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presented

in connection with the Degree of

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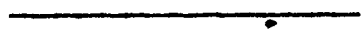
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E D U C A T I O N .'

C O N T E N T S.

INTRODUCTION.

- Part I. The Development of Science Teaching
with special reference to Biology.
- Part II. The Importance of Biology in Scientific
Training.
- Part III. The Historical Outlook in Biology Teaching.
- Part IV. A Scheme of Work in Biology.
- Part V. Final Word and Conclusion.



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PART I.

I N T R O D U C T I O N."LET NATURE LEAD."

"In boys' schools generally, Biology suffers from neglect This situation is satisfactory neither from the cultural standpoint nor the utilitarian. To neglect Biology is, on the one hand, to ignore one of the fundamental expressions of the scientific life, to shut one's eyes to a half of nature, and to remain a stranger to ideas which have exercised an immeasurable influence on modern thought. On the other hand, it is to be ignorant of, and therefore unsympathetically disposed towards, matters of the highest importance to individual happiness and social well-being."

Professor Sir Percy Nunn, -
"The New Teaching - (Science)"

Biological study - man's attempt to probe into the mysteries of Nature - has existed since man's arrival on the face of this planet, yet it is only a short while ago that the gradual accumulated effect of this study and of Science in general has been able to produce the weight of opinion necessary to modify the course of study in our schools from pre-ponderingly humanitarian

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to partly-realistic and practical. Even then the old tradition lingered on in the form of a model-plan of approach to the study of Science.

For instance, Science was introduced in a tentative way at Rugby in 1849 - lectures were given in the Town Hall and it was optional for the boys to attend. It was ten years after that a laboratory was built. Again, the 1870 Royal Commission Report stated that at that time boys were prepared for examination in Science by means of lectures and text book reading, and even in schools which possessed laboratories practical work was regarded as a privilege for Advanced pupils. Stress was laid on facts and not on principles.

The subject, therefore, was taught for a time, by minds trained in the humanistic school, taught according to fixed rules and set methods, which caused it to lose its essence, for the study of Science and Biology in particular must be based upon actual contact with natural phenomena.

More recently, however, there has been more freedom in Education, and Biology as a subject, besides coming slowly but surely into its own, is also helped along by this freedom. The teacher is allowed more 'lateral play' and thus is more likely to become inspired by a true love of nature. Nature herself

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is beginning to take a hand in the arrangement of the teaching material, the inspiration of the teacher, and in the welfare of the taught. It is being realised, that Biology, by the training it offers in practical observation of the various aspects of plant and animal life, culminating in the vital problems appertaining to man's body and mind, is at the very foundation of individual, national, and world welfare.

Slowly, but surely, if only for this reason alone, the subject will come to occupy a very prominent position in the school curriculum of the future.

Man is the child of Nature. She is his best teacher, and he will do well to hearken unto her teachings, for they are precious and her secrets are revealed only to those who seek in the right spirit. This is her way, so let her lead the way - the way of the Universe - the way of Evolution - the way of Life - the path of Progress - History.

An attempt has been made in the following pages to trace the importance of Biology as a subject in the school curriculum, and to demonstrate a method of presenting the subject. A claim is put forward for the historical-observational method as a true basis for the teaching of

the Science, and it is suggested that the method might not only benefit the teaching of other Sciences but possibly also of other subjects in the curriculum.

The main portion of this Thesis has been devoted to a Scheme of Work in Biology based upon these suggestions, and to a large extent already tried out and refined by experience.

P A R T IThe Development and Value of Science Teaching with
Special reference to Biology.1. The Growth of the Scientific Attitude of Mind.

The development of the teaching of a subject must necessarily depend largely upon the development of knowledge in that subject. The teaching is naturally dependent upon the subject-matter to be taught.

The old Greek Philosophy which had held up the lamp of knowledge and wisdom to the whole world was discouraged and forgotten by the Romans in their excessive love of the physical. Some Arab tribes, however, were able to preserve some of this Greek culture and it was this remnant that, following upon the Dark Ages, formed some sort of a stable foundation for the Awakening which came in the 13th century.

The first sign of this awakening was the rise of the Universities - Oxford and later Cambridge being established by batches of students from Bologna and Paris. For a long time the tradition of Aristotle lasted and for centuries, up to the 19th, the Church was against the scientific spirit of probing too deeply into the nature of things.

Translations of Galen's works formed the basis of study in the 14th and 15th Centuries, and there was no experimental work, although Roger Bacon in the 13th Century had advocated it. Still the spirit of enquiry in Science grew, in spite of heavy persecution. Men set themselves well-defined problems and the enquiry tended to become intensive rather than extensive - deep rather than superficial. This intensiveness became the mark of the scientific spirit in England early in the 17th Century and it is the keynote of present-day specialisation in research.

During the Civil War small groups of men, inspired with the new spirit, eventually established a Club, which later became the Royal Society, a landmark in the history of Science. Its meetings brought together investigations from various fields and the interchange of ideas helped the progress of Science. The publication of its Proceedings was a further aid.

Thus the scientific spirit prevailed and developed. Knowledge was rapidly advancing and the public was gradually becoming scientifically-minded. It became imperative to give serious thought to the teaching of Science.

The Development of Science Teaching in General.

The antagonism of the Church and the close connection that existed between the Church and the Universities was one of the causes which considerably delayed the change in outlook in the Schools. The Church was against the experimental Scientific method and the change of ideas which Scientific thought implied. Owing to this and other causes the curriculum of the Grammar Schools remained essentially classical until the 19th Century. The course prescribed by founders was rigidly followed. Thus Natural Science, as we know the term, did not enjoy an established position in the teaching until the second half of the 19th Century. It was introduced, tentatively, into some schools about the middle of the century, but the work was done under great difficulties. Gradually it won respect - due partly to the writings of men like Kelvin, Darwin, Spencer and Huxley. The tendency, however, was to teach it to pupils who failed at Classics or Mathematics, and to girls at this time no Science was taught at all. Some kinds of laboratories were found in the 80's, and the number slowly increased, but these laboratories were ill-equipped and the little Science taught was done at demonstration tables. The advance since then has been in the direction of laboratory experimental work.

It is not strange, therefore, to find the pendulum swinging too far in the opposite direction in schools which sprang up under the direction of the Science and Art Department towards the end of the 19th Century. In these the curriculum became so scientific that literature tended to be excluded, and this became one of the first problems to beset the newly-formed Board of Education in 1899, with the result that during the first twenty years of the present Century Science teaching has become more balanced in the grant earning secondary schools, and has secured a firmer hold on the other Schools. Still, even to-day, the old tradition dies hard in the older schools.

The rise of the newer Universities did much to the cause of Science by offering a lead in its teaching and opportunities of research in it.

Finally, the Great War brought home to the Nation the inadequacy of its scientific training and Sanderson of Oundle became the champion of the Scientific cause in Schools. He laid great stress upon experimental work and introduced workshops and machines. Every possible branch of Science was included and every craft taught. During the War the boys turned these workshops to good account. This was applied Science as understood by Sanderson - one of our great Headmasters. "Education for a New Age", he said, "must be broadly based on Science, and the master must always

remember that Science is alive, still open, still developing."

The Development of Biological Teaching
in Particular.

In this long struggle for recognition on the part of Science, Biology has had to bear, possibly, more than its share. In its case the fight has been prolonged and (at the present day) it is only beginning to reap the fruits of victory.

Harvey's work on the movement of the blood, early in the 17th Century created modern physiology and its bearing upon biological thought was profound. His method of inquiry, by direct experiment, had a marked influence on the progress of Natural Science teaching.

Up to the 16th Century the Study of Biology had been linked up with that of Medicine. The new birth of Science in that Century gave rise to its independent existence as a subject. At this time too, many schoolmasters were physicians and they naturally introduced Natural History into their schools. Comenius (1592 - 1670) advocated the teaching of Natural History, mainly by means of pictures. Woodward (1590 - 1675) - a London Schoolmaster, was a pioneer of Nature Study training.

The first Professor of Botany at Oxford was appointed in 1669, and he read on Plants in the Garden twice a week for five weeks. Yet there was very little change in the official University attitude towards biological study for a long time, and those interested sought unofficial tuition. Ray (1628 - 1705) did much to systematize Zoology and Botany, but his influence ~~on~~ the teaching has only been felt comparatively recently. Many Clubs and Societies played their part, among them being the Lunar Society of Birmingham, founded in 1766 by Erasmus Darwin and his friends, and the Literary and Philosophical Society of Manchester founded in 1781. At the close of the 18th Century practical application of Science to industry was occupying attention, and whereas up to then the teaching of all the Sciences had been more or less linked up (meagre and disorganised though the teaching was) from then onwards the seeming utilitarian advantage of Chemistry and Physics (the latter in particular) tended to oust out biological considerations. Yet many developments in Chemistry and Physics came from Biology - for instance, Lavoisier's investigations on the relations between work and energy in animals.

Thus Chemistry and Physics began to be taken seriously as school subjects during the latter part of the 19th Century, whereas Biology is only now (1934) beginning to receive serious attention. This in spite of the

fact that possibly Biology as a Science is older than either of the other two. The utilitarian motive was behind this over-emphasis of Chemistry and Physics at the expense of Biology. Following the industrial revolution the cry was for the teaching of those Sciences which had a mechanical bearing. Necessity gave Chemistry and Physics the victory in the 19th Century - necessity is pointing the way to the ascendancy of Biology in the 20th Century. It is being slowly realised that the teaching of this Science is at the root of human happiness.

Huxley's influence went a long way towards bringing about this interest in Biological teaching. He waged an energetic campaign on its behalf. His labours finally led to the establishment of the Royal College of Science. Other Colleges and Universities sprang up, including London and Manchester Universities, the latter producing one of the greatest Biologists of the 20th Century - J.A. Thomson - another man who made his contribution to the cause of Biology teaching.

Royal Commissions since 1860 have emphasized in their reports the neglect of Natural Science in general and of Biology in particular, and since that date also Examination requirements have considerably influenced the work in the schools. Most Examining Boards now include Biology in their syllabus and it has changed its name from the Botany (of Girls' Schools) of the old days. During the last few years attempts have been made to raise to a high

standard the School Certificate and the Higher School Certificate syllabuses and examination questions. This has helped to make the subject a definitely standardised Science in the curriculum.

A Summary-Review of the Development of
Biology-teaching.

Towards the end of the 19th Century, most schools with a public, grammar, secondary or private foundation, catered for Science in their curriculum.

Of recent years the growth in numbers of those proceeding to the Universities has led to a tightening of the regulations concerning entrance, and authorities are faced with the problem of eliminating those who are not likely to profit by an Univerisyt education. Thus Matriculation has become almost the ~~max~~imum standard. The teaching of specialised subjects for particular purposes led to the inauguration of Senior Local Examinations by the Universities. This led to the establishment of Advanced Courses in Schools, that is, courses which, normally, before, were taken at the University in the first year. This lowered the cost of such a course considerably.

This reason, coupled with the fact that interest in Biology had been gradually roused, due in no small measure to Darwin and Huxley, led to an increased tendency towards the teaching of the Science in the

schools, and it became established as a Matriculation subject (it was adopted by the Oxford Board in 1906).

The brilliant work of the 19th Century in physiology and pathology is becoming part of general Zoology. The study of Embryology is now being tackled from the point of view of Physiology. In fact, Biology is fast establishing itself as a real Science. New knowledge is stimulating the application of Biological ideas in many fields, and this is turning men's minds to a serious study of a Science which they are beginning to realise, is so intimately connected with social and moral problems. The change in attitude is being registered in the schools.

Besides these moral and cultural aspects, the utilitarian point of view, very little stressed in the past, is making itself felt. Attention is drawn to a Subject which has so much bearing upon Agriculture - and other industries. People begin to take serious notice of a subject which forms the basis of their occupation.

County authorities, Societies, Research Stations, and great business firms are gradually becoming mindful of the fact that a Biological training is, at least, useful for employer and employee alike. At the present time, education authorities (e.g. Staffordshire) offer Agricultural and Medical Scholarships to Universities. The conditions laid down (and indeed implied) make it essential that candidates shall have been taught Biology

at School.

Yet there are many Schools to-day which have not kept pace with this growing consciousness of the value of the subject.

The Social Hygiene Council is the latest advocate of Biology-teaching, - it has issued a Handbook on the Proceedings of the National Conference on the Place of Biology in Education, organised by the Council - and it promises to be a powerful one.

P A R T II.

P A R T II.THE IMPORTANCE of BIOLOGY in SCIENTIFIC TRAINING.The Influence of 19th Century Pioneers.

In 1861, describing Science as "the Cinderella of the family of knowledge", Herbert Spencer spoke of biological facts as reaching man in the course of everyday information, as scanty, indefinite, and rudimentary, and yet aiding him so essentially. "What must be the value to him of such facts", says Spencer, "when they become positive, definite, and exhaustive?"

Even at that time, a man of vision, like Spencer, saw the benefits that rational biology conferred on Man, in teaching him rules of diet and habit, and curing his diseases - and, prophet that he was - he foresaw the great possibilities of this branch of Science. He maintained that it was our duty in education, to adopt a course of culture indicated by Nature's own bidding - as exemplified by the innate interest taken by the young in their natural surroundings - to follow this up, develop it and build upon it a wonderful edifice of the mind, by progressing along natural channels. He deplored the narrow conception

of utility that prevailed in his own time, a conception which measured results by money values only, and he maintained that the laws of life underlie not only all bodily and mental processes, but, by implication, all transactions of everyday life of commerce, of politics, and of morals, and that, therefore, without a comprehension of them, neither personal nor social conduct can be rightly regulated.

Due to a great extent, at least in the first place, to the stir caused in the educational world by the writings of such men as Spencer, Darwin, and Huxley, it can now be claimed that Science - being one of the grand expressions of the human spirit - has a right to a prominent and honourable position in the curriculum - at least equal to that accorded Art and Literature. This being so, and since the main importance of Science lies in the scientific life and not in the scientific method, important though that certainly is - it becomes necessary for all those who play a part in educating the world of to-day to investigate and find out what must be the true characteristics of the Scientific life.

The Scientific Life.

Their basis, we maintain, lies in true love of nature. Nature gives up her secrets sparingly - she guards them with a jealous eye - and she invariably reveals them, one

by one, and very cautiously, to the ones, and the ones only, who have proved themselves inspired by the quest for her truth for that truth's sake alone. All great discoveries of truths in realms of Science have been made by true Scientists, those who dedicated their lives to the passionate search for truth. It is an irony of fate, too, that these men, generally, gain very little for themselves, except this passion for knowledge, and self-satisfaction, together, of course, with incidental fame.

Aim of Science Teaching in General and
Biology Teaching in Particular.

It must thus be the first aim in Science teaching in general, and in Biology teaching in particular, to foster this love of nature in the pupil, and, at the outset, this brings conflict with at least two types of people. The one believes in all teaching from the standpoint of cash value only. The other does not believe in, or at least minimises, this cultivation of a 'love of nature' as a means of mental discipline. The first never realises the truth of what has already been said, namely, that nature herself does not deal out her secrets from the 'cash value' point of view, but demands stern self-sacrifice and application of mental powers entirely free from any motives other than those of the

quest for knowledge. Therein lies, also, the answer to the second type of critic.

If therefore, we accept this 'love of nature' as the foundation-stone in our edifice, how do we propose to set about attaining this aim? By ignoring the pupil's natural tendency? or by making use of it and building slowly and surely upon it? The answer is obvious. The everyday lives of plants and animals, their mysteries and beauties, the majesty of the universe - these form the golden key which will, in the first place, unlock the young mind.

The Neglect of Biology.

From a consideration of the very obvious truths of the foregoing arguments we are justified in expecting the teaching of Biology in our institutions, to-day, to occupy a very prominent position - to have a status, at least equal to that accorded any other Science, so as to bring the teaching of all the Sciences into one whole. This would seem to be the only way to build up true scientific knowledge and method. Any other way, one would imagine, would be analogous to building upon sand.

Yet, even as late as 1917, we find from Reports published by the British Association Committee on Science-teaching and by a Committee set up by the Board of Education to enquire into the position of Natural Science in

the Educational system, that "among State-aided Secondary Schools, only a few teach Biology and then only as 'Nature Study' to those under the age of twelve." Presumably this meant that Biology was not taken seriously as a Science, but as a general subject which the Committee chose to call 'Nature Study'. From this age onwards Science meant nothing but Physics and Chemistry. In Public Schools things were a little better, but here again, Science as a whole, broadly speaking, still occupied a subsidiary position - was still inclined to be looked upon as the Cinderella of the family of subjects.

This neglect of Biology - very obvious as recently as 1917 - was a neglect of one of the fundamental expressions of the Scientific life. To ignore this Science was to walk about half-blindly in the realms of Scientific thought and to refuse to pay attention to one of the greatest influences on modern thought, individual happiness, and social well-being.

Various reasons have contributed to the avoidance of Biology in the past, amongst them being -

- (1) The dearth of trained teachers. Few have taken the subject with a view to teaching it.
- (2) Lack of the offer of a livelihood from it.

The one reason follows from the other and we get that very dangerous situation when Biology was not taught

because of lack of teachers and there were no teachers due to the lack of facilities in the teaching of the subject. With the introduction of Biology as a regular school subject this condition will gradually disappear.

It has been different in the case of Chemistry and Physics; the utilitarian value has played a leading part and there has been no lack of either teachers or pupils.

Chemistry and Physics are better from the point of view of training the pupil in experimental methods and exact reasoning, but for quickening powers of observation and for general education Biology surpasses them.

Biology is unique in that it deals with living material (though a good deal of work is still done with dead material - a practice hardly justifiable). Physics is a better Science for clear cut data and for mathematical expression of generalisations, and Chemistry for reasoning leading to crucial experiment. In Physics we get quick activity and quick results with a ready application together with an easy understanding of purpose. This is true, more or less, of Chemistry. On the other hand, Biology results are often delayed and are sometimes variable. Living processes take time, and sustained interest and attention are required. There is not the same direct appeal in the purpose. ^{This} ~~This~~ presents a difficulty, but if treated properly it also affords a very systematic and permanent

training of observation and thought, and hence it has a very positive value. For instance, we have had experience of a Vith Form boy observing and measuring the heart-beat in a dead dissected frog, continuing the observations methodically at intervals all day and well into the night ~~after~~ school hours, and then coming back an hour before the school started the following morning in order to miss as little as possible. This boy was able to draw out a table on his observations, and to graph his results, which have definite value. (See chart).

In the years subsequent to the Reports mentioned, there has been some attempt to remedy matters and to assign to Biology some of the attention due to it - a notable example being the 'push' made to encourage the teaching of the subject by Sir Charles Grant Robertson and other members of the British Social Hygiene Council, during the last few years - a move inspired mainly by the lack of trained biologists.

Reasons for the Slow Introduction
of Biology.

Still, things move slowly in education and tradition dies hard, so that the realisation of the importance of the subject to-day, although infinitely higher than it was twenty years ago, nevertheless, falls far short of

what it should be. This is partly due to the lack of 'plasticity' in our educational system, as witness the case of the introduction of any 'new' subject - it takes far too long to establish itself. It is partly due, also, to the attitude adopted by educators of all types, very often, and by pupils, ~~towards~~, towards any novel idea. The 'novel' stage is apt to be prolonged indefinitely, and there comes a sheer inability to get down to the real nature of the subject and to fathom its true value. It is only when novelty ceases that real interest begins.

The subject too, being in its infancy as regards the curriculum, suffers from the lack of an organised scheme and not till there is 'Unity of Scheme' interpolated into a 'wide scope of plasticity' can we hope to have the subject well grounded. The period of 'pioneering' must, of necessity, be tedious and experimental, and it is only by combined action and a sympathetic appreciation by public and ~~the~~ authority alike, that the ground will be finally cleared, and the light of day, with its stabilising and vitalising influence, be allowed to peep through.

~~That~~ ^{Not} the least embarrassing factor is the depreciating attitude adopted by some persons, towards the work of all pioneers, and, we may add also, somewhat reluctantly perhaps, that there does exist some amount of professional jealousy on the part of some members of the profession - they are apt to think exclusively in their own sphere,

and thereby, tend to shut out (or slight) any influence besides that of their own subject.

If, and when, we arrive at a time, when the teaching profession (namely, all who deal with education as an organisation) is solid, united, and possessed of a supreme duty, one towards another, and to ideals, then progress will be made and every innovation will be given its proper chance to play its part in educating and humanizing mankind.

It may be noted in passing, also, that there can be no doubt but that the question of building and equipping new laboratories is also retarding the progress of the Science. It seems, however, a weak excuse when far-reaching effects are at stake.

Drawbacks of Biology teaching

up to the present.

Biology, to be of real value and to become a force in education, must be taught throughout the school. Thus and thus only, can it become truly established and leave its lasting effects on the life of the citizen-to-be. At present the tendency is (very obviously) to assign to the subject a sort of subsidiary and auxiliary position. For instance, in many schools it is taught to the lowest forms, merely to satisfy the curiosity of the child, and

with, apparently, no further aim. It is considered a useful subject to divert the attention of the pupil for a brief space from the more rigid, serious, subjects, by its appeal to his play-instinct, and this lack of seriousness and thoroughness is enhanced by the fact that a non-specialist teacher (who may be a specialist in other subjects) is considered good enough to undertake the work. This attitude is detrimental - particularly so at that stage in the pupil's career - to the growth of the real scientific life and method (which demands stern observation and strict accuracy of thought). In other schools it is taught to lower and middle school Forms, and then at the critical stage in the development of the subject, it is discontinued, partly because the other subjects are considered - judging by old standards - more important, and partly because the teacher is required for other work. Again in some schools it is taught only to would-be medical students. In few schools - comparatively speaking - is the subject taught throughout the School (e.g. Dudley Grammar School) and it is in such a case only that the science can be made to influence a pupil's life for permanent good. Then and then only can he acquire enough of the spirit of the science and of its teaching to be able to think biologically or have the biological outlook on life, which is the vital point

as far as the science is concerned, and, we maintain, as far as true education is concerned.

While this tendency lasts, therefore, it will be seriously handicapped and no permanent results can be looked for. As long as educators look upon it as a subject of which a smattering is useful but not essential, so long will the training and knowledge derived from the subject tend to remain superficial and those who advocate it fight a needless fight. So long, too, will the products of our educational system be denied the undeniable benefits which the subject can bestow.

These benefits are many - among them being -

- (1) It is associated with our food supply.
- (2), It helps us in the struggle for Existence.
- (3) It helps us to conquer disease and promote health.
- (4) It has a cultural value.
- (5) It teaches us the inter-relationship of all living things.
- (6) It gives us the idea of the wonders of the Universe and thereby helps us to understand and to love God.

It is only when serious attention is turned to it that we can hope for deep results. The end seems to be somewhat agreed upon, but, strangely enough, the means are left to themselves.

