellows must proceed to the degree of Bachelor and Doctor of Medicine in the University. At the late election to this fellowship natural science was the principal subject in the

* These Colleges exercised the powers of making statutes granted to them by the Oxford University Act of 1854, 17 and 18 Vic. cap. 81. In the statutes of Exeter College it is provided that, in the election of Fellows, "preference shall be given to those candidates in whom shall be found the highest moral and intellectual qualifications, such intellectual qualifications having been tested by an examination in such subjects as the College from time to time shall determine." In the statutes of Lincoln College the following clause occurs:—"Pateat autem societas non iis tantum, qui in literis Græcis et Latinis se profecisse probaverint, sed etiam aliarum bonarum artium peritis juvenibus." And in the statutes of Corpus Christi College, "Quicunque se candidatos offerant examinentur in bonis literis et scientiis, sicut Præsidenti et sociis videbitur."

examination. The number of College fellowships in Oxford is at present about 400.

II. Cambridge.

It is important to distinguish between the University and the Colleges at Cambridge as at Oxford.

There is a natural-science tripos in which the University examines in the whole range of natural sciences, and grants honours precisely in the same manner as in classics or mathematics.

The University also recognizes the natural sciences as an alternative subject for the ordinary degree. As the regulations on this point are comparatively recent, it will be well to state them here.

A student who intends to take an ordinary degree without taking honours has to pass three examinations during his course of three years,—the first, or previous examination, a year's residence, in Paley, Latin, Greek, Euclid, and arithmetic, and one of the Gospels in Greek; the second, or general examination, towards the end of his second year, in the Acts of the Apostles in Greek, Latin, Greek, Latin prose composition, algebra, and elementary mechanics; and the third, or special examination, at the end of his third year, in one of the following five subjects: —1. Theology; 2. Moral Science; 3. Law; 4. Natural Science; 5. Mechanism and applied science.

In the natural-science examination a choice is given of chemistry, geology, botany, and zoology.

There are only five Colleges in Cambridge that take any notice of Natural Science, namely, King's, Caius, Sidney

Sussex, St. John's, and Downing. At King's two exhibitions have been given away partly for proficiency in this subject; but there are no lectures, and it is doubtful whether similar exhibitions will be given in future. At Caius there is a medical lecturer and one scholarship given away annually for Anatomy and Physiology. At Sidney Sussex two scholarships annually are given away for mathematics and natural science, and a prize of £20 for scientific knowledge: there is also a laboratory for the use of students. At St. John's there is a chemical lecturer and laboratory; and though at this College there is no sort of examination in natural science, either for scholarships or fellowships, it is believed distinction in the subject may be taken into account in both elections. Downing was founded with "especial reference to the studies of Law and Medicine;" there is a lecturer here in medicine and natural science, and in the scholarship examinations one paper in these subjects; no scholarship is appropriated to them, but they are allowed equal weight with other subjects in the choice of candidates. It is believed that the same principle will govern the election to fellowships in this College, though no fellowship has yet been given for honours in natural science. We believe that, owing to the new University regulations (mentioned above), the authorities of Trinity College have determined to appoint a lecturer in natural science; the matter is under deliberation in other Colleges, and it is not improbable that the same considerations will induce them to follow this example.

It must always be remembered that the practice is rare in Cambridge of appropriating fellowships and scholarships

to special subjects. At present public opinion in the University does not reckon scientific distinction as on a par with mathematical or classical; hence the progress of the subject seems enclosed in this inevitable circle—the ablest men do not study natural science because no rewards are given for it, and no rewards are given for it because the ablest men do not study it. But it may be hoped that the disinterested zeal of teachers and learners will rapidly break through this circle; in that case the subject may be placed on a satisfactory footing without any express legislative provision.

III. The University of London.

At the University of London the claims of science to form a part of every liberal education have long been recognized. At the Matriculation Examination the student is required to show that he possesses at least a popular knowledge of the following subjects:—

a. In *Mechanics*: the composition and resolution of forces; the mechanical powers; a definition of the centre of gravity; and the general laws of motion.

b. In *Hydrostatics, Hydraulics,* and *Pneumatics*: the pressure of liquids and gases; specific gravity; and the principles of the action of the barometer, the siphon, the common pump and forcing-pump, and the air-pump.

c. In *Acoustics*: the nature of sound.

d. In *Optics*: the laws of refraction and reflection, and the formation of images by simple lenses.

e. In *Chemistry*: the phenomena and laws of heat; the

chemistry of the non-metallic elements; general nature of acids, bases, &c.; constitution of the atmosphere; composition of water, &c.