Biology teaching up to now has been too much linked up with the training of pupils for the medical profession. It has meant mere technical training applied to the few. Moreover it is a most uneducational, if not dangerous method. Pupils who up to this stage have been deprived of all opportunity of becoming biologically-minded are suddenly thrown into the throes of a new subject with its separate method and technique (and we maintain - what is perhaps ^{little} realised - that Biology, whilst conforming in general principles with the other sciences as regards the scientific method in general - must of necessity possess a method of approach and of training entirely its own; e.g. the laboratory technique in section-cutting and 'culture' work in bacteriology and plant pathology). Under such circumstances these future members of the medical profession are very seriously handicapped and it is small wonder that many of them fail entirely to acquire even a fair measure of the broad biological spirit which should form the background of all their professional and social work. It is indeed a wonder that many of them do manage to become something akin to true biologists. The aim must be to bring within the reach of the many the general culture-value of the subject.

Justification for Introduction
of Biology.

The problems with which Biology deals face us everywhere in our daily life and it is therefore hard to understand why there has been such apathy and reluctance in connection with it. Besides it is becoming universally recognised that it is vital for every child to learn about the fundamentals of his own body and mind and that the health of the nations and of the whole world, physically and morally, depends on this. In a comprehensive Biology Course the study of the system in the mammal culminating in the nervous system, the brain and the mind in man, the study of bacteria and disease, and the universal application of this (like all Science study) throughout the world, should occupy a prominent position. This is calculated to offer to the pupil the basis of a healthy body and mind, and to suggest to him important laws of health, besides cultivating in him the idea that 'natural laws' are common to all countries and all nationalities.

Biology well taught, offers exceptional opportunity for stimulating the inquisitive, and directing the observational, mind of the pupil, not only during school hours but in spare time, and this can give rise to many intellectual hobbies which continue to inspire, and to guide the reserve energy of the grown-up all his life.

For instance we have experience of boys who in school were encouraged to keep pets such as dogs, rabbits, poultry, tortoises, sheep, and taking a liking to collecting wild plants, or gardening, forming a habit which has remained with them to interest them in after life and to be a source of extreme pleasure to them. Besides this hobby has helped them to keep body and mind healthy. Is any further justification for the subject necessary?

The Essence of Biology Teaching.

It has been said that all Science teaching should aim at giving, not the conceit of knowledge, but an intellectual humility that recognises that all we can know and do does but open up fresh horizons of the limitless unknown. Since Biology is so intimately connected with everyday actions and environment, that is with "all we do and see" what better way can there be of reaching out towards the truth of the statement than by teaching Biology and fostering interest in it?

The teacher of Biology must be equal in training to any other specialist, and his knowledge as exact. This is one thing that is going to help to give to Biology the really serious attention that is due to it, but what is going to help more in this direction is that he must also be alive - his mind actually pulsating along with that of Nature ~~h~~ ^h ~~it~~ ^{it} ~~self~~ ^{self} - and this quality need not

necessarily be present in any other expert, say, a mathematician. Even another Scientist - a physicist or a Chemist for instance, is not so intimately connected with living things and therefore does not partake of nature to the same extent.

Music will not produce musicians, but it can produce a love of music - that is, music-culture. So nature-study is not designed to produce naturalists (very rare creatures, in fact - as rare as musicians or any other born geniuses) but it can and should help to create that enriching quality called nature-culture or a love of nature.

How this can best be achieved will be dealt with later in this Paper, but a few broad hints can be given here.

One definition of Education says - "it is the process which aims at the adjustments of the growing organism to his environment and the control of conditions by understanding them." If the definition was based upon Biology teaching only it could not have been more appropriate. It sounds as if Biology teaching was at the root of all true education. Certain characteristics of the child must be borne in mind in formulating any schemes of teaching in order to make this teaching conform with the aim and essence of the above definition.

Some of these are -

- (1) Intense interest, in the younger child, at any rate.
- (2) Great mental and bodily activity which makes it hard for the young to concentrate for a prolonged period.
- (3) Vivid imagination and strong emotion, which make for *hasty* conclusions.
- (4) The gradual changing of the interest to that of intellectual interest.

This makes it imperative for the teacher to have 'plasticity' in his methods of treatment of the subject - a plasticity which will meet these changing conditions, and the changing mental outlook of the pupil. In short he must be possessed of, or else endeavour to acquire, some of that dynamic energy of Nature ~~herself~~. The teaching in the schools must be progressively adapted to phases of growth and interest, and be observational and concrete.

A claim is put forward in this Thesis that the teaching should also be on historical lines.

It must aim at preparing youth for the responsibilities of manhood and womanhood. It is hard, indeed, to find a subject better suited for these purposes.

Summary.

To sum up therefore, we maintain that every pupil should receive the quota of Biological teaching that is assigned to any other principal subject. It should be as important in the Upper School as in the Lower and even those taking the Advanced Course in Arts in School, let alone all Science students, should be given a certain definite course in the subject just as Advanced Biology Students and all Science Students in general should have an Arts subject on their time-table. This is the only means of ensuring that either class of Students does not become one-sided - a tendency which is often very obvious.

Life is one and knowledge is one, and every pupil should be led to realise this great truth. By this means, and this only, will an attempt be made to bring harmony into the lives, which are supposed to be moulded in our schools.

P A R T III.

PART III.The Historical Outlook in Biology teaching.

The rapid advance of knowledge has necessitated the sub-division of Science into separate branches. This facilitates work, but has the tendency to 'isolate' these branches and to cut them away from the tree of thought. This, if continued, will alienate the general interested student more and more and in the end make Science, as a whole, so specialised and technical that it will become the sphere of the few, and thus fail to enlighten the world in general.

There is a vital need, therefore, for supplying the complete picture as it progresses - a picture of scientific knowledge as a whole - and this picture must be drawn in such a way as to impress the general reader and make him interested. It is not an easy task as the essential element of Scientific thought - continuity - must be ever present.

The use of the historical method in Science-teaching seems to be the first essential step in the process. The path along which Scientific thought has travelled throughout the ages seems to be a way of connecting the whole. This method is, actually, present, more often than not, unconsciously, to the

teacher himself. Discussion of conclusions and theories must, perforce, involve discussion of the way by which they have been arrived at. This is history and must be taken into account by the man of Science, both from the point of view of his own training and from that of his teaching of his subject. As Scientific knowledge increases scientific problems also increase, and this brings about Specialisation which tends to divide Science into water-tight compartments. Under this system Science is apt to break away from history - by loss of that continuity of thought - and this becomes detrimental to its true development, since all new knowledge must take into account continuity of process. We must endeavour to penetrate the darkness of the unknown by making use of, not a part of, but the whole circumference of the circle of light bordering upon it; just as man uses the whole range of light given off by his lantern on a dark night .

Knowledge is one and Science is one, and this in itself implies a historical continuous thread throughout the ages. We must therefore trace all knowledge and its development, from the main stock.

The historical method, therefore, seems to be the only true basis for the acquisition of scientific knowledge and the presentation of that knowledge (in the teaching of it); It must also underlie

any account of Science or of a Science separately -
and upon this basis all else must be built up.

History - Initial Importance of Biological Studies -

Separation of Science into departments.

Re-union and Biology's part in it.

The spheres of Science are so vast that for the sake of convenience its whole study must be split up into departments, in each of which there is an attempt to reach new discoveries. Thus we get the study of the planets and the universe - called Astronomy that of our own planet, its structure and its own story told in the language of rocks - called Geology, that of light, sound and electricity - called Physics, that of the intimate constitution of substances - called Chemistry, and that of life on this planet - plants and animals and how they live - Biology.

Within these divisions we again find sub-divisions; each is fast splitting up into sub-sections, each one of which in its turn centres round specialisation of some one topic. This is the state of things in Science in this twentieth century, and it is the result of the accumulation of knowledge throughout the ages - bought dearly by the sacrifice of unselfish men and women - and of the gradual effect of this growing knowledge on every-day life, and its consequent importance. The world has learnt to

respect, and even to hold in awe, that which it once trifled with, or at least played with, and this growing consciousness of the value of Science as a whole is fast becoming evident with regard to Biology in particular. It is the application of discoveries rather than the discoveries themselves which has brought this about, by the bearing of these discoveries on the conduct of life and especially by the tremendous part they have played in practical life.

The history of Biology - one of the newer branches of Science, from the point of view of public attention though one of the oldest in point of time - has followed the same lines. It is only when the practical application of biological studies became a fact and a very essential factor in the everyday lives of men and women of all nations that Biology as a Science became important from the point of view of education. When the world realised that the Science was the handmaiden of the Goddess of Health, and as such was of vital importance to every human being, the world welcomed her as a serious guest. This is also the keynote in education, national and international, at the present time, but the process of educating the world is a slow one -

the educationist thinks and speaks in periods, not in years - something similar to what the Geologist does. Yet, this process - the gradual realisation of the seriousness of Biological Study, just like the parallel process in Science in general, which preceded it - was and is, inevitable. Biology, as now proved, and at last slowly realised is at the bottom of our well-being as individuals, as nations, and as a race. The battle with disease, the constant problem of the world's food supply, medical and surgical research, are now considered to be the very background of social, moral, and economic life. Hence this historical process in every phase of life and knowledge (of life) is practically one - and it underlies the whole of life's activities.

In spite of this extreme "specialisation" which follows the splitting of Science into departments - a step which was inevitable owing to the advance of knowledge, there is, at the same time, at the present day, a tendency towards the reverse of this - the blending of two or more of these departments into one. Thus we get the Biologist and the Chemist meeting and pooling their knowledge on the common ground of Bio-Chemistry. Physics and Chemistry, likewise, meet in Physical Chemistry, and Geologists now take great heed of Physics in their study of the earth.

As scientific knowledge grew to vast dimensions the more rapidly along individual streams of specialisation, this very specialisation needed specialised knowledge which must include knowledge from other branches. Knowledge is one, and life is one, and any specialisation in one branch must have 'common knowledge' for its foundation. Science having reached the high standard it has, the specialist-physicist cannot advance far without some knowledge of what his fellow-scientist-chemist is doing, neither can the specialist-biologist advance without, for instance, knowing something of what his fellow-physicist is doing in the realms of the constitution of matter. The web is so intricate - each thread plays such an important ^{the} part in/making of the final pattern, that, if all the threads are not considered and studied then it is easy to lose the way completely in the tangle.

The history of Science has been likened to the story of a bud. In the Autumn it lies wrapped up in its coat of scales, the young leaves and axis are all there in the miniature. Winter follows - a period of rest and dormancy. Spring sees the opening of the bud and the emergence of the shoot. In Summer there is fast growth of all parts and new buds form on the axis. These ^{four} ~~four~~ stages can be traced in the history of Science. The bud-stage was the time of the Ancient Greeks, the

winter stage - the Middle Ages - over a thousand years - the buds being preserved, however, by the Arab tribes. Spring arrived with the new life in Science which started with Roger Bacon. The young shoots dared the danger surrounding them (in the form of direct and indirect antagonism) and emerged under the care of Galileo and Newton. The expanded branch appeared in its fulness in the time of Faraday and Darwin.

For the future buds there seems little hope of sleep. The tree is growing so fast - new buds appear everywhere in the axils of the old leaves, and each new branch adds to the splendour and majesty of the tree, each in its turn driving energy from the main trunk.

The story of Science is also similar to that of a stream which starts from a tiny 'spring' on the mountain-side, gradually gaining strength as it gets fed by small tributaries which grow in number as they empty their contribution from the surrounding area into it, until, at last, it has grown to gigantic dimensions and, in its turn, empties its contents into the common store - the mighty ocean. The tiny 'spring' was the first serious attempt of the ancient philosophers at probing into the secrets of Nature. The stream has grown until to-day - with its great number of tributaries, each draining the area in which it finds itself, and emptying its

contents into the main stream - it is sweeping down the plains of human life, with a mighty force, **whither?** No one knows. The nature and volume of the waters in the stream, naturally, depend upon those of the waters in the tributaries, **whereas** they, in their turn, get their bearing and direction from the course of the big stream itself.

So it is in Science. Each branch contributes fast to the common stock of knowledge. Each, in its turn, derives its bearing and impetus from the sum-total of the nature and contents of the main stream of Scientific thought.

We have, therefore, the historical process underlying life, and all knowledge appertaining to it, and from this process must arise the historical method of presenting this knowledge.

A Method of Approach in Biology Teaching.

The Historical Method - The Evolutionary Method.

Biology, at the present time, being a comparatively new subject in the school curriculum, is apt to be taught somewhat haphazardly, very often by experts in other subjects and non-experts in the subject itself. This naturally leads to a diversity of methods and of purpose, and it **becomes** a case of muddling through somehow.

There is, therefore, a very great need of a standard method of teaching the subject, the basic principle underlying which method will serve as a guide for the young teacher. The word 'guide' is used advisedly, as in Biology of all subjects one must not adhere too closely to a fixed way of approach to the subject.

In the first place, in dealing with the subject one must follow the dictates of Nature herself and the true teacher of Biology is essentially first and foremost a nature-lover, and hence his teaching must pulsate with life-it cannot be regulated too much by mechanical means since it deals with living things and must, therefore, be itself alive in the sense that it must be guided by nature - her seasonal changes, her rhythm, her variations and yet her constancy.

Evolution underlies the whole of Nature and life, and we put forward the suggestion that the best method of teaching the pupil about living things and life in general is what we choose to call the historical or evolutionary method and we propose to deal with ways by which this Method can be evolved and standardised so that it can be put to a permanent use in the teaching of the subject.

Different Aspects of the Historical Method.

Many possible lines of approach to the question suggest themselves when we make the first attempt at producing a satisfactory method on the basis mentioned.

Some of these are:-

1. A brief outline of the history of Biology as a Science - the sequence of events and discoveries throughout the ages.
 2. The arrangement of topics in the Syllabus in an evolutionary order, or in sequence.
 3. The building up of knowledge on a topic by the discussion of the great work done by the pioneers in the past - progress as registered by their struggles and achievements.
 4. The story of the topic as the knowledge of it has been gradually increased as time went on.
 5. The life-history of self-evolution of a plant or animal mentioned in the topic and its relation to the greater whole - Nature.
 6. The application of this idea of evolution (as exemplified in the law of bettering) to the pupil's own mind - Psychology.
-

We will deal with these Aspects separately:-

This Method of Survey in the Teaching of the Science.

Aspect 1.

A very brief outline of the history of Biology as a Science - i.e. sequence of events in biological discoveries throughout the ages.

A lesson or two taken on this at the beginning of each year in each Form will afford background for the Historical Method as outlined in the other aspects. It will prepare the ground for the introduction and the development of the Method, by giving a bird's-eye view of Biology.

It will also create interest in and a keenness for the course that is to follow for the year.

Aspect 2.

Topics are arranged in the Syllabus from the point of view of Seasonal Sequence, i.e. Nature's Seasonal Evolution.

The idea underlying this treatment is that the story of each topic should lead on to the next in sequence, ~~tell~~ ~~his own story~~, following on to the larger whole, finally arriving at ~~the~~^{'s} comprehensive ~~story of Nature's own~~ Seasonal story of her own revelation.

Most of the remarks made under Aspect 5 apply here.

Aspect 3.

In any given topic from the Syllabus the lesson or period is centred round personalities (pioneers) and knowledge is built up bit by bit through the medium of their trials, errors, and perseverance.

The pupil's mind is directed more to the personality than to the subject-matter which becomes secondary in importance, in his mind (the pupil's) to the great force of intellect, and the concentration displayed by the pioneer discussed. This makes for hero-worship of the best kind and tends to create a desire in the pupil to try and emulate. Such a tendency tends to increase his own powers of concentration and of observation, and thus cultivates the habit of careful and sustained observation - the essential quality a scientific education aims at developing.

Aspect 4.

In any given topic the lesson is centred round the evolution of the knowledge gained on the topic, the pioneers involved being brought in, incidentally.

The pupil's mind is directed to the advance of knowledge - the advance of truth for truth's sake. The subject-matter becomes the centre of interest and the story of the topic, rather than those who worked on it, is concentrated upon. We thus get a detailed survey of the evolution of knowledge gained on the topic.

The attention is guided on to the help given by this advance of knowledge to the progress of the human race and to general progress, whereas in Aspect 3. the attention is drawn to the effect of the Struggle by which this knowledge was gained. In both Aspects - the idea of evolution in everything underlies the teaching, and this idea, in time, points a way to the pupil as to how he can better himself.

Aspect 5.

A topic is dealt with from the point of view of Nature. The life-story of the organism - plant or animal - becomes the pivot on which the whole lesson turns. How the organism lives its life in relation to its surroundings, how it endeavours to overcome its difficulties, and adapt itself in relation to other organisms^{as} discussed and concentrated upon, and the whole story, in each case, is placed in its true perspective as regards Nature in general.

The pupil in time gets hold of a series of pictures of separate topics each in its true relation to the big picture (of Nature).

This treatment also tends to produce hero-worship - where the hero is Nature herself - the Universe - life - the law of progress - it tends to create respect and love of God - the guiding force behind all this Evolution. He gets, in time, to couple the idea of God with the

idea of this progress. By cultivating a true love of Nature, by showing the pupil how to look for God in the flower, the ear of corn, and the trees around him, this treatment may produce eventually a sound basis of religion.

Aspect 6.

The experience gained from the treatment of these ~~five~~ ~~four~~ Aspects is applied to the Study of the practical Psychology of the pupil, i.e. to the study of the evolution of his mind.

From this treatment we should, perhaps, get the most lasting influence of all - that on the pupil himself - an influence that is going to affect his whole life. We are ~~giving~~ ^{going} to leave with him the accumulated benefit of his whole biological course.

Moreover, when given some broad lines of suggestions along which he can, by using the experience gained in his course, improve his own thinking powers and thereby improve his personality, the pupil, whilst still at School can apply the same principles in his attitude towards other subjects in the curriculum and thus his biology teaching can influence for good the whole outlook of his student life and after.

One, two or ~~more~~ more of these Aspects incorporated into one Method and adopted by the teacher in every lesson - becoming a part of his very (teaching) personality would

seem to us to be the ideal, which of course, in practice is never reached. The aim, therefore, must be to get as near to this as is possible when one is surrounded by rules, regulations and Examination requirements.

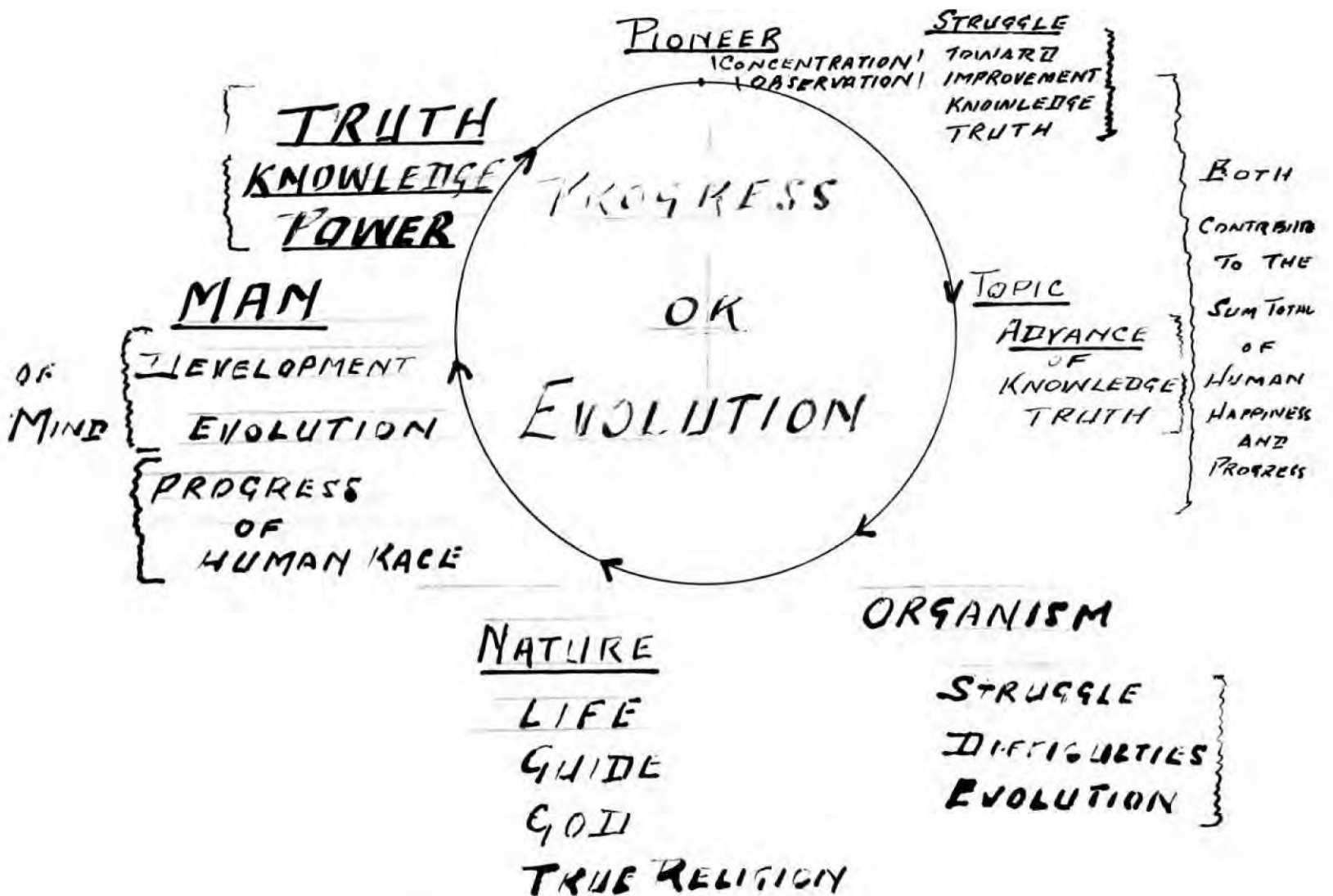


FIG. 1.

DIAGRAM - EVOLUTION.

Let us take one or two examples of topics dealt with in Biology teaching and try and analyse each Aspect separately first, and then see how it may be possible to blend some of these treatments into one consistent and constant Method.

Note.

The work of all pioneers ~~and~~ need not be investigated under Aspect 3 - indeed, time would not allow - it will suffice to give and discuss a few, the idea being to give the pupil some indication of the struggles, disappointments and triumphs of these men and women.

Again under Aspect 3, only some of the main milestones on the road of progress in the topic need, and can, be touched upon - enough to give the pupil a general idea of how the knowledge on the topic has advanced.

Topic - Seeds and their Germination.

Aspect 1.

A very brief outline of the history of Biology as a Science - i.e. the sequence of events in Biological discoveries throughout the ages.

This can conveniently form a background for the whole teaching of the subject in every Form throughout the School.

In the lowest Forms, say up to **Forms** 111. a mere outline can be made of the Story under this Aspect, in the first

lesson or two in the first term of the year. A skeleton table or Chart is built-up by Form and teacher - a copy of which each pupil makes in his notebook and a copy is also made in the Master's Record book. The pupil who makes the best Chart makes a Wall Chart for future reference. When this Form moves up the following year the Story is again reproduced in the first two periods of the first term, but this time the pupils having gained experience in the previous Form will be able to profit by experience and appreciate fuller details. The Chart or Table will thus be fuller than a year before. Copies are made as before in the pupil's Note book, Master's Record Book and on a Wall Chart. This procedure is followed all the way up the school so that in the VI. Form a most comprehensive account can be given and a somewhat detailed Chart made.

A little more time (a talk on 'Great Biologists' can be given say once a month) can also be devoted to it in the Higher Forms, since more periods per week are allotted to the Subject. By giving a bird's eye view of Biology, this Aspect will prepare the ground for the proper introduction of the Method of teaching the various topics under the other Aspects. It will also create interest in, and a keenness for, the course that is to follow for the year.

Aspect 1.(1) The Greek Period.

B.C. (Hippocrates,) Influence on the Scientific Thought
 (Aristotle,)
 (Theophratus) of coming generations.

(2) The Roman Period. Decline of Science except Botany.

1st C. A.D. Pliny) The only two names of note.

130-200 A.D. Galen)

(3) The Dark Ages. Absence of Observation.

200-1200 A.D.

(4) The Revival of Learning.

13C. A.D. Roger Bacon) Effect of Eastern Scientific
) zeal on Western Civilisation.

(5) 15 C. A.D. (a) The Humanists. Students of original
 Greek Works.

(b) The German Fathers of Botany.

(6) 16 C. A.D. The Discovery of the Circulation of the
 Blood.

Harvey. Starting point of modern
 physiology.

(7) 16-17 C. A.D. First Scientific Societies. Collect-
 ing information.

(8) 17 C. A.D. (a) Discovery of the Microscope. Great
 impetus to investigation.

(b) Classification.

Ray.
 Linneaus.

- (8) 17 C. A.D. (Continued)
- 18 C.
- (c) Comparative Anatomy
Cuvier.
Owen.
- (9) 18 C. - 19 C. A.D.
- (a) Biological Exploration.
Darwin's Voyage in the "Beagle."
- (b) Evolution
Darwin.
Lamarck.
Wallace.
- (c) Structure of Cell and Protoplasm.
- (d) The Chlorophyll System.
- (e) The Nitrogen Cycle.
- (f) Respiration as Combustion.
- (g) Tropisms and Nerves.
- (h) Pasteur on Fermentation.
- (i) Embryology.
Van Baer.
- (j) Nuclear Character of Sex.
- (k) Heredity.
Mendel.
Weisman.
- (10) 20 C. A.D. (a) Morgan on Heredity.
(b) Mutations.
- 19-20 C. A.D. De Vries.
- 20 C. A.D. (c) Nuclear basis of Heredity.
(d) The gene.
(e) Effect of this modern research on Man's Progress.

An alternative treatment, under consideration at the moment is the following:-

Relative Stress on various periods.

e.g. (1) Greek Period, (2) 1500-1800, (3) 19th Century to date -
at different Stages of School life.

Greek Period:

Lower Forms - in connection with Games and Athletics which were so prominent a feature of this period. This is the time to get this treated while the element of wonder is at its highest.

It is also more of a natural sequence - other periods can follow naturally in School life; so as to end up in Higher Forms with the work done in present day Science. Hence VI. Form - present day research - which will take all the time available for History of Science.

1500 - 1800:

Middle School. - Follows naturally on work in Lower Forms. Better able to understand 'eclipse' of Dark Ages, and follow threads. Also better able to grasp the Renaissance in Science in the 16th and 17th Centuries and acceleration in Science at this time - laying the foundation for Science 'branches' - increased research - and complicated network.

Work of 18th Century in fair detail - milestones.

19th Century to Date:

Higher School. V. Lower, leading up to research and discoveries in various fields during last 50 years in fair detail in VIth. Thus pupils get the complete picture by end of school career.

ASPECT 2.

- Evolut-)
ionary)
Sequence)
of)
topics.)
- (1) The Soil - as the home of the plant.
 - (2) How a seed is formed. The flower -
pollination - fertilisation.
Essential parts of a flower. How
the ovule (baby seed) becomes a
seed (containing baby plant), and
the ovary a fruit. The flower
as a branch bearing specialised
leaves.
 - (3) Structure of a Seed. Baby plant
surrounded by a coat, feeding
bottles, etc.
 - (4) Germination of a Seed. How the
prisoner escapes and fights for
itself.
 - (5) The Seedling. Photosynthesis, Root
Absorption, Respiration, Transpir-
ation.
 - (6) Mature Plant. Each part, shape,
function, etc.

ASPECT 3.

Source books are used and Extracts are read, or, to vary the procedure, a standard book on the History of Biology, e.g. Singer's, is used in the Upper School - relevant parts being shown under the epidiascope. In the Lower School simpler books are similarly used.

Theophrastus (380-287 B.C.)

2000 years ago. Let us take our minds back. People then did not realise that plants had parents. They had no lenses and microscopes.

Theophrastus was taught by that great scientist - Aristotle - one of the first scientists we hear of. He loved his master, and devoted his life to the study of Botany, a good thing for us since no Botanical work of Aristotle has survived.

Considering the times he lived in, he made wonderful observations on seed germination - he wrote the best account of it until the 17th century - nineteen hundred years after his time. He even found the difference between the germination of the seed in a Dicotyledon ~~from~~ that in a Monocotyledon - that in the former the root and shoot come out of the seed at the same place and

in the latter at different places.

He also found that in the Date Palm, where the male and female organs are in different trees, if the dust off the male is shed over the fruit of the female - the fruit develops. This is a description of the artificial fertilisation of the Palm tree, practised centuries before Theophrastus by the Babylonians and Egyptians.

Then followed the Dark Ages - very dark for Science - when only the Arab tribes kept the lamp burning.

MALPIGHI (1628-94)

He became Professor of Medicine at Bologna University. The microscope had been recently devised and this helped him tremendously - it made it possible to examine the structure of the seed. He became very proficient in the use of the microscope. He was a fine observer and experimented on many things in Biology. He wrote a fine account of the germination of the bean, laurel, date palm, pea and wheat. He made good distinctions between the seeds of Dicotyledons and those of Monocotyledons.

He found swellings on the roots of the bean but he did not understand what they were for. He made many good diagrams of the embryo-sac and endosperm.

GREW (1641-1712)

He was a pious man. He studied plants and animals because they were, like himself, made by God; and because they both were parts of God's design. He thought there was some similarity of structure between them. He looked for this similarity everywhere in Nature.

He guessed that flowers were the sexual organs of plants. In the 18th century there was still a dispute about sex in plants.

SPRENGEL (1750-1816)

He was a Rector. He lost his parish because he neglected his duties and spent his time studying Science. He went to live a lonely life in Berlin, and was looked upon as a crank, as many great scientists, lost in their work, are looked upon to-day. He wrote a work of genius on sex in plants. He observed, carefully, how insects pollinated certain flowers.

HOFMEISTER (1824-77)

A German, with no training, and yet he became Professor. He studied fertilisation and the germination of seeds. He traced the development of the ovule.

About 1855 sex in plants was definitely admitted - that a tube (pollen) grows from the grain, enters the ovule through the opening in it - that a cell from it joins with the egg cell in the ovule - which then enlarges and divides forming an embryo (baby plant) inside the old ovule.

Our knowledge has not advanced much since then.

ANOTHER EXAMPLE of ASPECT 3 - treatment.

Topic - Bacteria. Fermentation (Form Remove).

outline only.

PASTEUR (1822-95).

His Early Life. Interesting points about his private life (always appeal to boys).

Fermentation Workers before him. e.g. Schwann, 1837.

His Chances to study - Professor.

His Isolation of Bacteria from Sour Milk

His Work on Anthrax and Rabies

Rabies, particularly a serious disease at that time. His cure of sixteen Russians who had travelled to Paris to see him.

His Fermentation Experiments

Description in detail. Some of his Apparatus still to be seen at Pasteur Institute.

The Strong Opposition he had to fight against.

e.g. Liebig, considered to be one of the greatest scientists living at the time, firmly believed that fermentation was a chemical process, and had nothing to do with living things. Gay-Lussac believed that e.g. Oxygen was necessary since air appeared to be necessary. Helmholtz was another opponent.

His Great Experimenting to prove to the world that he was right.His Victory.Pasteur's work in preventing the Souring of Milk.

Found that certain yeasts or moulds were always present on the skins of the ripening grapes used in the process.

His Fight to prove that germs (bacteria) were present in the air, and that Fermentation and Decay were processes caused by them.

His Famous "Bent-necked Flasks" Experiment to prove this. These flasks still at Pasteur Institute.

His Perseverance in repeating his Experiments.

The benefit to his Country and to the world of his discoveries.

Summing-up of the life of a Great Benefactor of Humanity.

ASPECT 4.

Man from early times a food-collector.

Gradually became a food producer. Probably seeds had been discovered 5000 years before Christ, as had nearly all the elements which distinguish civilised man from the savage.

Seeds found in Tutankamen tomb of the Egyptians. Mustard seed of the Bible. Parable of the Sower. Thus seeds must be very old. The earth's crust cooled and plant life appeared. These plants produced seeds. The early tillers of the soil used seeds, and bit by bit men began to study how these seeds grew into new plants.

When the Greeks held power Science flourished, and much attention was paid to seeds. Then came the Roman Empire and Science suffered, because the Romans, laying stress on producing strong warriors, did not realise the value of science, and the only people who took a great interest in seeds were the medical men who wanted them for growing plants they needed for obtaining their drugs. The Dark Age followed (many centuries) and we hear little about any experiments in seeds or anything else in Science.

Then came the revival and plants became prominent again in the work of the herbalists who again used them for medicinal purposes. Then men of Science grew more serious and started to study life in more detail. Along with other topics they studied seeds, and how they germinated. The microscope was devised and after that Biologists were able to cut sections of seeds and see what they were made up of. They also began to watch carefully what happened when a seed was soaked in water, and planted, until step by step we have had handed down to us the story as we know it to-day. It is for us now to try and discover, by careful observation, more about the topic for ourselves.

(The story as we know it to-day is summarised).

ASPECT 5.

The seed-coat swells by absorbing water, - bursts - the baby plant comes out of its prison, - stretches its legs, - eats its store of food in the cupboard and starts fending for itself. It grows a small root (radicle) which makes for the nearest water to enable the plant to get the necessary minerals from the soil. It is also going to anchor the plant firmly in the soil; the young shoot grows slowly until the root gets established, and with the energy of the sun it makes the green colour which then helps it to manufacture food from the minerals and water brought from the soil and the carbon from the CO_2 of the air brought in through holes in the leaf. The young plant gains strength, adds more leaves (factories) and makes more food to build itself up with. It breathes like an animal, gives off waste, ceases activity (rests) at night, works hard in the daytime, just like an animal and eventually prepares for the future by producing flowers and seeds.

(Here the full story of how a seed is formed is given). Hence we get the complete life cycle or the self-story of the plant.

Aspect 6.

When a topic (or series of topics) has been presented according to one or more of the Aspects considered, ^{a discussion} at the beginning ~~and~~ end of a period, on the general impressions formed on the mind of the pupil, aids the development of ideas. Logical sequence makes for logical thinking and deductions (the underlying principle of the Scientific Method).

For instance, in the case of the topic "Seeds and Germination" - the treatment under Aspect 3 in particular, leaves on the pupil's mind very definite impressions as to the characters of the pioneers involved. He tends to consider them as guides to his own development along the sure way of perseverance and concentration. Gradually he begins to realise that progress in himself means the bettering of self through the power of the mind. It dawns on him that every action of his has an important bearing upon the sum total of his personality; that his progress depends, ultimately, upon the degree to which he can make his thinking evolutionary.

The impression gained from the treatment of the topic under the other Aspects, e.g. Aspect 5, tends to make him realise that, like other organisms in Nature, if he makes mistakes he must pay the penalty, and that this will retard his progress in the great struggle for existence.

Another Example of Aspect 6 - treatment.

The Brain in Man

Form VI.

Outline.

Rapid Revision of the Systems -

Digestive, Circulatory, Excretory, Respiratory, etc.

The Nervous System (in more detail) as the Controlling System.

The Brain as Headquarters of the Nervous System.

Composed of white matter with a coating of grey matter.

Convulsions (more surface exposed).

White matter responsible for directing routine of life. Great thoughts (decisions, etc., - intellect) emanating from Grey matter.

Quality of mind depending upon amount of grey matter.

Yet even this (seat of thought, of mind) has physical basis. (Depends upon food, etc.)

How marvellous Mind is.

Discuss Psychological Aspect - Training of Mind and Body.

How important.

This leads to consideration of self-development.

The Method of Procedure evolved from a Study of these
Aspects.

It becomes fairly obvious then that any topic laid down in the syllabus can be approached from various angles. The same topic can be treated from different points of view or from different "aspects".

If time allowed, a lesson on a given topic could be repeated, each time with a different way of approach to the subject. This would entail as many lessons on the same topic, possibly, as there are Aspects under consideration. This would, of course, result in a thorough treatment of the topic and would mean that the pupil would gain very comprehensive knowledge of the subject and at the same time derive those benefits which, it is maintained, a consideration of each separate Aspect could bestow.

Where, as is often the case, two or three topics can be dealt with together, as being intimately connected, as, for example in the case of the following:-

The Flower, the Seed, the Fruit, Seed Germination and Seed Dispersal.

Then in, say, six lessons (as many as there are Aspects) it would be possible, by dealing fairly briefly with each topic under each Aspect, to cover the ground in all these topics and at the same time gain continuity and sequence.

Here, then, is one way in which a permanent (yet ever flexible) Method could be evolved and a careful selection of topics as outlined in Aspect 2 would form an inevitable initial step in the building up of this Method.

First, the topics to be discussed in any one Form would, under Aspect 2, be arranged in the Syllabus in a series - a short evolutionary series - so that each succeeding topic has a definite bearing upon the one before, a knowledge of which helps materially in the grasping of the other. The topics are then grouped together in twos, threes, or fours, according to their more intimate connection with one another. Each group is then discussed (one topic merging into the other whenever it is found convenient) under each Aspect or under as many Aspects as are applicable. Roughly half the total time allotted to a consideration of each group would deal with theory and half with practical work. In the practical work the pupil would act as a detective in Nature and the group of topics would be treated mainly as under Aspect 5. The other Aspects would be dealt with in the theoretical work, except that some of them could be lightly touched upon in the observational (practical) work.

Another way of arriving at a permanent Method of procedure that suggests itself is the following:-

Every topic does not lend itself to convenient consideration under each one of the Aspects. One Aspect, or perhaps two, strongly apply to it, whereas the others do not. For instance Aspect 3 is ~~eminently~~ eminently suitable for the treatment of topic 'Fermentation'. It seems the best method of gaining the fullest value from the lesson, to deal with this topic from the point of view of a great personality like Pasteur and his work - his struggles and triumphs. On the other hand the next topic - Diseases - which would under Aspect 2 naturally follow Fermentation - lends itself to treatment under Aspect 4, with a brief summary under Aspect 3 to supplement it. Of course, Aspects 1, 2, and 5 would be automatically included in both cases.

It seems reasonable, therefore, to work out as many Aspects for any one topic as most suitably lend themselves to the treatment of that particular topic. The one most suited of all would form the basis of treatment throughout the lesson, supplemented by the others.

If all the Aspects do not conveniently fit in with the main treatment, then those that do not can be left out in that particular lesson, and the method would still be historical. The main idea must be that following a discussion on the lines of the Aspect or Aspects by the teacher, the whole is summarized by means of questions

and answers supplemented ~~in the blackboard~~ by the teacher's guiding remarks. This summary is reproduced on the blackboard and when completed (or as it is being made) copied by the pupil into his book. A copy is kept in the teacher's own Note Book and this becomes a record for future reference and for improvements to be added or omissions made in future years. The best pupil also makes a Chart (a Wall-chart) by reproducing the Summary he has in his Note book. This Chart, the Form Chart, is also kept for reference to be discarded when and if a better one is made at a future date (in that Form in future years). Thus the treatment becomes a living study and these Charts grow out of the treatment of the topics. The whole method is historical and observational in its very essence and the Charts and Records become permanent and useful as guides and reminders to the teacher and taught, but to be improved upon each year - again this is in itself evolutionary and historical.

In a year the Master has, thus a complete account of the working of the Scheme. It is left to him then to improve upon it as time goes on.

One of these two methods, therefore, seems to be the best to adopt in practice if the maximum benefit, from all points of view, is to be derived by the pupil, and it is suggested here that this Historical Method is the truest Method of teaching the Science.

In actual practice, however, it is found, very often, that a compromise between the two is the best Method. When, perhaps, only two periods a week are allotted to the Subject in the Lower and Middle School, the teacher finds himself forced to economise both in content and Method. In the Upper School, where the subject is given four or five or even six (in the VI Form) periods a week, then naturally his problem changes its dimensions and he may be able to use the one or the other Method in full.

Generally speaking, the Method which has been most in use is that of dealing with a topic thoroughly under the Aspect which is considered most suitable, some or all of the other Aspects being given a subsidiary consideration.

The Method used, therefore, cannot become too fixed - there must remain a good deal of elasticity about it - as with ~~every~~thing else connected with the study of living things.

It is left to the teacher, working under his own conditions and circumstances, to choose his own particular procedure, the one he thinks the best suited to the immediate needs of the case, but it is suggested that his actual procedure had better arise from this historical Method, herein outlined. He can cut parts out from the main - omit here and include there, but ~~it~~ is well advised to keep to the direction and purpose indicated.

Many other considerations come into play such as the age of the pupils and the Form they are in. Most topics (but not all) will be dealt with in each succeeding Form as the pupil proceeds up the School. New knowledge gained in each topic must be placed in its historical background by reference to previous work in that topic and by summarising and as the pupil increases in age and gains (and learns from) experience, he will be the more able to understand and to appreciate the Method and thus gain increasing and more permanent benefit from it. Herein, also, lies the value of the Charts and Records ~~XX~~ for reference.

P A R T IV.

PART IV.

Various considerations operate in, and affect the actual procedure in connection with the Method - as outlined in Part III. - and we must naturally deal with these, either separately, or when discussing the details of the teaching itself.

It will be convenient, therefore, to divide this Part into the following divisions:-

- (1) A Detailed Account of the Organisation of the Biology Department at Dudley Grammar School.
- (2) A Discussion on the Age of the Pupil and on the Characteristics of the Age-period in each Form.
- (3) A Syllabus for Each Form.
- (4) A Detailed Procedure according to Aspects -
Typical and Comparative Illustrations of the Work Done.

-
- (1) Dudley Grammar School is a School of four hundred boys, in the heart of the industrial area, with, therefore, peculiar difficulties and opportunities for biological teaching. It has three separate Science Departments - Physics, Chemistry and Biology.

It was one of the earliest schools in the country to include Science in its curriculum. This was in

1848, and it furnishes us with an interesting example of the expansion of the curriculum in response to local demands - 'the adaptation to environment' of the syllabus, so to speak. The introduction of Science was to a large measure due to the tightening of the bonds between the School and the vital practical problems of the district it was in.

This area is the centre of very important iron, steel and mining industries. A large percentage of the boys turned out of the school are absorbed into these industries, so that there is a strong industrial bias in the school arising out of this local bias. Birmingham University, to which most of the boys bent on an University Course, proceed, possesses one of the best departments of Metallurgy in the Country. There is a very real difficulty, therefore, in connection with Biology, since its utilitarian value is not so pronounced in a district such as this, and it may seem a source of wonder that in a school catering for the needs of such a district the subject should hold such a prominent position and be taught throughout the School to the Higher Certificate and University Scholarship Stages. There is, however, an excellent Medical Department at Birmingham University, and this supplies some incentive. It has been realised, however, that

the subject's general educative and cultural value, quite apart from its utilitarian value, is as important, (if not more so) in a town school as in a country one, in order to give to the pupil that necessary balance to his education.

At the same time the circumstances under which the subject is taught in such a school, provide an unique chance for developing certain aspects of the work bearing upon the life of a busy town. These aspects will be discussed later in this Part.

The introduction of Science was also, no doubt, (and its subsequent development) a part of the inevitable process in education, which accompanied the Industrial Revolution and it was correspondingly introduced and developed in schools all over the country.

As to the actual matter taught in Science in the School up to the 19th Century, we know but little. From the little we do know, however, from old School Magazines and Local Literature, we conclude that the Science ran along natural Science lines - something in the nature of elementary Physics and Chemistry, blended into one course, with special application to local interest. We find that the Ironmasters of Dudley took an interest in the school and then the Guest Scholarship was established, in 1863, for the best result in Science.

After the new buildings were opened in 1899 there followed the tendency to divide the Science into two separate departments - Physics and Chemistry, but owing to the fact that they were taught by one master and in ill-equipped laboratories the conditions were not favourable to their complete separation - necessary for more specialisation.

In 1921 a separate Physics Master was appointed, and the two subjects finally separated.

With these two subjects well established in the school, in separate departments, a definite scientific atmosphere was acquired in each, not at the expense of any other subject, but purely as the result of a gradual evolutionary movement.

It soon became apparent, however, that there was something vital missing from the Science teaching as a whole, - that these two subjects required extension, in order to make the Science teaching in general complete in its essence.

The introduction of Biology as a definite subject took place in 1924, and thus, as in Science teaching in general, so in Biology in particular, the school can

claim to be placed amongst the pioneers. The development of the subject (and of the department) has also involved, naturally, some very hard and real pioneer work.

At first the Science was designated - "The Science of Living Things" and was taken in the lower Forms only, the idea being to start the subject at the beginning of the school career and continue it in each succeeding year, so that eventually each Form in the school would have it as an integral part of its time-table. This was considered the best way to ensure a thorough grounding in the subject.

By the time the School Certificate stage was reached it became necessary to establish a Higher Course and here, the matter presented a little more difficulty than with Physics or Chemistry. Of those wishing to take the Higher Course, some would require Botany, some Zoology, and some Biology, as definite subjects in preparation for their University life. It became necessary to organise for these three separate subjects, whilst yet preserving that unity of concept so essential to Biology teaching in general.

During this time, side by side with the actual teaching, it was imperative to build up a Museum, partly,

from specimens collected, and partly, from Specimens bought, to equip the laboratory, and to correlate the work done out doors, particularly in the garden, with that done indoors, so that an attempt be made to make the teaching of the subject alive.

The subject is now taken throughout the school, in the Lower and Upper V's as an alternative to Latin or Art and in the Higher Certificate Course as a Principal subject.

When first introduced it was agreed that the subject would have to work out its own salvation. The inauguration and development of the Natural History Society has been one of the last links in the chain which has pulled the subject through, and more than justified its introduction as a subject of both scientific training and cultural value. The fact that the Natural History Society is one of the most flourishing of the school activities is proof enough that the subject is very much alive after ten years of its existence.

The subject is taught then, in each Form in the school. The accommodation consists of a lecture room with terraced benches and a long Master's bench for



FIG. 2.
LABORATORY—GENERAL VIEW.



Fig. 3.
MUSEUM (LOWER).
(PORTION.)



FIG. 4.