At the examination for the degree of B.A. a more extensive knowledge of these subjects is required, and the candidate is further examined in the following branches of science:—

f. *Astronomy*: principal phenomena depending on the motion of the earth round the sun, and on its rotation about its own axis; general description of the solar system, and explanation of lunar and solar eclipses.

g. *Animal Physiology*: the properties of the elementary animal textures; the principles of animal mechanics; the processes of digestion, absorption, assimilation; the general plan of circulation in the great divisions of the animal kingdom; the mechanism of respiration; the structure and actions of the nervous system; and the organs of sense.

Besides the degree examination there is also an examination for *honours* in mathematics and natural philosophy, in which, of course, a much wider range of scientific knowledge is required.

We would venture to remark that, if a similar elementary acquaintance with the general principles of sciences were required for matriculation at Oxford and Cambridge, it is certain that they would at once become a subject of regular teaching in all our great public schools.

There are also two specially scientific degrees, a Bachelor of Science and a Doctor of Science. For the B.Sc. there are two examinations of a general but highly scientific cha-

racter. The degree of D.Sc. can only be obtained after the expiration of two years subsequent to taking the degree of B.Sc. The candidate is allowed to select one *principal subject*, and to prove his thorough practical knowledge thereof, as well as a general acquaintance with other subsidiary subjects.

IV. The College of Preceptors.

In the diploma examinations of the College of Preceptors, one branch of science, viz. either chemistry, natural history, or physiology, is required as a *necessary* subject for the diploma of a *Fellow*. In the examinations for the lower diploma of Associate or Licentiate some branch of science *may* be taken up by candidates at their own option. The Council recently decided to offer a prize of three guineas half-yearly for the candidate who showed most proficiency in science, and who at the same time obtained a second class in the other subjects.

In the examinations of pupils of schools, natural philosophy, chemistry, and natural history are optional subjects only, and are not *required* for a certificate for the three classes. Two prizes are given to those candidates who obtain the highest number of marks in these subjects at the half-yearly examinations; and it is an interesting fact that last year, out of a total of 651 candidates, 100 brought up natural history, and 36 brought up chemistry as subjects for examination. Two additional prizes were consequently awarded.

V. The French Schools.

In France the "Lycées" correspond most nearly to our

Public Schools, and for many years science has formed a distinct part of their regular curriculum. A strong impulse to the introduction of scientific teaching into French schools was given by Napoleon I., and since that time we believe that no French school has wholly neglected this part of education. The amount of time given to these subjects appears to average two hours in every week.

The primary education is that which is given to all alike, whatever may be their future destination in life, up to the age of eleven or twelve years. After this period there is a "bifurcation" in the studies of boys. Those who are intended for business or for practical professions lay aside Greek and Latin, and enter on a course of "special secondary instruction." In this course mechanics, cosmography, physics, chemistry, zoology, botany, and geology occupy a large space; and the authorized official programmes of these studies are very full, and are drawn up with the greatest care. The remarks and arguments of the Minister of Public Instruction (Mons. Duruy) and others, in the "Programmes officiels &c. de l'enseignement secondaire spécial," are extremely valuable and suggestive; and we recommend the syllabuses of the various subjects, which have received the sanction of the French Government, as likely to afford material assistance to English teachers in determining the range and limits of those scientific studies at which, in any special system of instruction, they may practically aim. The "Enseignement secondaire spécial" might very safely be taken as a model of what it is desirable to teach in the "modern departments" which are now attached to some of our great schools.

The boys who are destined to enter the learned pro-

fessions continue a classical course, in which, however, much less time is devoted to classical composition than is the case in our Public Schools. Nor is science by any means neglected in this course, which is intended to cover a period of three years. Besides the "elementary division" there are five great classes in these schools, viz., a grammar division, an upper division, a philosophy class, and classes for elementary and special mathematics.

In the grammar division there is systematic instruction on the physical geography of the globe.

In the second class of the upper division the boys begin to be taught the elements of zoology, botany, and geology in accordance with the ministerial programmes; and in the rhetoric class descriptive cosmography (which seems to be nearly coextensive with the German *Erdkunde*) forms the subject of a certain number of weekly lessons.