MUSEUM (UPPER) (PORTION)

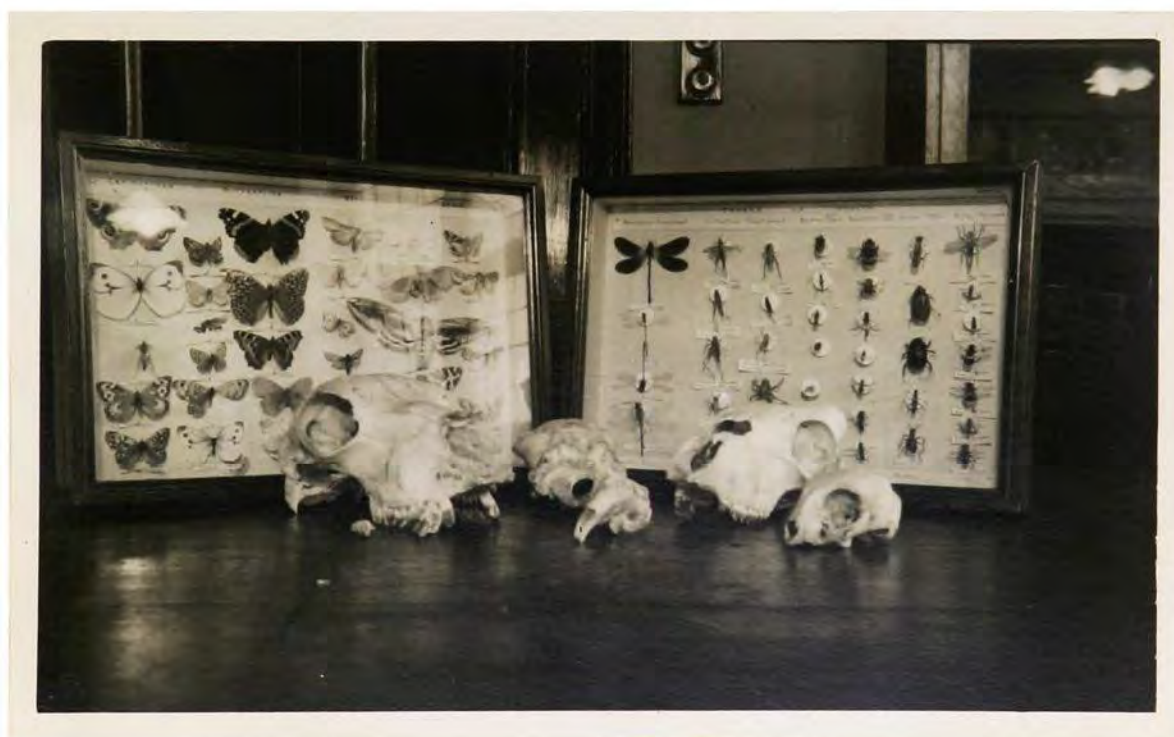


FIG 5.
INSECT CASES from WALL.
SKULLS " MUSEUM.



FIG 6.
DIGESTIVE TUBES.
-COMPARATIVE WORK.
—— VIS.
——



FIG. 7.

RABBIT EMBRYO.
SNAKE SWALLOWING
MOLE.

-

demonstration purposes, a small Master's room, and a laboratory which is well equipped and contains a good museum, various illustrative Charts, some hundreds of specimen bottles of seeds and other plant parts and two large central benches.

The Museum contains some bought specimens, e.g. dissected crayfish in a jar, and eggs of ostrich and emu, and (mostly) material collected by the boys, e.g. eggs of different birds, bones, (mainly of rabbit and frog), snake dissected to show small frog being swallowed (in jar), chrysalis showing insect in the act of emerging (in jar), skeleton of a frog, and various specimen jars containing specimens such as the frog, herring and crayfish, dissected and prepared by Vith Form pupils, together with the preserved brains of such animals as the dogfish, rabbit and frog, also prepared by Vith Form pupils.

This material comes in useful for comparative studies of the animals concerned and especially so since Vith Form pupils carry out some limited research upon the following:-

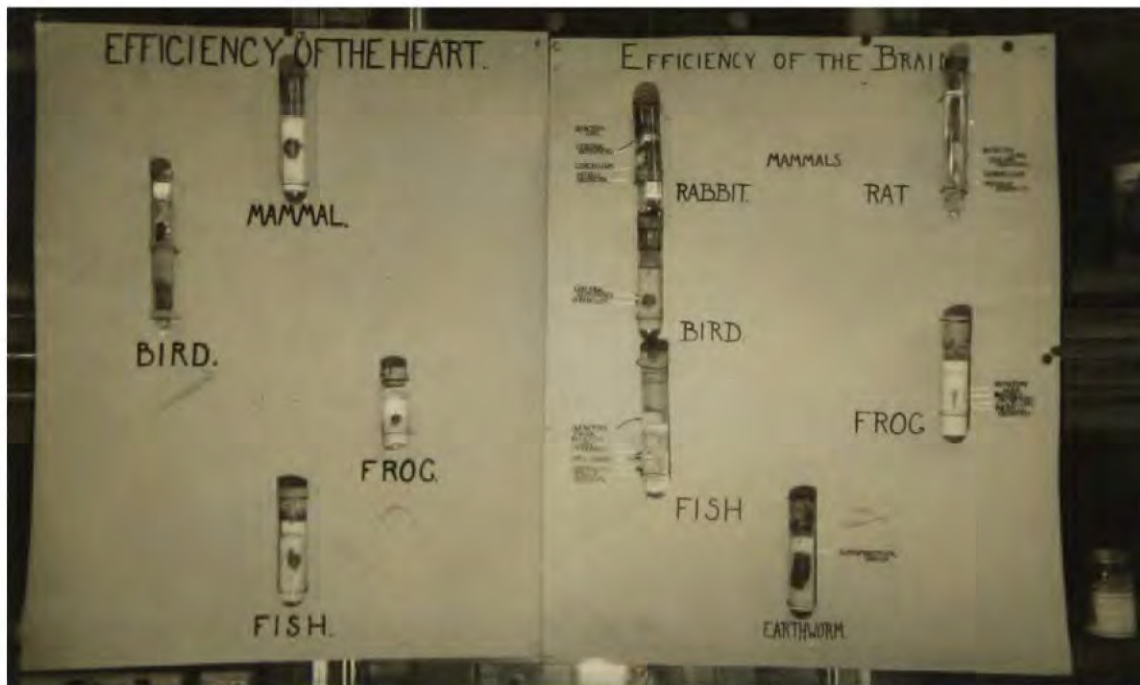


Fig 8:
 HEART & BRAIN.
 -COMPARATIVE WORK..
 ——— VIS.



FIG 9.
CHART.
(CIGARETTE CARDS.)

- (a) The relation between the size of the heart to that of the brain in the same animal.
- (b) The relation between the size of the (1) heart
(2) brain to the size of the body in the same animal.

The animals concerned, e.g. rat, chicken, frog, are dissected and the parts, ~~of~~ heart and brain respectively, are preserved in separate jars, kept on the shelves.

The present stage of this phase of the work does not warrant the deduction of any definite conclusions.

This Museum material is also used for demonstrating any particular topic discussed in each Form.

The lecture-room is also equipped with an up-to-date epidiascope and has its walls covered with charts on various topics. Other charts have been made showing the bones of various animals arranged in a progressive series.

All this, not only supplies useful and immediate information and facilitates the work, but is also destined to give to the department as a whole the atmosphere of the study of plants and animals.

There is a greenhouse attached to the department and also a large garden, both of which afford facilities



FIG 10.

GREENHOUSE (PORTION)

—GENERAL VIEW.



Fig. 11.

GREENHOUSE (PORTION.)

- GENERAL VIEW.

for the practical demonstrations of the subject matter studied.

On the first day of the school year the pupils are arranged to sit in alphabetical order both in the lecture-room and in the laboratory. Each Form votes for four monitors one to sit at the end of each long bench. Out of these four one is elected by the Form to be the Chief Monitor. Each monitor is made responsible for his own bench, keeping a list of the names, collecting books, checking any missing ones, and, in fact, being responsible in general for the bench and reporting all irregularities to the Chief Monitor who reports in writing to the Master. Thus the three Monitors are responsible to the Chief Monitor and each of the four looks after the welfare of his bench. The Chief Monitor in each Form is given a pocket note-book in which he records the progress of the work, homework, irregularities, and any other relevant information in each period week by week. For this purpose he uses the following table:-

followed from the Remove upwards except that instead of four week's work being entered upon one page, a double page is used for the week's work i.e. four periods in the Lower V Forms - V Lower B., and V.L.A, and five periods in Forms V. Upper B. and V. Upper A. The same applies to the VIs except that there are six periods per week to record, and that each scholar also keeps his own record Note book similar to the one used by the Chief Monitor - with the following headings:-

Week Ending -

Work Done -

(a) Lectures

1.....

2.....

(b) Private Reading.

(c) Practical Work.

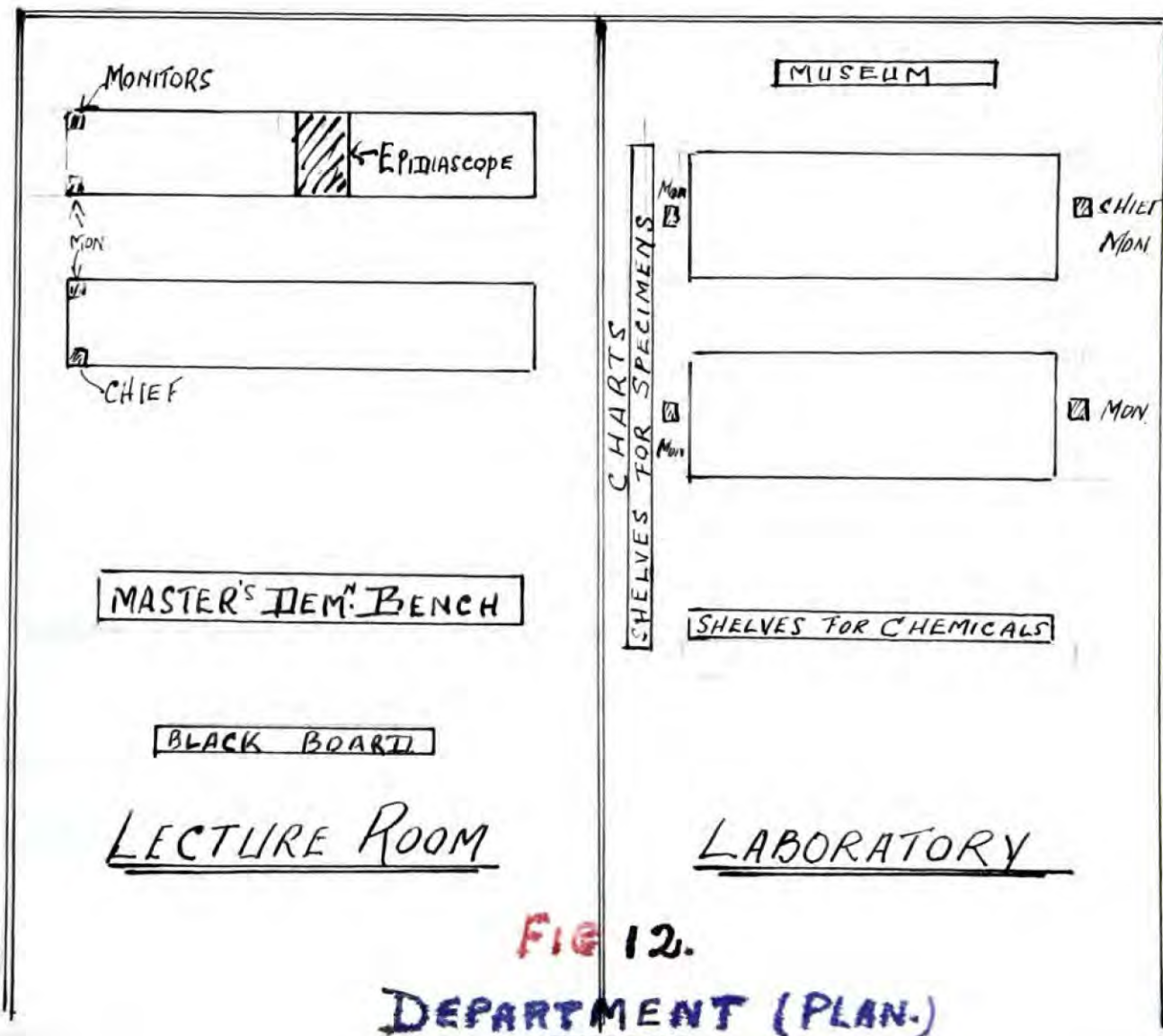
(d) Papers given, Scholar's Talk Series.

(e) Debates or Discussions.

Thus a full record is kept in each Form and continuity is effected. The Master has only to refer to the Chief Monitor's book in each Form to know the progress of the work and to refer back to any topic or date, or he may get each Chief Monitor to make an exact copy of his own

entry each time in a large Record Book kept by the Master.

At the end of a year the Master has a full record of the work done, stage by stage, from topic to topic, including the references in the Text Books, and the following year, in each Form, he is able to repeat the procedure, improving upon it as he himself learns from experience. The whole thus becomes progressive and evolutionary in character, and besides affording a record of the work it also becomes a measure of the pupil's progress and gain in experience as he continues his school career.



Laboratory Arrangement in Particular.

Each Monitor has his own row (which is the same as in the Lecture room) to look after. The instruments (scalpels, hand-lenses, seekers, etc.) which are kept locked up, are brought out by the Chief Monitor at the beginning of a period, and while the others in the Form are getting their books laid out for Practical Work (lined off in a certain way - see below) he takes the first set of instruments and gives one to each in his row, handing the box over to the Second Monitor when he has completed his row and then repeating with the second set of instruments (say, scalpels). The Second Monitor does the same thing, handing the box over to the ~~Chief~~ Head Monitor when he has finished with it, and so on until all the instruments have been given out and each Monitor knows the exact number he has disposed of and, therefore, the number he must get back. Five minutes before the end of the period the Monitors begin to collect the instruments, following the same procedure as before. The Chief Monitor puts them away in their places in the cupboard at the end of the period. After a little practice this process at the beginning and the end of the period occupies but two minutes or so in a Form of thirty to thirty-five.

When ready the pupils file out in order and the laboratory is then fit and ready for the in-coming Form (unless it is going into the lecture-room² where about half of the time allotted to each topic is spent).

The boys collect their own material for Practical Work (a practice, it is maintained, that tends to increase their powers of observation), and bring it in specimen boxes (any old tobacco tins, etc.) which are of convenient sizes for carrying about, and which have the ^{boys'} names, Form and 'Biology Specimens' labelled on them. Larger specimens, if necessary, are brought besides. Examination of material is done on square wooden boards (made in the woodwork room).

The work is laid out in the books thus:-

Experiment 3.

Date.

Practical Work		Practical Work	
Examination of.....		Examination of.....	
Diagrams.		Observations.	
Diag. 1.	Diag. 2.	Diag. 1.	
Diag. 3.	Diag. 4.	Diag. 2.	
Diag. 3.	Diag. 4.	Diag. 3.	
		Diag. 4.	
" 5.	" 6.	Diag. 5.	
		Diag. 6.	

(this
(is a
(draw-
(ing
(page
(of the
(Note-
(book.

Thus a double page is always used for Practical work, one being a drawing page and the other a writing page. Each pupil has his own option as to the number of drawings he will make. He is allowed a certain amount of free choice in order to bring out his originality and initiative. He is told that he is a detective in the realms of nature and that he is going to observe the specimens in that Specimen-box to be studied under that particular topic, in the same way as a Scotland Yard detective, for instance, observes in the realms of crime. e.g. in practical work on the Fern the pupil has in his specimen-box a piece of a frond bearing sori. He will examine these sori, counting the number in an area of 1 sq. c.m. of the under surface. He examines them with the naked eye, then with the hand-lens, and finally he teases one off with a dissecting needle, places it in a drop of water on a slide, observes under the microscope (small one in this Form, say Form IV) and then breaks it up with his needle and observes the torn sorus showing sporangia with the annulus ring particularly in evidence. He records his observations, supplementing them with knowledge gained from the guidance given by the Master.

The pupil draws what he sees and writes his observations on it with as little guidance from the Master as is feasible (some pupils will require more guidance than others). The whole is summarised briefly with the whole Form (guiding principles only) and this Summary is included in the pupil's observations as an ending to his observation page.

Generally speaking the observational stage on the part of the pupil precedes the work done on the topic in the lecture-room. He is encouraged to make what he can of it first, before it is discussed in detail according to the Method under consideration in this thesis. Thus he is the better equipped for theorising on it. Sometimes, however, some topics better lend themselves to theorising upon first, e.g. Bacteria (discussed with reference to the personalities of pioneers like Pasteur), and the matter must be settled by the Master to suit the needs of the particular case.

Each Form works in Groups (of two or three - three usually - it depends on the size of the Form), and each with a leader. It is found that this Group System makes for team work and cultivates the team spirit which it is so essential to foster in our Schools. Sometimes, as the case may be, only one

set of instruments is required by a Group and not one for each individual member of it. In the case of experiments other than dissections (e.g. Yeast fermentation) one set of apparatus is used by a Group, i.e., the experiment is set up by each Group and each member of the Group will contribute his share. The results obtained by each Group are then discussed.

Pieces of apparatus required, e.g. glass tubing, flasks, etc., are laid out by the Laboratory Assistant, who is given a list of the things required beforehand.

Observation Charts.

Each Form up to IV A. (inclusive) has an Observation Chart. The pupils who are the best in Art, volunteer, at the beginning of the year, to make a Chart according to their own design (the school motto being placed at the top), but with the following headings:-

Date.	Name	Observation	Locality.

These are brought along and judged in the Form, the one voted the best being hung up on the wall. *Each*

pupil writes a summary of any observations he makes in nature, in his pocket-book, and periodically, every fortnight or three weeks, a part of a period is set apart for the selection of the best observation made in the Form. Each one who has an observation reads it out, the rest of the Form writing a very brief summary of it. When all the observations have been read out, the Form, acting as a jury, judges them. The top four, according to votes, are put up for final voting, and the one that receives the highest number of votes is written down on the Form Observation Chart.

In this respect, as in many others, boys and girls prove themselves wonderful judges. A really outstanding observation never fails to stand apart from the rest by an overwhelming vote.

The boy who makes the winning chart looks after it throughout the year and enters the names and observations on it. Some pupils manage to get their names on three times, which is really a fine record. Great enthusiasm is aroused. Towards the end of the year the Master and the Chief Monitor from each Form, by the use of the same method, arrive at the best Biology Observation made in the whole school during the year. (To carry the matter still further, the top two or three could be sent up to some Natural History Society of note for comment and possible mention in its proceedings). One or two

are of the best/also included in the School Natural History Society's Notes in the Magazine.

Form Collections.

Along with these Observation Charts, collections of actual specimens are made. The Forms that make the Charts also make these Collections. Specimens considered to be unique in any sense, and of outstanding importance are brought and placed on the window-sills in the Form room. A small card is attached to each specimen giving the name and Form of the owner, and a brief summary of the nature and history of the specimen. Each member of the Form endeavours to make his contribution. The Monitors look after the Collection which is commented upon by the Master periodically and particularly at Half-term. Before the end of the term the Master, with the aid of the Chief Monitors, decides upon the best collection and similarly the best collection at the end of the Year. The pupils who brought specimens take them away at the end of the term to be returned again the beginning of the next.

This brings out the competitive spirit in its best form by coupling it with the team spirit, and the spirit of individual contribution towards a common good.



FIG. 13.

GARDEN (WINTER.)

- GENERAL VIEW.

—

Gardening.

A garden ($\frac{1}{8}$ acre) is divided into fourteen plots, together with two rockeries and a raspberry plot in the centre. One Form normally takes charge for a year - the Remove Form - but this year the V Lower Class ($\frac{1}{2}$ of each of V.L.A. and V.L.B.) mostly last year's Remove, are allowed to carry on in order to reap the benefit of last year's experience. Every other Form in the school goes down to the garden periodically for a talk and discussion of what is going on there, and for Examination of the actual specimens growing there. The growth of peas and beans serves three purposes -

(a) the study of the nodules on the roots of leguminous plants, and (b) the study of a flowering plant as regards mainly the appearance of the first leaves, the rate of growth, manures and fertilisers, effect on the succeeding crop, and the time of flowering, and (c) the study of the structure of a leguminous flower. The Forms observe the time taken for the appearance above ground of other plants after the planting of seeds, and the structure of other flowers, e.g. cress, and gain an insight, by first-hand observation, into such practices as the banking-up of celery, the care of strawberry plots, the thinning out of cabbages and lettuce, ~~and~~ the care of rockery plants, weeding, and the general clearing up of plots,



FIG. 14.
CHART — GARDENING.

paths, and hedges. Considerable practical experience is gained in this way.

Two partners usually look after a plot. The remaining boys are divided between the rockeries, and those boys working on the plots bordering on the raspberry plot look after that one.

The plots are cleared of all rubbish and old plants in the early Autumn and then are dug deep and the soil left in big lumps for the frost to act upon it. If any manure is to be added this is dug in at the same time. This turning over is done twice in the first term and the edges and paths trimmed and cleared.

In the Spring term the plots are got ready for the seed, and the initiative and interest of the boys are roused by allowing them to sow or plant any crops they wish in one half of the plot. One quarter is left for transplanting purposes and the other quarter is allotted to the seeds suggested by the Master.

The boys bring their own seeds or plants for their half and each row or bed is carefully marked. Each plot also has a sign-board put up giving the names of the partners concerned. The crops are tended carefully for the rest of the year, and at the end of the Summer term (or before if necessary) and early in the Autumn term the boys share the harvest with the school kitchen.

They have recently built up two rockeries, finding



Fig. 15.

AVIARY.

—



TUFTS
of
GRASS.

FIG. 16.

ROCK VEGETATION.

(SIDE OF SNOWDON.)

PLANT HABITATS.

—



Fig. 17.

Reeds (PHRAGMITES.)

(OXFORDSHIRE.)

— PLANT HABITATS.

—

their own plants for the purpose. They have also built an Aviary in which, at present, white pigeons are kept. Two boys who have aviaries at home are looking after it, and it forms a very interesting addition to the activities of the department. They afford a means of gaining experience of bird life and a source of much pleasure and curiosity, to younger boys in particular.

Photography.

Another Form (Upper School) not engaged in gardening, undertakes photographic work. Photographs of anything interesting in Nature are taken, the results periodically discussed and compared, placed under the epidiascope, and finally pasted on a cardboard sheet and suitably annotated. This collection forms an interesting record of the work of the Form in this respect during the year, and much enthusiasm prevails.

Aquaria.

The benches in the laboratory are supplied with deep sinks - two to each bench - and as there are two others in the room which are adequate for the general use of the practical work, these four are utilised as aquaria. One of the IVth Forms takes charge of them

and actually turn them into aquaria. The Form works in Groups as for Practical work, except that there are only four Groups this time. The boys are allowed a good deal of free choice and it is most encouraging to find what enthusiasm they can bring to bear, and what the final products of this enthusiasm look like. The pupils devote a good deal of their spare time to the work, and very often it must be suggested to them that it can be continued the following day. They display the most ingenious methods of making fountains out of glass tubing, and even fix up a wonderful system of lighting the Aquarium by night (these Aquaria are on show on Parents' Evening, when some hundreds of people pass through the department). They buy coloured electric bulbs for the purpose and obtain a variety of fish, particularly goldfish. They keep a record of the life activities of the fish, and the aquaria, of course, are used for demonstration purposes in other Forms.

It has been found out in debates and from question⁷₇aires, that boys prefer the study of animals to that of plants. They revel in watching their movements and habits and this undoubtedly quickens their powers of observation. Every opportunity, therefore, is taken of allowing them to observe the animals in the aquaria. In this way every Form gains experience from what another Form has set up.

Each time a Form is in the laboratory, where the aquaria, once set up, remain permanent for some considerable time, looked after by the pupils concerned, the boys are allowed a few minutes, before the official work begins, to discuss freely all they can observe about the inhabitants of these aquaria. They get real joy out of it besides valuable experience, and, in many cases, it leads to pupils keeping an aquarium at home. In this way this phase of the work contributes towards the 'pet' habit.

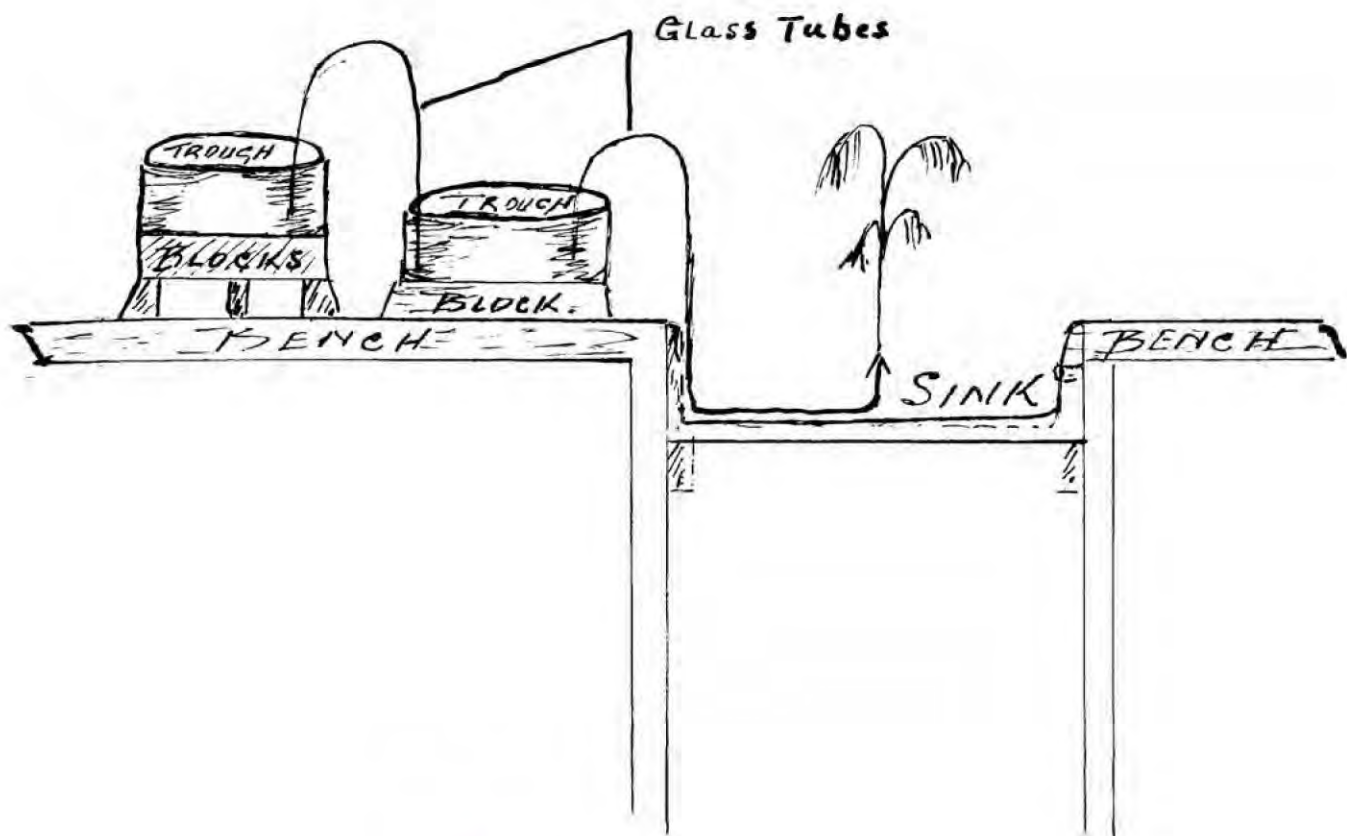


FIG. 18.

AGUARIUM.

Excursions and Rambles.

These are not easy to organise successfully, and need careful planning beforehand. The system which has proved most profitable is the following:-

The Master draws out a plan of the work to be done, the aim being to do a limited amount well rather than to do a large amount imperfectly, haphazardly and meaninglessly. Broad habits are discussed carefully with the Form before it sets out, and the work begins when the Master is fairly certain that the Form, on the whole, is aware of the purpose of the ramble, ^{and} also the extent of the value to be derived. The 'Group' system which operates throughout in Practical Work operates here. Each Group sets out to investigate, the Groups keeping fairly close together so as to be always under the eye of the Master and near at hand for his advice and guidance. Specimens of interest are collected, notes are made and these are examined and summarised later in the laboratory, when an account of the ramble is written in the books. Generally speaking, the same ramble is made a few times, at intervals, and the same plants (including trees) examined in particular, in addition to others. Seasonal changes thus become real and the true foundation of ecological study is made. More of these rambles are made in the Spring term when Nature is so active.

A limited number of excursions are made also - the same plan operating - to places of interest such as the Birmingham Natural History Museum, which can boast of an excellent collection, the Midland Dairy Headquarters at Birmingham or at Wolverhampton, for Clean Milk demonstrations, and Kew Gardens. Material from the first two named and from different firms, is displayed, also on Parents' Evening every year, when some hundreds of people pass through the department and view the work done by the boys during the year, in addition to such displays as mentioned above.

Similar Excursions are also made in connection with the Natural History Society, e.g. to the Biology Department of Birmingham University.

Scholars' Talks, Debates and Discussions.

These are a prominent feature of the work, particularly in the School Certificate and Higher School Certificate Forms. A rota is posted up and a pupil gives a talk on any of the topics in the Syllabus for the term. This is followed by a discussion. An epidiascope talk is generally preferred. Once a fortnight, alternately with the Scholars' Talk Series, an epidiascope lecture is given by the Master on "The Great Biologists".

In the other Forms boys occasionally give a talk, but no definite rota is used. There are, however, periodical debates and discussions, e.g. an imaginary conversation between Pasteur and Lister, represented by two boys, was thoroughly enjoyed by Form II. It ran on the following lines:-

Conversation.

Lister. "How do you do, Mr. Pasteur - this is my wife, -
Mr. Pasteur, my dear, - the great French
Biologist and the man you have heard me
talk so much about.

(Formal introduction - Mrs. Lister excuses her-
self and retires.)

Pasteur. What brought you over to France - such a busy
man as you?

Lister. My wife and I came over for a short visit
to friends and I am taking the opportunity of
seeing some of your famous experiments. Reading
about them, even, has helped me tremendously
in my work.

Pasteur. Oh, I'm doing my best you know - and I may
tell you now how your great fight against
disease is thrilling me. It will bring
great happiness and joy to sufferers all
over the world.

Let's have a look round - no doubt you'll be
interested in some of my apparatus. These are
some of the flasks and tubes I used, to prove
that bacteria are carried in the air. Yes,
it was a hard fight - there are so many people
who ridicule everything, aren't there? It is
the same with you, I expect.

Lister. Yes, rather, even some of my colleagues are
critical ~~forxxxx~~ (or else jealous) at first,
and this means that their poor patients suffer.

Note.

A School Play on the lives of Pasteur and Lister,
written and produced by the Department (at Easter
or Christmas) is now being considered. In this
connection the help of the French Master, who is
a good amateur actor, would be invaluable.

Natural History Society.

Extracts from the Account of the Proceedings in
the School Magazine - December, 1934.

- September 28th - A Lantern lecture on Scotland and Switzerland by Mr. Rollason. The use of coloured photographs greatly enhanced the usefulness of such a topic. Also the inauguration of a Junior Society, since the flow of new Junior members was proving too great.
- October 5th - A talk on Charles Darwin by Mr. E. Wallin.
- October 12th - Two papers by Mr. Rollason. He completed his excellent paper on Scotland and Switzerland, with the Epidiascope, and also gave a lecture on Psychology.
- October 19th - "Fabre" by Mr. G. Jones. He described the work of Fabre, with several interesting pictures shown on the Epidiascope.
- October 26th - An educational lecture entitled "Science and Food" by Mr. D. Cutler.
- November 2nd - Mr. Green gave a paper on the "Evolution of Plant Life", starting from ^{the}Thallophyta and finishing at the Gymnosperms and Angiosperms of the Spermatophyta.
- November 16th - An excellent paper by Mr. Young, on "Common Fishes of our Islands". The paper was enhanced by coloured drawings and photographs of the fish described.

November 21st - A paper on "Italy", by Mr. D. McNish.

The idea underlying all this is to give the pupil an interest in life - not a fleeting one, but an interest that will remain with him beyond school days. If Biology did nothing but this it will have served a purpose - the future citizen will have found means of keeping his mind healthy by the pursuit of healthy pleasure in the world around him. It will have given him one of the clues to happiness.

To sum up our account of the Organisation, the time allowed in the Upper School increases (in many schools it is vice versa - the subject - when taught at all, being discontinued after the Lower or Middle School). The time allotted, then, increases in the same proportion as the knowledge in the subject increases and hence real interest and purpose increase. Charts, aquaria, museum, are built up gradually by the boys, specimens being labelled with the name of the donor. A garden correlates the indoor and outdoor work, and Practical and Field work hold a prominent position in the Syllabus. 'Biology by Discovery' with the historical treatment underlying it, is the watchword and 'Let Nature Lead' the motto of the School Natural History Society, which is the rallying-point of the biological interest of the school. An epidiascope is an essential part of the equipment as,

by its means, by far more ground can be covered and a wider range of interest secured. Form debates create a keen enthusiasm as do, even more so, Form collections of Specimens and Form Observation Charts.

One of the aims is to bring to the young mind, gradually, in an evolutionary manner, the realisation of the Web of life each part of which is so subtly interconnected with the other. From this the idea arises that we are all units in the Great Scheme of things, and that life is one whole.

Books in Use in the Scheme:-

<u>Form</u>	<u>Title</u>	<u>Author</u>	<u>Publisher</u>	<u>Price.</u>
Prep. I & II.	Eyes & No Eyes	Cadwallader Smith	Cassel & Co, London.	1/3 vol.
II.	Living THings	Churchill- Bailey		
III.	Nature Study for Beginners	Patton	Oxford Clarendon Press	2/6.
IV.	A First Course in P. & A. Biology	Furneaux	Univ. Press	3/6.
Rem.	Biology for Beginners (also in IVA 3rd Term)	Holmyard	Dent & Sons, London	2/-
V.Lower.	Biology By Discovery	Green & Potter	Dent & Sons, London	5/-
V.Upper Vis.	A Text Bk. of Botany for Colleges	Ganong	Macmillan	15/-

Books in Use (Contd.)

<u>Form</u>	<u>Title</u>	<u>Author</u>	<u>Publisher</u>	<u>Price.</u>
Vis.	A Manual of Elem. Zoology	Barrowdale		16/-
	Elem. Physio- logy	Murche	Blackie & Sons	2/6d.
	Animal Biology	Haldane & Huxley	Oxford Claren- don Press	6/6d.

Reference Books - in the Scheme:-

Biology for Schools	Spratt & Spratt
First Book of Zoology	Burlend.
Living Things	Latter
Botany of Living Things	Bower
Biology of Flowering Plants	Skene.
Text Book of Botany	Strasburger
Practical Bk. of Botany	"
General Zoology	Dakin.
Zoology	Masterman.
Outlines of Zoology	Thomson.
Living Creatures	Von Wyss.
Biochemistry	Roaf.
Origin of Species	Darwin.
The Gist of Evolution	Neurman
The Case Against "	O'Toule.
Comparative Anatomy of Animals	Bourne.
In Nature's Workshop	—
Outlines of Science	H. G. Wells) Julian Huxley) G.P. Wells.)

(2) The Age-Period.

The views expressed throughout this Section of Part IV. are based upon actual experience of boys, supplemented by those of such authorities as Nunn and Von Wyss, where such are not in conflict with experience.

The age of the pupil must necessarily have an important bearing on the Syllabus, and therefore the average age of each Form decides to a large extent the syllabus for that Form.

Living things have great attractions, naturally, for even very small children. At an early age they have their pets and they soon become observant in the garden. Thus there is a beginning before school life starts and Nature herself is the first teacher followed by the parent. A little later short descriptions of life around are written and these compared with similar ones by another child - say, of a rabbit, canary, tortoise, toad, goldfish, tulip, wallflower, and so forth. It is pressed home early that plants are living things just as much as animals, that all living things not animals are plants, and that birds and fishes are classed as animals. Thus the idea is fostered that the lives of all living things are very similar, including that of Man.

Later, the arrival of swallows, martin, cuckoo, the budding of plants, the opening of flowers, the flight of bees, are studied and they become a source of interest, and cultivate the habit of observation.

Next follows more detailed study of the life, habits, and functions of animals and plants - how they feed, breathe and move - what their home is like, their nest, and their young - the pupil being encouraged to find out as much as possible for himself and to make careful sketches. The rule here is to choose the common everyday animal or plant. Insects, fish, frogs and fauna of pools, mosses, fungi, lichen, dissection of flowers, study of leaves, stems, and roots are next included, and this will bring in a systematic use of the garden-plots, and visits to ponds and streams.

By this time we are entering upon the Upper School stage and systematic studies in germination of seeds are undertaken. Here it is well to include some common weeds, to show how they spread. Groups look after half a dozen species each and keep records and photographs taken at intervals. The whole life history of the plant is observed - seed- seedling - through various stages - adult - new seed. The same is done with animals, e.g. the frog, whose whole life history is

observed in the aquarium. The pupils are encouraged to endeavour to find something out that is new to Science, something not to be found in text books; thus they begin to realise that they can not only learn facts already established by someone else in the past, but find out something new by their own efforts. The pupil learns that he can learn.

For instance, the following interesting discoveries have been made in the department:-

- (1) Starlings always follow a leader - Form III A.
- (2) A Chrysalis with the butterfly in act of emerging - " V.Lower.

The boy who found this ran half a mile back to school with it, and it was discovered that a dent in one side prevented the insect from freeing itself. It makes an interesting specimen - preserved in spirit.

- (3) Butterfly emerging from a chrysalis in the laboratory - wings half as long as body - in half an hour the wings had grown to almost the length of the body. - Form II.
- (4) The heart of the frog beating for about 20 hours after dissection (mentioned in Part IV. and Chart included) - " VI.

Function looms large now, correlated with Structure, Elementary human Physiology, made as experimental as possible, explains to the pupil the real meaning of why he breathes, moves his muscles, and has headaches in a stuffy room - things he is already aware of but cannot explain scientifically.

This leads on to the systematic study of the various systems in the body and how these systems work together for the common good. Such treatment necessarily leads to a realisation of the importance of keeping this wonderful living machine in good health, by the cultivation of clean habits and exercises.

This leads to the more systematic study of both parts of Biology - Botany and Zoology, which are undertaken at about 16. By this time the pupil will have gained that grounding of Physics and Chemistry necessary to the fuller understanding of Biology. Compound microscopes become essential now, whereas simple ones suffice for the Upper and Middle School, with lenses in the Lower.

Dissections also become important, whereas, before, very little is done. Opinions differ as to the advisability of commencing the systematic study of structure and function with a one-celled organism. Huxley was in favour of a frog as the starting-point

and other prominent authorities favour this view. They hold that after a course in the essentials of human physiology pupils can appreciate the generalised structure and absence of specialisation in lower forms of life, and can the better grasp the evolutionary stages in the production of the higher forms.

In this department the one-celled organism is taken first, leading on to division of labour and the production of a multi-cellular organism. It is thought that by this method the pupil gains a better idea of the evolutionary series from, say, an amoeba to Man. This method also allows for the fact that by the time Man's intricate systems - controlled by the main system - the Nervous - culminating in the brain as the seat of Man's wonderful mind - are due for study, the pupil has reached an age and gained experience, which will enable him to understand this most difficult and perhaps most important part of the work.

The systematic study of structure and function in plants and animals, commencing with one-celled organisms, actually commences in Form IV. and by the time the pupil reaches Form V. Upper he has gained a fair insight into the biological wonder of his own body, as well as into the place that Man takes in the evolutionary scheme. His mind is now ready to undertake specialisation and to fathom, to a large extent, the real meaning of it.

In the latter course (the Higher Examination Course), clear ideas are gained of the chief types of animal and plant structure, principles of classification and the meaning of 'genus' and 'species'.

Lectures and private reading occupy a prominent position at this stage, on such topics in biological philosophy as evolution, heredity, ecology and physiology. The 'Origin of Species' for instance, is read and discussed during the course, together with 'The Case for Evolution, and 'The Case against Evolution'.

The point of view (of the pupil) and thus the means of approach (by the Master) changes as the pupils grow older. This means of approach affects the treatment according to the various Aspects embodied in the Method of Teaching discussed in this Paper, but it leaves the general Principle of the Method untouched.

We may summarise this discussion of Age-Period by offering a few examples of actual work done in the School under each Age-period.

Stage 1.

Age under 7

The period of general interest and curiosity and in animals more than in plants. The Stage of 'Making Acquaintance?' Pupils are given ample opportunity of watching creatures in their natural surroundings, e.g.

frogs, newts, birds.

Nature charts full of colour should be made and the feeding of animals observed.

(Note:- Boys enter the School at 8 or 9 years of age, so that no intimate knowledge of this work can be given.)

Stage 2.

Age 8 - 10.

At this Stage Motor energy is pre-dominant. Each year in this Form (Preparatory and Form 1.) much manual work is undertaken, in an attempt to focus interest, and the whole idea of the study of Biology (and the value to be derived from it) may be made or marred, by the treatment of the Subject during this period.

Examples:-

(1) Boxes are collected or made and seeds planted in them in soil, in sawdust, in sand, respectively. The plants are tended and pupils are quick to learn from their observations.

(2) Jam jars are used for keeping tadpoles.

Groups are interested in this kind of work and gain useful first-hand information on the life of the frog.

(3) Cages are made for keeping caterpillars. Boys become keen on collecting different kinds, and studying the life story of insects in cages they themselves have made.

Stage 3.

Age 10 - 12.

Curiosity now passes into a desire to investigate in order to understand and interpret. The judgement becomes more cautious and records are more exact. There is excessive motor energy too at this stage, together with a development of the mind towards a fuller investigation, so as much manual work as possible is coupled with biological study proper.

Examples:-

(1) Measurement of the rate at which an earthworm moves. Each group experiments with one earthworm, one boy acting as time-keeper.

(2) Simple experiments on the importance of soil to a plant. The boys observe that a plant dies if pulled out of the soil in the garden.

They observe that a plant does not grow well if planted in sand alone.

(3) The Measurement of the Growth of Seedlings.

Peas and beans are planted in boxes which the pupils bring to school or make with cardboard or wood. The time taken for the plumule to appear is observed. A mark is made in ink on it, and the distance between this mark and the surface of the soil is periodically measured from then onwards.

(4) Observation of the development of a frog from an egg.

Jam jars (a few to each Group) are found useful.

Stage 4.Age 12 - 14.

This is the Analytic Period. There is more detailed observation of Structure and an increased inquisitiveness as to the meaning of phenomena. The Group system works better from now on, particularly if the Groups, consisting of, if possible, like-minded individuals, are organised to pursue some particular line of investigation. The study of plants and animals becomes more Scientific at this stage.

Examples:-

- (1) Observation of processes of Growth and change -
 e.g. the life-history of an animal (frog) from
 the egg to the adult.
 the life-history of a plant from the seed
 to the adult.

(1) Contd.

Jam jars as before are used, and bench aquaria are also used for observations.

(2) Simple Experiments on:-

Feeding, respiration, locomotion in plants.

(3) The Study of Function, and correlation of Structure and Function.

e.g. The wing and beak of a bird, the Structure of a Stamen.

(4) Human Physiology - Systems in Man.

Stage 5.

Age 14 - 16.

Towards the end of Stage 4 a clear change comes over the pupil - he reaches the age of adolescence and becomes distinctly more thoughtful and contemplative. He now begins to look into the future. It is the age of the dawning of real self-consciousness in more ways than one. He becomes more attentive to everything that appertains to his welfare. It is a very important stage and, incidentally, a very dangerous one, hence the calamity of the sudden break in education that occurs at this time, to the vast majority of our young people when they leave school.

As the result of all education is accumulative and progressive, this stage should see the endeavours of

previous stages bearing fruit. It is the period also of examination, which cannot fail to influence both teacher and taught. The pupil, becomes definitely more ambitious or ~~the~~ more directive in his ambition, and is ready for a more thorough study of structure and function in Plants and Animals.

In the School Certificate year the Seasons again determine the syllabus to a large extent, but the basis of it is the official School Certificate Syllabus. A little specialisation work is done in the School, in the School Certificate Year, in section-cutting and bacteriology.

Training in the expression of ideas becomes intensified at this stage, in preparation for the examinations.

Examples:-

- (1) The internal structure of a root, stem and leaf of a typical dicotyledonous and monocotyledonous plant.

Sections are made by means of a razor, and simple stains are used. Simple microscopes are in use.

- (2) Human Physiology.
- (3) Simple bacteriology work.

e.g. Preparation of Agar-Agar medium.

The making of slant cultures of Mucor (for instance)

(4) Simple Tests for Carbohydrates, Fats and Proteins

Stage 6.Age 16 - 18.

The period of advanced and specialised work. The pupils have now reached the stage of scientific philosophical interpretation and investigation, and the 'research' attitude which has been gradually developing up to now, becomes more 'focussed' along definite lines and ideas. The spirit of the true Scientist becomes more revealed.

Independent investigation, much private reading and systematic lectures on the main themes, are the distinguishing marks of the work.

As for the School Certificate year, the Syllabus is drawn out as far as possible so that material for study can be collected in season - the basis being the Official Higher Certificate Syllabus.

Examples:-(1) Evolution.

The Study of Darwin's 'Origin of Species', and the cases for and against the theory of Evolution.

Micro photograph.