In the class of philosophy, the young students are initiated into the elementary notions of physics (including weight, heat, electricity and magnetism, acoustics, and optics) and of chemistry, in which, at this stage, the teaching is confined to "general conceptions on air, water, oxidation, combustion, the conditions and effects of chemical action, and on the forces which result from it."

In the classes of elementary and special mathematics this course of scientific training is very considerably extended; and if the authorized programmes constitute any real measure of the teaching, it is clear that no boy could pass through these classes without a far more considerable amount of knowledge in the most important branches of science than is at present attainable in any English Public School.

VI. The German Schools.

In Germany the schools which are analogous to Public Schools in England are the *Gymnasia*, where boys are prepared for the Universities, and the *Bürgerschulen* or *Realschulen*, which were established for the most part about thirty years ago for the purpose of affording a complete education to those who go into active life as soon as they leave school. An account of the Prussian Gymnasia and Realschulen may be seen in the Public School Commission Report, Appendix G; further information may be obtained in 'Das höhere Schulwesen in Preussen,' by Dr. Wiese, published under the sanction of the Minister of Public Instruction in Prussia, and in the programmes issued annually by the school authorities throughout Germany*.

At the Gymnasia natural science is not taught to any great extent. According to the Prussian official instructions, in the highest class two hours, and in the next class one hour, a week are allotted to the study of physics. In the lower classes two hours a week are devoted to natural history, *i. e.* botany and zoology. The results of the present training in natural science at the Gymnasia are considered by many eminent University professors in Germany to be unsatisfactory, owing to the insufficient time allotted to it.

In the Realschulen about six hours a week are given to physics and chemistry in the two highest classes, and two or three hours a week to natural history in the other classes.

* See also Étude sur l'instruction secondaire et supérieure en Allemagne, par J. F. Minssen, Paris, 1866. A brief Report addressed to the Minister of Public Instruction in France.

In these schools all the classes devote five or six hours a week to mathematics, and no Greek is learnt. In Prussia there were in 1864 above 100 of these schools.

APPENDIX B.

On the Natural-Science Teaching at Rugby.

Before the summer of 1864 a boy on entering Rugby might signify his wish to learn either modern languages or natural science; the lessons were given at the same time, and therefore excluded one another. If he chose natural science he paid an entrance fee of £1 1*s*., which went to an apparatus fund, and £5 5*s*. annually to the lecturer. Out of the whole school, numbering from 450 to 500, about one-tenth generally were in the natural science classes.

The changes proposed by the Commissioners were as follows:—That natural science should no longer be an alternative with modern languages, but that all boys should learn some branch of it. That there should be two principal branches,—one consisting of chemistry and physics, the other of physiology and natural history, animal and vegetable; and that the classes in natural science should be entirely independent of the general divisions of the school, so that boys might be arranged for this study exclusively according to their proficiency in it.

Since, owing to circumstances which it would be tedious to detail, it was impossible to adopt literally the proposals of the Commissioners, a system was devised, which must be considered as the system of the Commissioners in spirit, adapted to meet the exigencies of the case.

The general arrangement is this,—that new boys shall

learn botany their first year, mechanics their second, geology their third, and chemistry their fourth.

In carrying out this general plan certain difficulties occur, which are met by special arrangements depending on the peculiarities of the school system. We need not here enter upon these details, because it would be impossible to explain them simply, and because any complications which occur in one school would differ widely from those which are likely to arise in another.

Next, as to the nature of the teaching.

In botany the instruction is given partly by lectures and partly from Oliver's Botany. Flowers are dissected and examined by every boy, and their parts recognized and compared in different plants, and then named. No technical terms are given till a familiarity with the organ to be named or described has given rise to their want. The terms which express the cohesion and adhesion of the parts are gradually acquired until the floral schedule, so highly recommended by Henslow and Oliver, can be readily worked. Fruit, seed, inflorescence, the forms of leaf, stem, root are then treated, the principal facts of vegetable physiology illustrated, and the principle of classification into natural orders explained, for the arrangement of which Bentham's 'Handbook of the British Flora' is used. Contrary to all previous expectation, when this subject was first introduced it became at once both popular and effective among the boys.

The lectures are illustrated by Henslow's nine diagrams, and by a large and excellent collection of paintings and diagrams made by the lecturers and their friends, and by botanical collections made for use in lectures. When the

year's course is over, such boys as show a special taste are invited to take botanical walks with the principal lecturer, to refer to the School Herbarium, and are stimulated by prizes for advanced knowledge and for dried collections, both local and general.