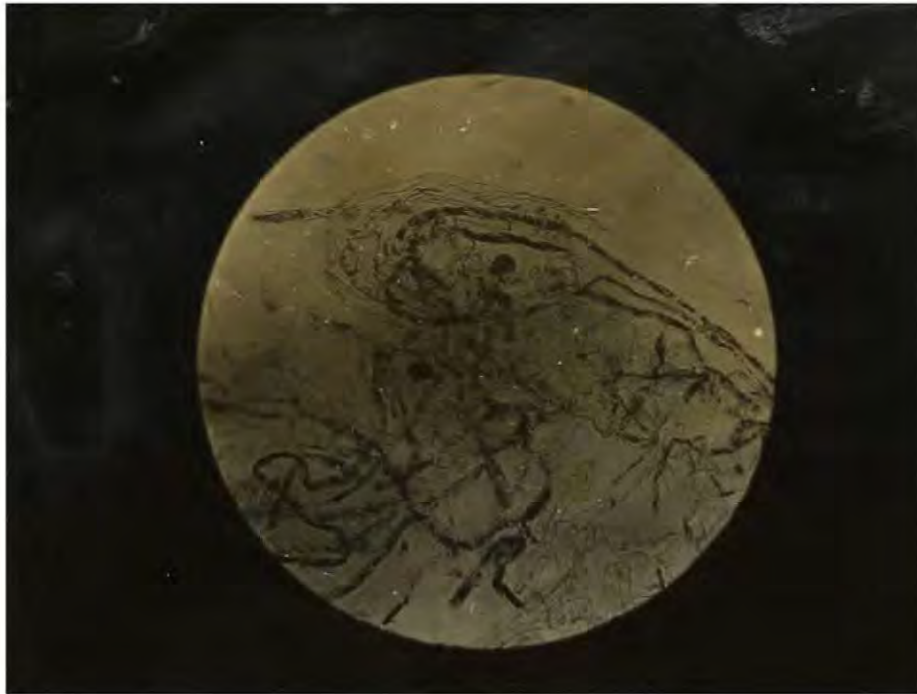


FIG. 19.

VAUCHERIA (Specimens)

STAIN: METHYL BLUE

TO SHOW: ACTIVE ALGAL CELLS (Filaments)

Specialised for PHOTOSYNTHESIS.

and Fertile Filaments fusing to form Zygotes.

Micro photograph.

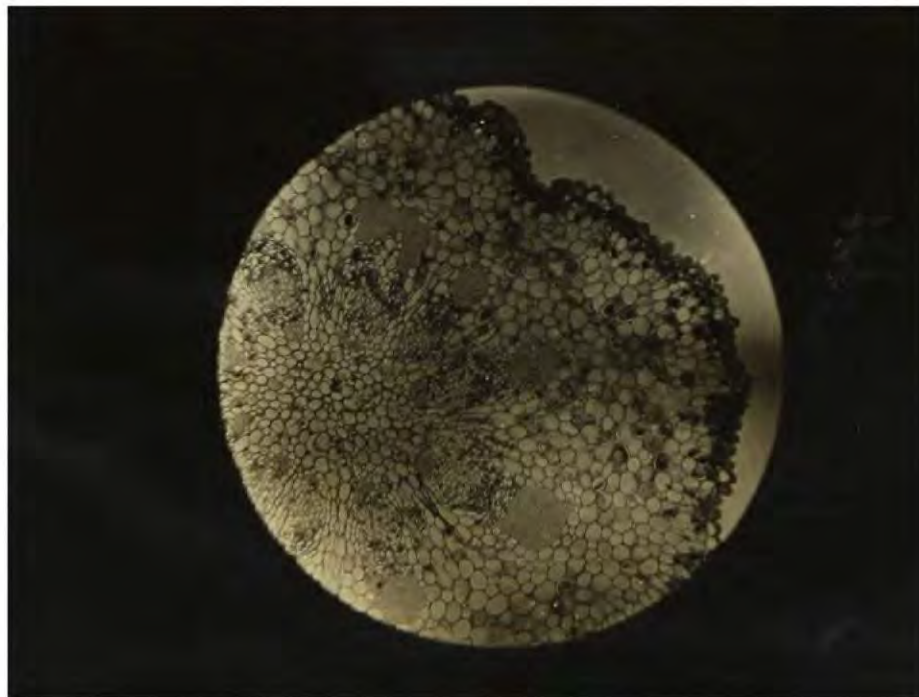


FIG. 20.

T.S. STEM - **VISCUM ALBA** (Mistletoe)

STAIN - ANILINE BLUE + Safranin.

TO SHOW - Morphology of HETEROPHYTE

Special Features. - Separate Sclerenchyma.

LARGE spherical Chlorenchyma

cells. Resinous deposits in

Phloem Cells.

(2) Sectioning.

The technique of cutting sections of a root, stem, and leaf, and of staining them is carried to an advanced stage. Every boy, on the average, makes thirty prepared slides in the limited time devoted to this phase of the work during the Higher Certificate Course.

(3) Bacteriology.

Media, e.g. Agar-Agar, and Agar, plus varying amounts of different fruit juices in each case, are prepared. Tubes are inoculated with different fungi, e.g. Mucor and Phoma (dry-rot).

The rate of growth of each fungus, the time of the appearance of fruit bodies, etc., are carefully observed. The rate of growth of bacterial colonies - obtained by introducing dust, milk, etc., into each tube respectively - is studied, and from these 'first' growths in the case of the fungi and bacteria - 'sub-cultures' are made.

(4) The Frog.

Fairly advanced work is done. Dissections are made, careful diagrams added, parts (e.g. heart, brain) are preserved, attempts are made to inject a coloured liquid into the blood vessels, and 'slides' are made of thin sections of various tissues (e.g. epithelia).

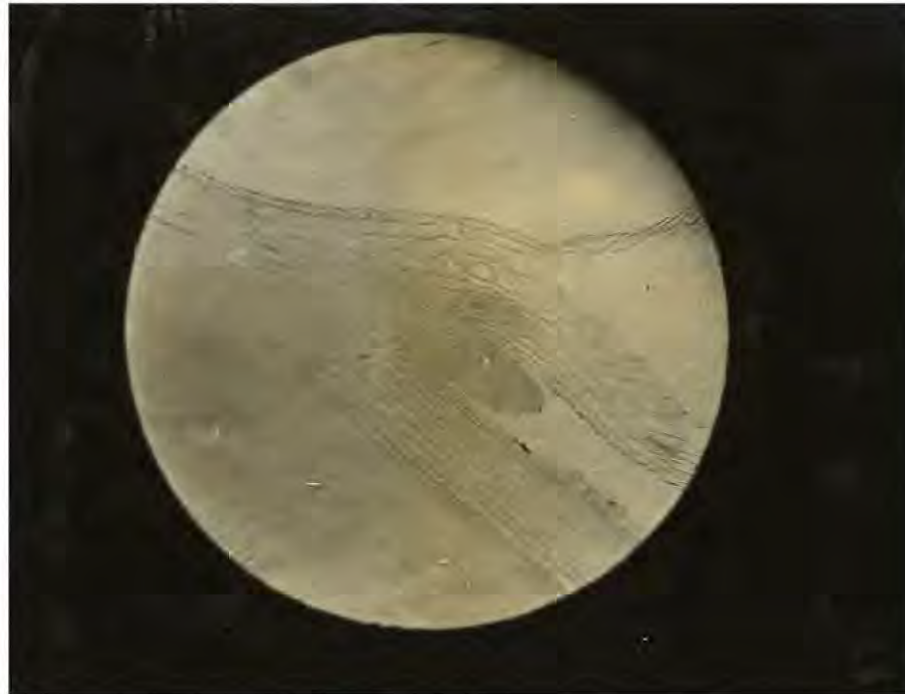


Fig 21.

L.S. STEM of SAXIFRAGA:
(TRIDACTYLITES)
STAIN — METHYL BLUE.
TO SHOW — GROWTH of BUD IN
LEAF AXIL

SPECIAL FEATURES. — NO TISSUE
DIFFERENTIATION IN MERISTEMATIC
GROWTH of BUD. NO CONDUCTING
VESSELS LEADING TO BUD.

—
Micro-photograph.

(Observations on the heart-beat in a dissected frog are mentioned elsewhere).



FIG. 22.

T.S. of ILEUM of FROG.
 STAIN - HAEMATOXYLIN
 To SHOW - MUSCULAR WALL
 of INTESTINE, VILLI
 & their BLOOD-VESSELS
 & LACTEALS.

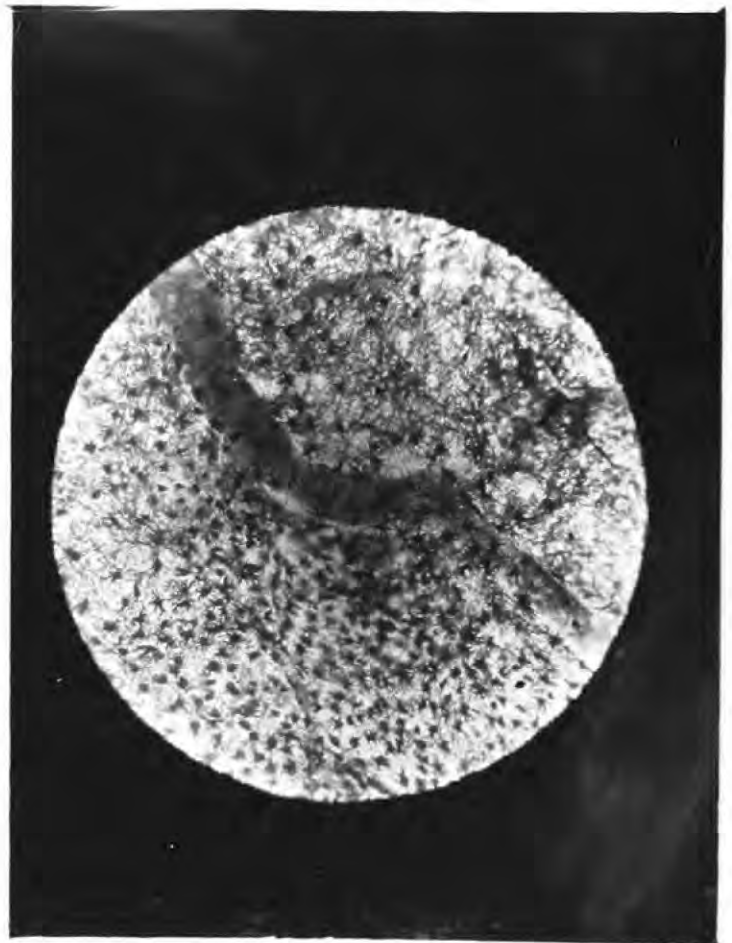


FIG. 23.

SKIN of FROG (from ABDOMEN)
 STAIN - INSOL. CARMINE
 To SHOW - LARGE CAPILLARY
 BLOOD VESSEL
 STAR-SHAPED PIGMENT
 CELLS.

(3)

SYLLABUS.Preparatory Form. Age - Under 9.Term 1.Text Books:-

The Reason-Why Nature Readers - Martin & Martin.

Book 3. - Autumn.

" 4. - Winter.

1. The Parts of a plant, illustrated by some typical plant, e.g. Shepherd's Purse.
2. Fruits. Different Shapes and Sizes. Common names. Diagrams coloured from observation of specimen and of model charts.
3. Disposal of Seeds. Coloured diagrams made. Comparison with farmer scattering seeds.
4. Bulbs. Growth in pots. List of plants with bulbs.
5. Trees. Evergreens and Deciduous.
6. Hibernation and Migration - (a) Animals which go to sleep in Winter,
(b) Animals (birds) which go away in Winter.
7. Animals of the Field and Hedgerow in Winter.

Revision.

Term 2.

Text Books (Additional) - The Reason-Why Reader.

Book 1. - Spring.

1. Twigs. Buds. Observation of specimens kept in water.
2. Trees. Those that bear (a) Cones, (b) Catkins,
(c) Blossoms.
3. The Frog. Observation of spawn and tadpoles.
4. Early Spring Flowers - Snowdrops, Daffodil, Narcissus,
Primrose. Observations and diagrams (coloured).
5. The Parts of a Flower. Elementary. Diagrams coloured
as per Nature.
6. Birds' Nests. Observations. Drawings. Specimens of
old ones.

Revision.

Term 3.

Text Book (Additional) - The Reason-Why Reader.

Book 2. - Summer.

1. Birds in Summer. Water Birds.
 2. Pond life. Newts, toads and frogs. Observations on
tadpoles. Collection of Spawn Stages
Diagrams.
 3. Some Water plants.
 4. Insects. Life-story. Silkworm. Constructing of
Caterpillar cage.
 5. More wild flowers and their families - the Pea, Deadnettle.
Revision of year's work.
-

FORM I. Age 9 - 10.Term 1.

Text Books. "Eyes & No Eyes" Bk.111. Plant life in Field and Garden.
 " 4. Birds of the Air.
 " 5. Trees & Shrubs
 " 6. Highways & Hedgerows.

1. A plant and its parts. Simple account of work done by each part. e.g. Corn and Wheat. Ripe Corn. - value. Harvest. Damage done by mice and birds.
2. Fruits and Seeds. Different kinds. Construction of coloured chart.
3. Bulbs. Diagrams made of stages in growth - with dates.
4. Trees. Autumn colours in leaves. Diagrams painted. Collection of different colours. Colour Scheme. Christmas trees. Folk stories.
5. Autumn Flowers. e.g. Nasturtium. Purpose of flower. How seeds are formed. Elementary.
6. Hibernation & Migration (a) Animals which go to sleep in Winter, e.g. Squirrel.
 (b) (Birds) Animals which go away in Winter.

Food - Habits - Preparation for Winter.
 Compare with Man.

7. Bird life. Parts of a wing. Compare with arm. Feet and head of fowl.
 The Bat - a Flying Animal.
8. Night Prowlers - Hedgehog, Rat, Fox, Badger.

Revision.

Term 2.

Text Book (Additional) "Eyes & No Eyes", Bk. 2. -
By Pond & River.

1. Buds. Markings on twigs kept in water. Different kinds -
e.g. Poplar, Chestnut, Hazel (for Catkins).
 2. Seeds. Different kinds - construction of coloured chart.
Sown in boxes on window - in soil, water,
moist sawdust, blotting paper. Records.
 3. Birds. Sparrows, Pigeons. Characteristics. Identificat
Ways of photographing them close up.
Paint Pictures of feathers.
Collection of Cigarette Cards, cuttings, etc.
Eggs & Nests - specimens.
 4. Frog. Observation of growth of stages from spawn to
frog. Care of tadpoles - Aquarium. Compare
with a seed.
 5. Frogs, toads, newts, sticklebacks. Observations on
habits (movements) in Aquarium.
Drawings (coloured)
 6. Spring flowers. Snowdrops, tulips, Narcissi, Violets.
Pupils bring from own garden. Discussion
and coloured drawings.
 7. Examination of flowers. Elementary. Name and colour,
parts. Diagrams.
Poetry on topic.
 8. Plants around the School. Observarions on soil, wind,
height, branching, fruit & seeds. Names.
- Revision.

Note: From now on for about 25 pages, there have been some
typist's errors in the numbering of pages.
It has been considered wise not to alter the numbering,
since it rights itself later on.

WALY

Term 3.

Text Books (Additional) - None.

1. How plants defend themselves. Compare with animals.
2. " " climb.
3. Bird food in summer. Care of young. Old nests.
4. The Story of the Cuckoo.
5. Insects - The Spider, Dragon fly, Caddis fly, Water bugs
e.g. Scorpion, Boatman, Measurer;
Specimens in Aquarium.
6. How insects help in making of Seeds. Insect cages.
Collection.
7. Examination of flowers.

Revision of Year's Work.

FORM II. Age 10 - 11. 2 Periods a week.Term 1.

Text Books - "Eyes & No Eyes" - Bk. 3. Plant Life in
Field & Garden.
" 4. Birds of the Air.
" 10. Highways & Hedge-
rows.

Living Things - Bailey - Churchill.

1. Fruits and Seeds. Autumn flowers - different stages.
Development of ovary into fruit and ovules
into seeds. Pupils collect material & data.
Chart made - observations & sketches and
actual specimens if possible.

2. Winter buds. e.g. Horse Chestnut, Oak, Drawing of twig and one bud (enlarged) Markings, etc. Dissect and draw what is revealed. Winter buds - means to prevent evaporation of moisture when roots almost idle. Unfolding of buds to be noticed in Spring term. Twigs kept in water in warm room for the purpose.
3. Some very queer low animals and how they reproduce or bud. e.g. bacteria, Yeast. Good and bad bacteria. Chart. Value of yeast.
4. Pasteur - another great Biologist. What he found about bacteria. His experiments. The debt the world owes to him.
5. Lister - a Great Bacteriologist. What he did. What he found about bacteria in wounds. His great work for humanity.
6. How Nature improves herself - What we call Evolution. A few examples. Chart made, pupils suggesting comparisons such as evolution of modern motor car.
7. Darwin - another great Biologist - His travels and what they meant to the world. Coral reefs. His home life and hobbies.
8. Earth worms. What Darwin found out about them. Nature's plough. Their importance. Examination of specimens with a hand lens. Rate of locomotion, length, likes and dislikes, etc.

Revision.

Term 2.

Text Books (Additional) - "Eyes & No Eyes" -
 Bk. 5. Trees & Shrubs.
 " 9. Riverside Rambles.

1. Buds. Twigs kept in water in a warm room. Unfolding. Stages - sketches - observations - rate of growth.

2. Seeds. Germination. Common seeds sown in pots, etc., as in previous Form. % Germination, early stages, rate of growth. Chart finally made of sketches of complete life history with notes on rate, etc.
e.g. Barley, Mustard, Cress, Pea, Bean.
Drawings.
Experiments on need for light, warmth, moisture, etc.
 3. The Plant as a Living thing - how it breathes and feeds.
Simple experiments.
 4. Frog's Spawn. Tadpoles - observations as in previous Form. Compare with the Story of a fowl's egg.
 5. How plants and animals multiply (reproduce).
Refer to 4. Other methods.
 6. Bird Life. Ways, eggs, nests, Bird calls. Identification.
Photography. Chart.
 7. Pond life. Saddis fly, snails, beetles, etc.
An adventurous little animal - the Water Spider.
Chart of sketches and notes.
 8. Spring Flowers. (As in previous Form) Examination of Specimens, collected in the school vicinity.
Revision.
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Term 3.

Text Books (Additional) "Eyes & No Eyes", Bk. 6. Insect Life.

1. Examination of flowers, e.g. Hazel, Willow.
2. Mendel - another famous Biologist. Some of his Experiments.
Pupils to try some at home. (crossing of tall and short Sweet Peas).
His work and life. Importance of his work - new varieties, etc.
Results of "crossing" observed in pets, e.g. differently coloured mice and rabbits.

3. Life-history and habits of insects. e.g. honey bee, ant, Cabbage White Butterfly.
Construction of Caterpillar cages.
Stages observed.
Chart on life-history as observed.
4. Flowers and Insects. A wonderful plan of Nature.
5. Fabre - the Poet-biologist. His love of nature.
His struggles and achievements.
His fight against enemies and poverty.
His experiments on plants in their homes.
6. The homes of plants - their home-life, and how they try to solve their difficulties.
Outdoor work mostly.
Chart on plant communities.
Photographs (collection)

Revision of the Year's work.

FORMS III. Age 11 - 12. Periods 2 per week.

Term 1.

Text Books - "Eyes & No Eyes", Bk. 12. O'er Moor and Fen.

Nature Study for Beginners - Patton.

1. Fruits and seeds. How formed, kinds, classification.
Chart made.
2. Seed dispersal. Different ~~means~~ means. Chart of notes and pictures.
3. The Soil in relation to Plant life. How formed.
Different kinds.
Rotation of Crops - Why?
Sand, Clay, Humus.
Water and minerals in the soil for plants.
Root hairs.
4. ~~Sundays~~
Animal Life in and above the soil. Harmful and helpful animals. e.g. Wireworm, bacteria, Slug, Lady-bird, earthworm, mole, rabbit.
Chart made.

5. The intimate connection between living things -
 - (a) between plants and other plants
 - (b) " plants and animals
 - (c) " animals and animals.

The Aquarium and its inhabitants.
 6. The life-history of a fish, e.g. Stickleback, eel.
Diagrams (coloured).
 7. The Struggle for Existence in Nature.
Insects and their enemies; why so few seeds become mature plants and so few eggs mature animals. Insectivorous plants. The balance in Nature and how man upsets it.
Chart.
- Revision.

Term 2.

Text Books (Additional) "Eyes & No Eyes",
Bk. 5. Trees & Shrubs.
" 11. Nature's Nurseries.

1. The Call of Spring. The parable of the Sower. Discussion.
2. Seeds. How they germinate. Seedlings. Different kinds of Seeds. Parts of a seed, e.g. pea. Experiments on germination.
3. The Full-grown plant. Root, Stem, leaf-structure and function. Tendrils, Spines. Ecology (Effect of environment, etc.
4. The Plant at Work. Root pressure. Root hairs. Stomates. Respiration. Photosynthesis. Experiments.
5. Trees. Birds, - activity in plant and animal world in Spring. Rapid growth. Evergreen, deciduous, coniferous trees. Identification from leaf, twig, and fruit. Collection of Cigarette cards.

6. Other Ways in which plants multiply:-
Cuttings, bulbs, corms, rhizomes, tubers,
runners, etc. Chart - Notes and Sketches.
7. Life-history of the frog, ant, etc. Reproduction.
Metamorphosis.
8. Some Common birds. Chart made. Eggs.
9. Nursery life of - Rabbit, Hare, Hedgehog, Bat, etc.
Comparisons and Contrasts. Chart made.
10. The flower. Examination of Spring flowers.
Floral parts, formulae (elem). Complete and
incomplete, Monoecious and Dioecious, simple
and compound flowers. Chart.

Revision.

Term 3.

Text Books (Additional) Eyes and No Eyes - Book 6,
Insect Life.

Book 9 - Riverside
Rambles.

1. The Flower (revision) and the relation to insects.
Pollination. Self and Cross pollination -
Adaptations in each case, wind, insects and
other animals as agents - adaptations.
2. Insects. The Cabbage White Butterfly. Cage.
Observations on complete life-history.
Bee, Fly, Wasp, Ant, Dragon fly, etc., in
less detail. Chart on Insects.
3. Trees in Summer. Identification. Outdoor Work.
Trees around the school.
4. Some Moorland plants, e.g. Heather, Sundew, Butterwort.

5. Some Moorland animals - Snake, Deer.
6. " " " (birds) - Buzzard, Curlew, Grouse.
7. " " marsh birds.

Revision of the Year's Work.

FORMS IV. AGE 12-13. Periods 2 per week.

Term 1.

Text Book: A First Course in Plant and Animal Biology -
Furneaux.

1. The Amoeba. How it lives, grows, and reproduces.
 2. Yeast. " " " " " "
 3. Protococcus " " " " " "
- One-celled organisations. Discussion. One cell to do
everything. Microscopic examination where
possible.
4. Differences and Similiarities between 1, 2, and 3.
 5. " " " " plants and animals.
 6. Evolution as exemplified in Progress or Specialisation.
From one-celled to many-celled organisations.
Chart of Sketches and Notes.
 7. Starch and Chlorophyll, etc. Microscopic Examination.
Experiments (tests).
 8. The Fern as a type of a flowerless plant. Compare
with Flowering Plant in reproduction.
Chart on Reproduction in Fern.
 9. Flowering plant (commence) - Reproduction for comparison
with Fern.

Revision.

Term 2. TEXT BOOKS (Additional) - None.

1. The Flowering Plant (continued) Stem, Root, Leaf,
Feeding.
2. The Flower (revise). Pollination and Fertilisation.
Chart.

5. Flowers. Examination. Plant families (12 in detail)
Diagrams and Formulae.
Chart on points of contrast.
 6. Local vegetation and Farms. The study of plants and
animals in their homes.
Photographs.

Revision of Year's work.
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FORM REMOVE. Age 13 - 14.Periods 2 per week.Term 1.

Text Book. Biology for Beginners - Holmyard.

1. The Air. Its composition and relation to life.
2. Water " " " " " "
3. Living, non-living and dead things.
4. Classification of (a) animals Chart
(b) plants "
5. Seeds and fruits. How formed from flower.
Pollination and Fertilisation.
Chart showing classification.
6. Pasteur. His great work in bacteria. Chart on
his contribution to Science.
7. Flowerless plants. Types. Bacteria, Yeast,
Seaweed, Mushroom, Spirogyra, Moss, Fern.
How they reproduce.
Chart showing these points.
8. Flowerless and Flowering Plants.
Chart of comparison and contrast.
9. Methods of Reproduction. Sexual, Asexual,
Vegetative. Examples. Chart.

Revision.

Term 2.

Text Book (Additional) None.

1. Amoeba & Hydra.
Types of one and many-celled organisms.
Milestones in Evolution.
Chart.
2. Systems in animals. Evolution - continued.

3. Seeds. Germination. Experiments. Charts on Growth.
4. The full-grown plant. Root, stem, leaf. Structure
Chart with diagrams.
5. The full-grown plant. How it lives, feeds and grows.
6. Photosynthesis and Root Absorption. Experiments.
7. Respiration.
8. Nitrogen Cycle. Chart.
9. Fertilisers.

Revision.

Term 3.

Text Book. (Additional) None.

1. Floral Diagrams and Formulae. Examination of flowers.
2. Flora and Fauna of School district.) Excursions,
Photographs.
3. Geology " " ")
4. Life history of Spider, Snail, Slug. Examination of
Specimens, rate of locomotion, etc.
Diagrams.
5. Pond life. Discussion. Photographs of different kinds
of ponds.

Revision of Year's work.

FORMS V. Lower. Age 13½ - 14½Periods 4 per week.Term 1.

Text Book. Biology By Discovery - Green & Potter.

1. How to study Biology.
2. " " " the " of Autumn and part of Winter
General Discussion.
3. How Plants and Animals are built.
 - one-celled: Chlamydomonas
Bacterium
Yeast
Amoeba
Paramecium
 - many-celled: Spirogyra
Pea
Hydra
Cat - Compare with man.

Briefly: Fungus, Alga, Liverwort,
Moss, Fern, Pine, Sweet Pea.

Essential headings.
Summary chart.

4. How Plants and animals are classified.
5. Carbohydrates, Fats, Proteins. How formed.
Tests. (Elementary)
6. Vitamins.
7. Some animal diseases: Malaria) Charts of
" plant " Rust) Life-histories.
8. How to avoid diseases.

Revision.

Term 2.

Text Book (Additional) - None.

1. How to Study the Biology of part of winter and spring.
2. How to keep an Aquarium.
Water Scorpions, Caddis worms, beetles, etc.
3. Some larger Aquatic animals and plants:
e.g. Stickleback, Herring, Trout, Crayfish,
Frog, Crowfoot
4. The Feeding of Plants. Experiments on Conduction,
Transpiration and Respiration.
Absorption. Starch formation.
5. The Nitrogen, Carbon, and Oxygen cycles.
6. Strange methods of feeding:
Lichens, Yeast, Bacteria.
7. The Classification of Flowering Plants. Plant
families (revision)
Chart.
8. Spring flowers. Examination of specimens.
9. How to keep a garden. Grafting, Rotation of crops,
(Associated with Weeds, etc.
School Garden)

Revision.

Term 3.

Text Books (Additional) None.

1. How to Study the Biology of part of Spring and Summer.
2. How to keep insects. The Cabbage White Butterfly.
Leather Jacket, Wasp, Ant.
Life history. Charts.
3. Climbing Plants.
4. Ecology. The home life of plants; how they cope with
their difficulties. Photographs.

5. The cultivation of flower varieties as a hobby.
6. Summer flowers. Examination. How seeds and fruits are formed.
7. Identification of trees and other plants. Key chart made.

Revision of the Year's Work.

FORMS V. UPPER - Age 14 † to 15 † (av: 15)

School Certificate.

5 periods a week.

Term 1.

Text Books. Elementary Biology for Matriculation -
Phillips & Cox.

1. The Flower. Structure. Sexual Reproduction.
Pollination and Fertilisation.
Diagrams.
2. How a seed is formed. A fruit. Classification.
3. Asexual & Vegetative reproduction.
Chart on Reproduction.
4. The Cell and its contents.
5. Food material in plants and animals.
Carbohydrates, fats, proteins.
CO₂, N, and O₂
6. The Soil and its importance to plant and animal life.
Chart.
7. Water and its " " " " " "
Chart.
8. Air and its " " " " " "
Chart.
9. Other ways of feeding in plants and animals.
Chart.

10. The Stem, Root, leaf, Structure and Function.
Adaptation to environment and to seasonal changes. Autumn coloration.
Experiments. Section - microscopic examination
Series of pigments, from leaves.
11. Life-history of a flowering plant. Complete story.
Chart.
12. One-celled plants (e.g. Chlamydomonas)
Many-celled plants (e.g. Spirogyra), etc.
13. One-celled animals (e.g. Amveba) etc.
Many-celled animals (e.g. Hydra).
14. Common trees. Chief characteristics. Identification.

Revision.

Term 2.

Text Books (Additional) - None.

1. Seeds and Seedlings. Structure of Seeds.
Germination. Experiments.
2. Plant requirements. Physiology, processes -
Respiration,
Photosynthesis.
Transpiration,
Absorption (revision) and the main.
Facts re growth and feeding.
3. Habits, Respiration, Nutrition and Locomotion in -
Earthworm, Fish, Snake, Bird, Butterfly,
Crayfish, Amœba and Mammal.
The Rabbit as a type of Mammal. Systems.
Compare with Man.
Chart of diagrams showing evolution of systems,
etc.
4. Life-history in detail of Butterfly and Hydra. Charts.
5. The Frog. Structure and Function of parts and life-history.
6. Respiratory Organs. Diagrams and Chart on evolution.
7. Sensitivity and locomotion. Nerves in animals.
Tropesius in plants.

8. Heat in plants and animals.
 9. Plants and Animals - Comparison and Contrast.
Table.
 10. Carbon Compounds and composition of the air in
relation to plant and animal life.
 11. Form and Colour in Nature.
Chart.

Revision.
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Term 3.

Text Books (Additional) None.

1. The Animal Kingdom - General discussion.
2. Flora and Fauna of ponds and streams.
Chart.
3. Flora and Fauna of Soils.
Chart.
4. Some trees in Summer. Identification. Diagrams.
5. Natural Orders (revision); Examination of Specimens.
Charts.
6. Ecology of Woodlands, Moors, etc.
Plant formations and Association.
Ecological Maps.
7. Plants and animals - Differences & Similarities (revision)
8. Inter-relationship of living things.

General Revision of Year's Work.

FORM VI. (Science), Higher School Certificate.Age 15 † to 16 † (av: 16)5 periods a week.First Year - Subsidiary Stage.Term 1.

Text Books (for boys proceeding to full H.S.C. Course)

A Text Book of Botany for Colleges - Ganong.

A Manual of Elementary Zoology - Borradaile

Elementary Physiology. - Musché.

1. The Flower. Structure. Pollination and Fertilisation.
The Evolution of the flower (from grain and ovule)
Alternation of Generations.
Charts of diagrams and notes on Evolution of flower and Alternation of Generations.
2. Sexual, Asexual and Vegetative reproduction.
3. The Cell and Protoplasm. The properties of living matter.
4. The Root, stem, leaf. Structure and function in detail.
(a) Dicotyledon, (b) Monocotyledon.
Sectioning and examining.
5. General Physiology. The Systems in Man. Compare with other animals. Experiments to illustrate digestion, respiration, etc.
Dissections - Respiratory apparatus preserved in tubes, etc.
6. Amveba, Hydra. Frog, Rabbit.
(a) Habits. (b) Main facts re systems.
Dissections.

Revision.

Term 2.

Text Books (Additional) - Animal Biology - Haldane & Huxley.

1. A Plan of Animal life.
Animals of the Course compared and contrasted.
Evolution.

Amoeba - Paramoecium - Hydra - Worm - Frog - Mammal
One-celled - many-celled -
organs - tissues - systems.

2. A Plan of Plant Life.
Plants of the Course compared and contrasted.
Evolution.

Thallophyta - Bryophyta - Pteridophyta - Spermatophyta.
Pleurococcus, Liverwort, Ferns (a) Gymnosperm
Vancheria, Moss (b) Pine.
Spirogyra (b) Angiosperms
Bluebell.

one-celled organisms - many celled, etc.,
i.e. Specialisation.
Charts.

3. The Frog. Systems. Comparison and contrast with those in Man.
Heart, main blood vessels, Brain, reproductive System, chief muscles and nerves, etc.

Dissections. Parts preserved for future use.
4. Cell division and Nuclear organisation. Diagrams.
5. Evolution (theories and evidences). Charts.
6. Heredity (Mendelism) "
7. Parasitism in Plants and animals.
8. Tropisms in plants and nerves in animals. Experiments.
9. Carbohydrates and fats and proteins. Biochemical tests.
10. Growth and Nutrition. Enzyme action. Physiological processes. Special means of nutrition.
11. Energy - Chart.
12. Storage in Seeds, Stems, and Roots, Chart. Revision.

Term 3.

Text Books (Additional) Elementary Biology (Revision Notes) -
Savory.

1. Classification of Plants: Hydrophytes, Aerophytes, Hysterophytes.
2. Classification of Animals. Charts.
3. Ecology. Plant Formations and Associations. Ecological Maps.
4. Fauna and Flors of Special areas:- e.g. ponds.
 - (a) Characteristics and habits.
 - (b) Life history.
 - (c) Inter-relationship.
 - (d) Adaptation to environment.
5. Parasitism and Saprophytism. (revision).
6. Tropisms. "

General Revision of the Year's Work.

N.B.

Important Experiments repeated at the end of Term 3.

FORM VI. Science. Higher School CertificateAge 16+ to 17 +2nd Year.6 Periods per week.Term 1.

Text Books. As for 1st year.

1. Properties of living matter: inorganic and organic substances.
Protoplasm (continued).
2. Carbohydrates, fats, proteins, qualitative tests.
3. Digestion of above in Animal and plant.
Enzymes. Experiments to illustrate.
Diastase, Oxidase and Lipase.
4. Physical chemistry of living (things) systems,
e.g. Osmosis, diffusion,
Plasmolysis, Permeability.
5. Metabolism - CHO's and proteins in plant.
" " " and fats in animal.
6. Nutrition in plant and animal.
7. The Frog. Systems, tissues, Epithelia, bone, muscle,
nerve, blood and germ cells, eye, ear, etc.
Reproduction and Embryology.
8. Amoeba, Paramoecium, Hydra, etc. Comparison with Frog.
Parts preserved (in Frog).
9. One-celled organisations: Amoeba, Pleurococcus, Yeast,
life-histories.
Many-celled organisations: Spirogyra, Hydra, Volvox.
Specialisation and division of labour.
Charts.

Revision.

Term 2.Text Books - As for 1st Year.

1. Building-up process in plants. Photosynthesis.
N - cycle. Bacteria.
2. Destructive process in animals. Digestion and Excretion.
3. Transport in plant and animal. Movement of water,
salts and organic substances. Blood and lymph.
4. Hoemoglobin^{ov} and Haemocyanin^a. Heart-beat.
5. Muscle action and effects of exercises. Diagrams.
6. Respiration in plants and animals. Gaseous exchange.
Charts.
7. Energy: Storage and release. Sun as source.
8. Food reserves in seeds, stems and roots.
9. Anatomy of a higher plant. Growth, intercalary and
apical. Stomates, Intercellular system.
10. Parasitism: Dodder, Rust, Tapeworm, Structure and
life-history.

Charts.
11. Paramoecium: Reaction to Stimuli. Experiments.
life-history.

Revision.

Term 3.Text Books - As for 1st Year.

1. Seeds and their germination. Root absorption, etc.
Experiments. Growth, Charts.
2. Light. Effect on plants. Etiolation. Growth
Curvatures.
3. Tropisms in detail. Experiments.
4. Ecology. Plant Formation in detail. Effect of
environment. Ecological Maps.
5. Animal Life of ponds.
General revision of year's work, and repetition
or chief experiments.

(4). Examples of the manner in which the Method works.Topic - Bacteria.

Topics in the syllabus, ^{which} are treated under Aspect 2, - together under this title - (association of ideas) -

Form II. Bacteria, Yeast, Pasteur, Lister.

Form III. The Soil in relation to plant life, leguminous plants, harmful and helpful bacteria.

Form IV. One-celled plants and animals, flowerless plants, flowering plants (leguminous).
Yeast and bacterium compared. Evolution as exemplified in Nature's progress from one-celled to many-celled organisms.

Form Rem. Flowerless plants, the air, Pasteur, one-celled plants, Nitrogen cycle.

Form V. One-celled plants and many-celled plants,
Lower. ditto animals, flowerless plants, animal and plant diseases, Nitrogen cycle, Strange methods of feeding in plants.

Form V. A-sexual reproduction, the cell, C.N.&O₂ cycles
Upper. soil and its importance to plant and animal life. Strange Methods of feeding in plants, One-celled and many-celled plants, leguminosae, lives of great Biologists (including Pasteur & Lister), flora of soils, Inter-relationship of living things.

Form VIs. One-celled and many-celled organisations,
process of decay, blood system and its fight
against invaders, general study of bacteria,
enzyme action, and nutrition.

Notes only are given, illustrative of the trend of the lessons - fairly detailed for Form II, to convey the idea underlying the Method. For the other Forms mere outlines will, perhaps, suffice, especially since Charts, representative of those made in each Form, are included.

FORM II.Treatment according to Aspect 3.

Under Aspect 1. the Form in the first week of the first term of the year is given a glimpse (very elementary and brief in this Form) of the meaning of Biology and of the story of the Science from pre-historic times up to the present. The Story centres round the chief discoveries and the men concerned with them, together with the value to us of these discoveries. A word on the growth of the subject in Schools is also given, and on the value of its study. (All these points are elaborated upon in the same period in each succeeding year, the treatment becoming more detailed and specialised as the age period of the pupil increases).

Under Aspect 2 the associated topics are arranged in the syllabus (called 'Work for the Term') in the following order:-

Pasteur,
Lister,
Bacteria

The work is now treated according to Aspect 3 mainly (which lends itself best as the Aspect of the Historical Method most suitable for the presentation of the topics concerned).

When the treatment under this Aspect is complete three topics in the Syllabus will have been covered. (Some of the ~~other~~ Aspects come in in a Subsidiary manner).

Treatment.

Pasteurized milk? - Meaning - the name?
 Drunk in Schools every day. Why do this to milk?
 To make it free from harmful germs.
 Pasteur - great French Scientist - born a little over 100 years ago - his great work for humanity goes on to-day.
 Early life - only an average pupil in School - other examples of this? Keen on Science - nuisance to his teachers - asked too many questions.
 Almost lived in his laboratory. Had to be fetched from there even for his wedding.
 Wife also interested and became his helper.
 Became Head of Science Dept., at Little University
 Introduced practical work for his students.
 (Explain lack of such at that time).

His Experiments on Fermentation.

Yeast - used for making bread. Was first to discover that Yeast spores are carried in the air and cause substances like jam (anything containing sugar) to become mouldy and to ferment. How did he prove this?

Boiled sugary liquid for a long time, poured it into bottles - stoppered one up with cotton-wool which filters and catches dust - other left open. No fermentation in the cotton-wool - one after years - others soon bad. He then shook the dust from the cotton-wool into the liquid and it fermented.

This discovery led him to think that other plants might do the same and have their 'spores' carried in the air, and he investigated.

Experiments in Inoculation.

Meaning of 'inoculation' and 'vaccination'.

Draw information from Form.

At that time - terrible disease called Anthrax, killing cattle, sheep, horses, and cholera killing chickens. Anthrax can also be carried from an animal to Man. Shaving Brushes from Abroad are sometimes the source of it. Pasteur tackled the problem. He thought these diseases caused by germs carried in the air (like yeast 'spores') and he had studied Jenner's (another great Biologist) methods of vaccination against small-pox (explain this very briefly). He was suspicious that the same thing might prove successful against Anthrax and Chicken Cholera, and set out to prove it to the world. Obtained bacteria from a chicken - died of cholera - experimented - produced substance with

which he was able to inoculate healthy chickens, giving them a mild form of the disease, which made them immune against a severe form of the disease. Proved this by inoculating them afterwards with the bacteria producing the severe form, and they remained quite healthy.

(Explain here how Inoculation prevents disease).

He then tackled Anthrax. Custom in France to kill animals suffering from Anthrax and bury them on the spot, as we kill animals in this country suffering from Foot and Mouth disease, because no cure known, and 'spreading' must be arrested.

Pasteur thought these dead bodies might be source of infection for outbreak often many years after in that same spot. He examined ground where carcasses buried - found worm castings - and in laboratory found bacteria in these castings. Same kind of bacteria as those producing Anthrax. These bacteria brought up from dead bodies by worms and castings eaten by sheep cropping short grass. He tested this - railed off ground over burial place - put 4 sheep in, ^{and 4 in} another enclosure far away. In eight days one of the first four died of anthrax - the other four perfectly well.

Months of experimenting - produced substance (vaccine) to inoculate sheep and cattle against anthrax. 50 Sheep - 25 in each fold - Inoculated 25 with vaccine (producing mild form of Anthrax) and then shortly after the 50 with severe form. Thousands of farmers and veterinary surgeons watched the experiment - many of them doubtful. Two months later, however, able to reap fruits of victory - 25 vaccinated sheep were not ill, while 25 unvaccinated had died of Anthrax.

The disease often takes a long time before the first symptoms appear. He next tackled 'Rabies' (disease attacking the nerves and caused by a bite of a mad or rabid dog) in the same way and discovered a vaccine which made patient immune. Nineteen Russians bitten by mad wolf - long journey to Paris to be treated by Pasteur - 16 cured even after long journey. The average time between the bite and the appearance of symptoms is six weeks. In children it is often much less. Hospital - Pasteur Institute for anti-rabies inoculation - opened in Paris - money by subscription. Architect refused fee and builders only what material cost - to express gratitude to this large-hearted benefactor of human race.

At 70 - great meetingⁱⁿ his house in Paris - representatives of almost every nation. Lister represented British people. Pasteur died 3 years after.

One of his sayings was 'Blessed is he who carries within him an ideal and who obeys it'. Explain this.

Lister.

Refer to fact that Lister attended, on behalf of Britain, the great meeting in honour of Pasteur, in Paris in 1892 (quite recently really) remembered by fathers, etc.), therefore they were contemporaries. Lister also worked on disease and just as Pasteur was helped by Jenner's work so Lister was helped by Pasteur's work.

Recall Pasteur's work on bacteria (spores carried in the air, etc.) These bacteria discovered over 200 years before by Leenwenhæek in Holland, but almost forgotten until Pasteur's work began. Pasteur proved that air contained bacteria, that they could be killed by boiling (recall experiment) and that they caused putrifaction.

Lister grasped meaning of this. Was studying cause of gangrene in wounds - a disease killing a high percentage of people in the hospitals at that time. He was convinced that it was result of bacteria 'spores' from air.

Explain 'Gangrene' and havoc caused by it.

He saw plainly that he must try and kill them. Tried different chemicals and liked Carbolic acid best.

Imagine his eagerness to see if this would prevent that dreaded disease. He succeeded, though first patient died - too ill to be saved even by Lister. The second was a little boy - recovered. Success followed success with the treatment - death rate declined. Students crowded to his lectures and then tried the same treatment afterwards on their patients. His fame abroad spread and many doctors came to him from foreign countries. Yet he had to fight against disbelief of many of his own countrymen even - who refused to believe. Did not mind for himself, but he felt for the thousands who would suffer through neglect.

Triumphed however. Great banquet for him in Germany in 1875 and four years after, asked to speak at International Congress of Medical Science on the Continent - had tremendous welcome. Pasteur was a great admirer of Lister who however attributed a great deal of his success to Pasteur's own work.

Further Work.

Having discovered a way of killing bacteria in wounds by antiseptics, he next tried to find a covering which would continue to keep out fresh bacteria and allow wound time to heal, Nature's way - make a scab - fairly hard yet gives a little with movement of the part - waterproof and durable. Lister tried to devise something on these lines - a good substitute for Nature

and in the end he produced something very much like pink boracic lint as we know it.

Change brought about by Lister's Work and its value to Man.

School sends subscriptions to hospitals. Visit one and see it, especially operating theatre - special room now (not so in Lister's time) and instead of trying to kill bacteria in wound the new way is to prevent bacteria getting in at all - by cleanliness in everything - special room, everything sterilised - only development of Lister's great work.

Meeting of Royal Society in 1902 - American Ambassador paying tribute to Lister - 'Lord Lister, it is not a profession, it is not a nation, it is humanity itself which, with uncovered head, salutes you.'

That sums up humanity's debt to him.

Early Life.

Take a glance back since no time before (his work done first following that of Pasteur).

Born 1827 died 1912 - long life. At beginning of his medical career Crimean War on in Russia, and Florence Nightingale one of first and greatest of nurses, wrote home from her hospital "We have now 4 miles of beds, not 18 inches apart. The mortality of the operations is frightful. We have fever and gangrene - - -" Lister felt the call to do something to stop this suffering.

Quaker family, 2nd child in family of seven, four brothers, three sisters. Good looking, athletic build - plenty of exercise, especially swimming. Not brilliant at School or at University (recall Pasteur).

Dead flesh - mortifying (compare festering of finger) caught his attention early on. Finger festers if dirt gets in wound. Got his chance when he became Professor at Glasgow and Surgeon at the University. Insisted on cleanliness in wards. More deaths in hospital than in private houses, and fact that if skin was not broken patient had far better chance of recovering, led him to ponder as to whether this disease was not caused by something carried in the air. (If so - air in wards would have more of these invaders - Why?) This led to his great work which has been described.

A Word on Disease in General.