In mechanics the lecturer is the senior Natural Science Master. The lectures include experimental investigations into the mechanical powers, with numerous examples worked by the boys; into the elements of mechanism, conversion of motion, the steam-engine, the equilibrium of roofs, bridges, strength of material, &c. They are illustrated by a large collection of models, and are very effective and popular lectures.

The lectures in geology are undertaken by another master. This subject is only temporarily introduced, on account of the want of another experimental school. When this is built the third year's course will be some part of experimental physics, for which there already exists at Rugby a fair amount of apparatus. It is very desirable that boys should obtain some knowledge of geology, but it is not so well fitted for school teaching as some of the other subjects on several grounds. Perhaps a larger proportion of boys are interested in the subject than in any other; but the subject presupposes more knowledge and experience than most boys possess, and their work has a tendency to become either superficial, or undigested knowledge derived from books alone. The lectures include the easier part of Lyell's Principles, *i. e.* the causes of change now in operation on the earth; next, an account of the phenomena observable in the crust of the earth, stratification and its disturbances, and the con-

struction of maps and sections; and, lastly, the history of the stratified rocks and of life on the earth. These lectures are illustrated by a fair geological collection, which has been much increased of late, and by a good collection of diagrams and views to illustrate geological phenomena.

For chemistry the lecturer has a convenient lecture-room and a small but well-fitted laboratory*, and he takes his classes through the non-metallic and the metallic elements: the lectures are fully illustrated by experiments. Boys, whose parents wish them to study chemistry more completely, can go through a complete course of practical analysis in the laboratory, by becoming private pupils of the teacher. At present twenty-one boys are studying analysis.

This being the matter of the teaching, it remains to say a few words on the manner. This is nearly the same in all the classes, *mutatis mutandis*: the lecture is given, interspersed with questions, illustrations, and experiments, and the boys take rough notes, which are recast into an intelligible and presentable form in note-books. These are sent up about once a fortnight, looked over, corrected, and returned; and they form at once the test of how far the matter has been understood, the test of the industry, care, and attention of the boy, and an excellent subject for their English composition.

Examination papers are given to the sets every three or four weeks, and to these and to the note-books marks are assigned which have weight in the promotion from

* Another and larger laboratory and school for Experimental Physics will shortly be built at Rugby.

form to form. The marks assigned to each subject are proportional to the number of hours spent in school on that subject.

There are school prizes given annually for proficiency in each of the branches of natural science above mentioned.

This leads us, lastly, to speak of the results.

First, as to the value of the teaching itself; secondly, as to its effects on the other branches of study.

The experience gained at Rugby seems to point to these conclusions:—That botany, structural and classificatory, may be taught with great effect and interest a large number of boys, and is the best subject to start with. That its exactness of terminology, the necessity of care in examining the flowers, and the impossibility of superficial knowledge are its first recommendations; and the successive gradations in the generalizations as to the unity of type of flowers, and the principles of a natural classification, are of great value to the cleverer boys. The teaching must be based on personal examination of flowers, assisted by diagrams, and everything like cram strongly discouraged.

Mechanics are found rarely to be done well by those who are not also the best mathematicians. But it is a subject which in its applications interest many boys, and would be much better done, and would be correspondingly more profitable, if the standard of geometry and arithmetic were higher than it is. The ignorance of arithmetic which is exhibited by most of the new boys of fourteen or fifteen would be very surprising, if it had not long since ceased to surprise the only persons who

are acquainted with it; and it forms the main hindrance to teaching mechanics. Still, under the circumstances, the results are fairly satisfactory.

The geological teaching need not be discussed at length, as it is temporary, at least in the middle school. Its value is more literary than scientific. The boys can bring neither mineralogical, nor chemical, nor anatomical knowledge; nor have they observed enough of rocks to make geological teaching sound. The most that they can acquire, and this the majority do acquire, is the general outline of the history of the earth and of the agencies by which that history has been effected, with a conviction that the subject is an extremely interesting one. It supplies them with an object rather than with a method.

Of the value of elementary teaching in chemistry there can be only one opinion. It is felt to be a new era in a boy's mental progress when he has realized the laws that regulate chemical combination and sees traces of order amid the seeming endless variety. But the number of boys who get real hold of chemistry *from lectures alone* is small, as might be expected from the nature of the subject.

Of the value of experimental teaching in physics, especially pneumatics, heat, acoustics, optics, and electricity, there can be no doubt. Nothing but impossibilities would prevent the immediate introduction of each of these subjects in turn into the Rugby curriculum.

Lastly, what are the general results of the introduction of scientific teaching in the opinion of the body of masters? In brief it is this, that the school as a whole is the better for it, and that the scholarship is not worse. The

number of boys whose industry and attention is not caught by any school study is decidedly less; there is more respect for work and for abilities in the different fields now open to a boy; and though pursued often with great vigour, and sometimes with great success, by boys distinguished in classics, it is not found to interfere with their proficiency in classics, nor are there any symptoms of overwork in the school. This is the testimony of classical masters, by no means specially favourable to science, who are in a position which enables them to judge. To many who would have left Rugby with but little knowledge, and little love of knowledge, to show as the results of their two or three years in our middle school, the introduction of science into our course has been the greatest possible gain: and others who have left from the upper part of the school, without hope of distinguishing themselves in classics or mathematics, have adopted science as their study at the Universities. It is believed that no master in Rugby School would wish to give up natural science and recur to the old curriculum.

APPENDIX C.

On the Teaching of Science at Harrow School.

From this time forward natural science will be made a regular subject for systematic teaching at Harrow, and a natural-science master has been appointed.

But for many years before the Royal Commission for Inquiry into the Public Schools had been appointed, a voluntary system for the encouragement of science had been in existence at Harrow. There had been every term

a voluntary examination on some scientific subject, which, together with the text-books recommended, was announced at the end of the previous term. Boys from all parts of the school offered themselves as candidates for these voluntary examinations, and every boy who acquitted himself to the satisfaction of the examiners (who were always two of the masters) was rewarded with reference to what could be expected from his age and previous attainments. The text-books were selected with great care, and every boy really interested in his subject could and did seek the private assistance of his tutor or of some other master. The deficiencies of the plan, if regarded as a *substitute* for the more formal teaching of science, were too obvious to need pointing out; yet its results were so far satisfactory that many old Harrovians spoke of it with gratitude, among whom are some who have since devoted themselves to science with distinguished success.

One of the *main* defects of this plan (its want of all system) was remedied a year ago, when two of the masters drew up a scheme, which was most readily adopted, by which any boy staying at Harrow for three years might at least have the opportunity during that time of being introduced to the elementary conceptions of astronomy, zoology, botany, structural and classificatory, chemistry, and physics. These subjects were entrusted to the responsibility of eight of the masters, who drew up with great care a syllabus on the subject for each term, recommend the best text-books, and give weekly instruction (which is perfectly gratuitous) to all the boys who desire to avail themselves of it; indeed a boy may receive, in proportion to the interest which he manifests

in the subject, almost any amount of assistance which he may care to seek. Proficiency in these examinations is rewarded as before; and to encourage steady perseverance, the boys who do best in the examination during a course of *three* terms receive more valuable special rewards.

As offering to boys a voluntary and informal method of obtaining much scientific information this plan (which was *originated* at Harrow, and has not, so far as we are aware, been ever adopted at any other school) offers many advantages. It is sufficiently elastic to admit of many modifications; it is sufficiently comprehensive to attract a great diversity of tastes and inclinations; it cannot be found oppressive, because it rests with each boy to decide whether he has the requisite leisure or not; it can be adopted with ease at any school where even a small body of the masters are interested in one or other special branch of science; and it may tend to excite in some minds a more spontaneous enthusiasm than could be created by a compulsory plan alone.

We would not, however, for a moment recommend the adoption of any such plan as a *substitute* for more regular scientific training. Its chief value is purely *supplemental*, and henceforth it will be regarded at Harrow as entirely subordinate to the formal classes for the teaching of science which will be immediately established.

In addition to this, more than a year ago some of the boys formed themselves into a voluntary association for the pursuit of science. This Scientific Society, which numbers upwards of thirty members, meets every ten days at the house and under the presidency of one or

other of the masters. Objects of scientific interest are exhibited by the members, and papers are read generally on some subject connected with natural history. Under the auspices of this Society the nucleus of a future museum has already been formed; and among other advantages the Society has had the honour of numbering among its visitors more than one eminent representative of literature and science. We cannot too highly recommend the encouragement of such associations for intellectual self-culture among the boys of our public schools.

THE END.

Printed by TAYLOR and FRANCIS, Red Lion Court, Fleet Street.