Most horrible thing in World? Grown up people would probably say - Disease. All have seen effect of some disease. Many diseases now curable which were not twenty or thirty years ago. Many still require hard research on part of patient scientists - e.g. Cancer, Consumption, Superstition still prevails, e.g. cobweb on a cut - is this wise? Knowledge of Lister's work helps us to answer. Fight against disease is a hard one - gradual, step by step. How can we help? (psychological effect. Aspect 6.)

Bacteria.

A good deal should be known about Bacteria by now. Draw from Form - chief points they have learnt, and tabulate. Invisible army all around us, above us, inside us, underneath us, in the air, in water, in soil - more than sand of sea in numbers - bacteria. Some very useful, some very harmful.

Structure.

Very minute - hard to see even with a powerful microscope. Half fluid-jelly substance called protoplasm. No skin - outer layer a little firmer. Vary in size, but on average - 25,000 in a straight row would stretch across a halfpenny (1 inch). Some have little tails to move about with in liquids. We stain them to see them better.

Reproduction.

When liquid dries bacterium body dries and floats in air like extremely small speck of dust - yet alive. This called 'spore'. Millions in the air.

When one alights on suitable spot for growth - splits in two - very shortly these split again. (In some cases only takes 20 mins. between splittings). This goes on and if temperature is suitable and food plentiful there will be about 2 million in a group in 10 hours and 75,000 millions in 24 hours (Calculate it).

o	1
oo	2
oooo	4
oooooooo	8
	16
	32, etc.

Like a horse galloping - hence the term 'galloping consumption'. Fortunately the body, if strong, fights and keeps the number down, and with the help of medical treatment has a chance to overcome this 'army' completely. When food is short for them, they round themselves off and grow a thick coat, and in this state can resist heat, cold, and other adverse conditions. Being so light they can float in the air and finding a suitable food supply in a warm moist place (maybe inside one of us) they begin their multiplication table again, eating a part of the body and giving off poisons.

Shape.

Various.

(1) Coccus - round - most common.

(2) ~~Bacterium~~ Bacillus - rod-shaped.

Each kind may be found in clusters or strings (bent or straight).

Bacteriologist - Scientist who studies them in little glass cases in the laboratory. He gives them suitable food, e.g. broth, and tries to find what substance will kill them without killing the patient.

Petri-dishes, culture tubes and diagrams of different kinds of bacteria are shown.

Homes.

Everywhere except in the middle of the ocean on the sea-bed. Fewer in deserts and open country and on mountains. Sunshine and fresh air are their chief enemies. Rain washes them from the air, wind scatters them, winter cold kills them, very often.

Different Classes.

(1) Helpful.

Many essential to life.

e.g. Those in nodules in roots of pea and bean family.

(Mention only in preparation for Form III. work)

Good bacteria in milk - help to form butter, cheese, etc.

Some bring about decay of (once) living matter.

(A good thing for us - Why?)

Some bring about rotting of leaves.

All this decay makes nourishing material in soil for new plants, hence, death helping life.

Practical Work.

Pasteur.

(1) Let each member of the Form see some Yeast cells under a microscope (Demonstration Experiment).

(2) Harmful.

Many diseases caused by some.

(Recall Pasteur & Lister's work).

How can we help to prevent these diseases? (Psychological Aspect). Breathe through nose, etc. (explain why)

Draw them. Bacteria are similar only much smaller.

(2) Let each Group place a little Yeast in some sugar solution in a warm place and describe what is observed.

Pupils encouraged to try this Experiment at home.

(3) Mark on Map of France places associated with Pasteur. Trace journey those patients took from Russia to Paris and calculate the time taken at that time.

(4) Show and explain - hypodermic syringe. Draw.

Lister.

(1) Make a list of the instruments and apparatus you find in an hospital, and particularly in an operating-theatre. Draw.

(See Biology Dept. instruments and compare - needles, scalpels, dissecting scissors, etc.)

(2) Examine (a) Carbolic Acid bottle (b) Lint (c) potassium permanganate. Make solution of latter by dissolving a few crystals in water - explain strength of solution. Let pupils gargle and keep some of the solution if they bring clean bottles. Write account of observations.

Bacteria.

(1) Why should milk be covered? - and straight-top jug used? Make a list of such observations with explanations.

- (2) Sketch different kinds of bacteria and name them.
- (3) Grow peas and beans in solution and watch growth of nodules. Draw stages and describe.
- (4) Suggest other experiments and perform at home, writing account in ordinary Note book.

Summarize (theory and Practical) and Make Charts.

Aspect 3 (mainly) - (1) Pasteur (a) Life, (b) Work for humanity.

(2 concentric circles).

" 3 " - (2) Lister (a) life, (b) work for humanity

(2 concentric circles).

" 5 " - (3) Bacteria (a) kinds & importance.
(b) Life-history of one type.

" 3&5 - (4) Practical work on -

(a) Pasteur) Yeast

(b) Lister) Hypodermic Syringe

(c) Bacteria) used in 'inoculation'

FORMS III.The Soil in relation to Plant Life.

Aspect 1. As for Form 11. with a little more elaboration.

The work is best treated under Aspect 5.

Bacterial action in the soil is the main feature brought out.

(Lockjaw also caused by bacteria from soil -
 (superstition with regard to.
 (Compare with diseases caused by bacteria from air.
 (Cobweb in cut finger. Discuss.

Good bacteria in soil - 'Nodules' . Explain. (Rotation of Crops) De-nitrifying and nitrifying bacteria. Bacteria rotting leaves after Autumn fall.

Practical work.

- (1) Peas and beans grown in ordinary and baked soil.
 Compare growth.
- (2) Examination of 'Nodules' - Sections cut.
- (3) " " roots of various leguminous plants.

Charts.

- (1) Bacteria in general (Form 11 work as foundation)
 with special emphasis on those in soil.
- (2) Practical work.

FORMS IV.Aspect 1.

Pupils reaching age when they appreciate more fully the struggles, achievements, and disappointments of the great pioneers. Evolution begins to have amore significant meaning, and this is somewhat emphasised in the survey with particular reference to the advancement of knowledge through the patient sacrifice of great men, and the meaning and value to us of their work. Darwin's investigations are discussed in this connection.

Aspects 3 and 5 together are best for the Study of these topics

Yeast in particular is compared with a bacterium. Recall Form 11. work. Both one-celled plants, devoid of chlorophyll and hence possessing special means of feeding. Both split (yeast budding) in two in reproduction.

Story of one-celled organism (which has to eat, digest, breathe, excrete, reproduce, and move) leads to that of many-celled ones then to tissues, systems, and organs as found in the higher plants and animals. Thus the idea of Nature's progress is introduced.

Practical Work. (1) Examination of Yeast.
(2) Fermentation Experiment.
Yeast and sugar solution.

Charts. (1) Comparison of Yeast & Bacteria Cells.
(2) Specialisation in Nature. (Division of labour)
(3) Practical Work.

REMOVE.Aspect 1.

The biological background becomes more full. Special emphasis is laid on actual experiments carried out by the pioneers - this appeals to the type of pupil who is inclined to be more manual than academical in his application.

Aspects 3,4 and 5, are made use of.

Pasteur's experiments in fair detail, particularly those by which he proved that bacteria and yeast spores were carried in the air.

Story of men concerned with knowledge on bacteria - Leuwenhok, Joblot, Pasteur, Cohn, Lister, etc.

From Aristotle, for hundreds of years, belief that living creatures could be ^{derived} ~~beformed~~ from lifeless matter. e.g. horse-hairs in water turning into eels, and meat becoming maggots. This idea scorned by Joblot and Pasteur.

Size, shape, classes, reproduction, uses, cultivation, of **bacteria**. Antiseptics, Vaccination and Inoculation - explain principles.

Practical Work.

(1) Examination of instruments and apparatus used in bacteriological work. e.g. hypodermic syringe, petri-dish, autoclave.

- (2) Examination of bacteria and fungi, in tubs and plates.
- (3) Sterilised medium in 2 flasks, e.g. broth - one stopped up with cotton wool, the other left open. Observe difference in a few days.

Charts.

- (1) Pasteur's Work.
 - (2) Advance of knowledge on bacteria.
 - (3) Life history of any bacterium causing a disease.
 - (4) Practical work.
-

V. LOWER.Aspect 1.

The big picture, as represented by the general survey of biology, is becoming filled up with details. Pupils at this stage are better able to grasp the full significance of the great discoveries and their meaning to Man. Reason is coming in to intensify and guide real interest.

Special stress is laid, therefore, upon the application of biological principles, particularly in connection with health and the care of the body.

Aspects, 3,4,5 and 6., are made use of.

Carbohydrates, Fats and Proteins.

Connection between health and feeding. Differences between plants and animals in method of feeding, yet both need same classes.

Food substances in each class, e.g. Carbohydrates in fruits and wheat.

Disease due to deficiency in food, e.g. beri-beri in Japan. Vitamins - explain.

Connection between food - blood - bacteria. Koch showed that blood of choleric patients contained enormous numbers of bacteria. Klebs - same for diptheria.

A few important diseases taken, and life-histories studied. e.g. Malaria, Tapeworm and Rust.

The great work of Ross on Malaria - his tremendous patience. Museum specimens shown where possible, e.g. Mosquito, and tapeworm.

General discussion on health.

Practical Work.

- (1) Simple Tests for Proteins, Carbohydrates (starch & sugar) and Fats.
- (2) Examination of instruments and apparatus used in work on bacteria. Experiments with tubes of media. Bacterial colonies and fungal mycelia (obtained by inoculating tubes with dust, milky saliva, etc.)
- (3) Examination of Slides of various diseased tissues.

Summary and Charts.

- (1) Foodstuffs.
 - (2) Bacterial Diseases.
 - (3) Life history of one disease.
 - (4) Practical Work.
-

V. UPPER.Aspect 1.

The big picture of biology is becoming clearer as the pupil is able (in reviewing past experience and knowledge) to view the picture from a distance. He begins to see the meaning of it and to understand it, which he failed to do perhaps, when he was closer to it.

Aspect 5 (with 3 subsidiary) underlies the treatment.

The story of a bacterium comes into each of the above topics. The whole bacterium becomes a spore. Compare with Yeast. Bacteria in air and water. Bacteria colourless, therefore strange method of feeding. Bacteria in soil - importance, Nitrifying, De-nitrifying, and N-fixing. Decay. N-cycle. Aerobic and Anaerobic bacteria. Discuss sterilisation, preservative in food, filtration of water in reservoirs. Recall work of Lister.

Practical Work.

2. A little milk put into each of two flasks. Plugged gently with cotton-wool. Brought gently to boil. When milk cooled small amount of baked earth put into one and unbaked earth into other. Following day noticed that milk in flask containing unbaked earth is sour - other still sweet. Some of sour milk examined under the microscope - rod-shaped bacteria present.

1. Tests for Carbohydrates, Fats, and Proteins (Revision).
Some further tests in addition to those mentioned for
V Lower.
4. Elementary mechanical analysis of soils.
3. Experiments with tubes of media (Revision).
Examination of bacterial colonies, or fungal hyphae under
the microscope.

SUMMARY and CHARTS:-

1. Bacteria.
2. Soil bacteria.
3. Practical Work.



FIG. 24.

BACTERIOLOGICAL WORK.

— VIS.

VI (SCIENCE)Aspect 1.

Picture of Biology becomes more focussed. Lectures on Great Biologists and on History of Biology become more systematic.

The accumulative effect of the method becomes evident. The pupil has learnt to associate ideas - to think historically, and by doing so to probe for the truth, by acquiring that patient endeavour and resolute purpose which were the noble qualities of those men whose work has meant so much to humanity.

Aspects 3, 4 and 6 become more prominent.

Revise all that has been learnt on Bacteria. No trace of sex - discuss. Physiological diversity amongst bacteria. Comparison with Blue-Screen Algae Yeasts and Viruses. Barnard's work on Virus (with ultra violet rays) Reading on present day research encouraged.

Practical Work.

- (1) Preparation of various media. Agar-Agar, Gelatine - various fruit juices added in different cases.
- (2) Series of experiments to obtain "growths" of bacteria and fungi.

- (3) Making of Slant and plate cultures by sub-culturing.
- (4) Repetition of some of Pasteur's experiments.

SUMMARY and CHARTS

- (1) Life-history any disease.
- (2) Bacteria (general).
- (3) Life of a great pioneer.
- (4) Practical Work.

RESULTS OF QUESTIONNAIRES.Form VI. - Science. (Age $16\frac{1}{2}$)6 Present.

<u>Question No.</u>	<u>Order of Preference.</u>
1. Your Hobby.	Swimming, Football, Golf, Music, Tennis.
2. Your Heroes.	Grenfel, J. Hens, I. Newton, Darwin.
3. Subjects liked Best.	Biology, Chemistry, Physics.
4. Topics in Biology preferred.	Heredity, Evolution (equal)
5. What in Biology Teaches the best Lesson.	Ecology, Evolution.
6. What Biologist Preferred.	Darwin, Pasteur.
7. Ideas for Work in Biology Course.	More Practical Work, Research, Making Summary Sheets.
8. Practical or Theory.	Practical, Theory.
9. Do you like making charts?	Yes - small majority.
10. Anything else.	Form VI. Students should do more research. Structure of animals should not be dealt with earlier than Lower V.

RESULTS OF QUESTIONNAIRES.Form Upper V. (Biology Section) (Age 15.)School Certificate Class. No. in Form - 23.

<u>Question</u>	<u>In Order of Preference.</u>
1. Your Hobby.	Cycling, Football, Tennis.
2. Your Heroes.	Captain Scott, Scott & Black, Disraeli
3. Subjects you Like Best.	Biology, Physics, Geography.
4. Topics in Biology Preferred.	Systems in Man Microscopic Work, Zoology.
5. What in Biology Teaches the best Lesson.	Physiology, Bacteria and Disease Food in Plants and Minerals.
6. What Biologist Preferred.	Darwin, Fabre, Lister.
7. Ideas for Work in Biology Course.	More Practical work, More Talks, More Outdoor work.
8. Practical or Theory.	Practical, Theory.
9. Do you Like Making Charts?	Yes. Large Majority.
10. Anything else.	More study of the Great Biologists. After school work should be encouraged. More work in the Garden.

Form - Lower V. (Age 14)

No. in Form - 30.

<u>Question No.</u>	<u>Order of Preference.</u>
1.	Swimming, Reading, Gardening.
2.	Scott & Black, Film Stars, Motorists.
3.	Biology, Physics, Physical Training.
4.	Physiology, Zoology, Plants, Animals.
5.	Physiology, Diseases in Man, Animal Life.
6.	Darwin, Pasteur.
7.	Unanswered - lack of time.
8.	Practical, Theory.
9.	Yes, in colours - large majority.
10.	Unanswered - lack of time.

Form - Remove. (Age $13\frac{1}{2}$) No. in Form - 32.

<u>Question No.</u>	<u>Order of Preference.</u>
1.	Football, Gardening, Handicraft.
2.	Scott & Black, Film Stars, Boxers.
3.	Physics, Biology, Chemistry.
4.	Study of Mammals, General Study of Plants. Bacteria.
5.	Human Body, Animals, Plant life.
6.	Darwin, Pasteur, Fabre.
7.	More practical work.
8.	Practical, Theory.
9.	Yes - small majority.
10.	Unanswered owing to lack of time.

Form IV.A. (Age 12 $\frac{1}{2}$) No. in Form - 32.

<u>Question No.</u>	<u>Order of Preference.</u>
1.	Reading, Chemistry, Stamp-collecting.
2.	Father, Belson, Beatty.
3.	Biology, Chemistry, Physical Training.
4.	Ferns, Study of Animals, Study of Plants,
5.	Physiology, Ant life, Reproduction.
6.	Darwin, Lister, Pasteur.
7.	More Practical. More Epidiascope.
8.	Practical, Theory.
9.	Yes, in colours. Large Majority.
10.	More Epidiascope.

Form IV.B. (Age 12½)

No. in Form - 29.

<u>Question No.</u>	<u>Order of Preference.</u>
1.	Stamp collecting, Reading, Fretwork.
2.	Film Stars, Aviators, Captain Scott.
3.	Physics, Biology, Art.
4.	Ferns, Animal & Plants, Mammals.
5.	Human Body, Study of Life.
6.	Darwin, Pasteur, Lister.
7.	More Epidiascope, Weekly observations of collection.
8.	Practical, Theory.
9.	Yes, with colours - large majority
10.	More talks.

Form III A. (Age $11\frac{1}{2}$) No. in Form - 35.

<u>Question No.</u>	<u>Order of Preference.</u>
1.	Reading, Drawing, Games.
2.	Nelson, Darwin, Parents.
3.	Biology, Physics, French.
4.	The Soil, Zoology, Fish.
5.	Fish, Birds, Animals.
6.	Darwin, Lister, Pasteur.
7.	Unanswered - lack of time.
8.	Theory, Practical - small majority.
9.	Yes, in colours - large majority.
10.	Unanswered - lack of time.

Form III. B. (Age $11\frac{1}{2}$) No. in Form - 35.

<u>Question No.</u>	<u>Order of Preference.</u>
1.	Astronomy, Football.
2.	I newton, Sir J. Hertschell, Aviators.
3.	Latin, French, Biology.
4.	Life of Fish, The Soil, Birds.
5.	Life of Animals, Diseases of Man.
6.	Darwin, Lister, Pasteur.
7.	More Epidiascope. More observation.
8.	Practical, Theory.
9.	Yes. Large majority.
10.	More Practical work.

Form II. (Age 10½)

No. in Form - 35.Question No.Order of Preference.

- | | |
|-----|-----------------------------------|
| 1. | Mother,
Father,
Darwin. |
| 2. | Drawing,
Mecanno,
Woodwork. |
| 3. | Biology
Art,
French. |
| 4. | Lister,
Bacteria,
Darwin. |
| 5. | Life of Dumb animals & Insects. |
| 6. | Lister,
Darwin,
Fabre. |
| 7. | More charts & Practical work. |
| 8. | Practical (almost unanimous). |
| 9. | Yes, in colours (large majority). |
| 10. | Unanswered - lack of time. |
-

SUMMARY RESULT OF QUESTIONNAIRES.Form VI.

	<u>Question.</u>	
	1. <u>Your Hobby.</u>	Sports.
	2. <u>Your Heroes.</u>	Scientists.
	3. <u>Subject liked</u>	
	<u>Best.</u>	Biology.
	4. <u>Topics liked</u>	(Heredity,
	<u>best.</u>	(Evolution.
	5. <u>What in Biology</u>	
	<u>teaches best lesson.</u>	Ecology.
Age - 16½	6. <u>What Biologist</u>	
	<u>preferred.</u>	Darwin.
	7. <u>Ideas for work in</u>	
	<u>Biology course.</u>	Practical work.
	8. <u>Practical or</u>	
	<u>Theory.</u>	Practical.
	9. <u>Do you like making</u>	
	<u>charts.</u>	Yes.
	10. <u>Anything else.</u>	More research.

Form V.
Upper.

	1.	Sport.
	2.	Adventurers.
	3.	Biology.
	4.	Man (Systems)
	5.	Bacteria - Disease.
	6.	(Darwin,
		(Pasteur.
Age - 15-	7.	More Outdoor Practical work
	8.	Practical
	9.	Yes, in colours.
	10.	(More study of Great
		(Biologists.

Form V.
Lower.

	1.	Sport.
	2.	Aviators.
	3.	Biology.
	4.	Physiology.
Age - 14	5.	Physiology.
	6.	Darwin.
	7.	- -
	8.	Practical.
	9.	Yes, in colour.
	10.	- -

Question No.

<u>Remove.</u>	1.	Sport.
	2.	Aviators.
	3.	Physics.
	4.	Mammals.
	5.	Human Body.
	6.	Darwin.
Age - $13\frac{1}{2}$	7.	More Practical work.
	8.	Practical.
	9.	Yes, in colours.
	10.	- -

<u>Form IVB.</u>	1.	Stamp Collection.
	2.	Film Stars.
	3.	Physics.
	4.	The Fern.
Age - $12\frac{1}{2}$	5.	Human Body.
	6.	Darwin.
	7.	More Epidiascope.
	8.	Practical.
	9.	Yes, in colours.
	10.	More talks.

<u>Form IVA.</u>	1.	Reading.
	2.	Parents.
	3.	Biology.
	4.	The Fern.
	5.	Physiology.
Age - $12\frac{1}{2}$	6.	Darwin.
	7.	More Practical.
	8.	Practical.
	9.	Yes, in colours.
	10.	More Epidiascope.

<u>Form III B,</u>	1.	Astronomy.
	2.	Scientists.
	3.	Languages.
	4.	Animal life. (Fish)
Age - $11\frac{1}{2}$.	5.	Animal Life.
	6.	Darwin.
	7.	More Epidiascope.
	8.	Practical.
	9.	Yes, in colours.
	10.	More Practice work.

	<u>Question No.</u>	
<u>Form IIIA.</u>	1.	Reading.
	2.	National Heroes.
	3.	Biology.
	4.	The Soil.
Age - 11½	5.	Animal life (Fish).
	6.	Darwin.
	7.	- -
	8.	Theory. (small majority)
	9.	Yes, in colours.
	10.	- -

<u>Form II.</u>	1.	Darwin.
	2.	Parents.
	3.	Biology.
	4.	Bacteria and Lister.
Age - 10½	5.	Animal life.
	6.	Lister.
	7.	More Charts.
	8.	Practical.
	9.	Yes, in colours.
	10.	- -

The Outstanding results of the Questionnaires are :-

1. Sport seems to be the chief Hobby amongst boys.
2. Adventure seems to have a strong appeal.
3. Darwin is the best liked Biologist.
4. Animal Life is preferred.
5. Practical Work is definitely preferred to Theory.
6. Chart-making in colours is very popular. As this is a prominent feature of the Historical-observational Method used, it proves its value from the point of view of the boys' interests.
7. Epidiastroscope Work (which is a blend of theory and practical) is popular.
8. Biology is a popular subject.

The nett result tends to show that the Method as outlined in this Thesis is producing the desired effect by appealing to the boys.

PART V.

PART V.FINAL WORD.

The aim of Science-teaching in general is to help the pupil to acquire some measure of the scientific life or spirit of true endeavour and enquiry. This aim can only be fulfilled in its fullest sense if we adopt the best method to get the pupil to strive to live the life of the man of science and to feel and think like him. Love of Nature is the fundamental basis of the true scientific life and thus the best way to reach the desired goal is to cultivate this love. Since Biology - the Science of Life - is so clearly ~~connected~~ with this love of nature (without being the only subject associated with it) it should constitute one of the most important ways of educating the child on the correct lines.

The neglect of Biology, therefore, from the logical point of view alone, is very hard to fathom, and the chief cause of it must be laid at the feet of traditional bias in favour of other subjects, the somewhat extreme conservative attitude concerning all matters within our educational system and appertaining to the scholastic profession, together with the erroneous notion that Nature herself is sufficient to look after this phase of the work.

If we grant the importance of Biology teaching, it follows that we must believe in the best methods in this teaching of the Science and these must be those more or less guided by Nature herself. The teacher must get as near Nature as possible - he must disentangle himself from the mire of convention and artificiality of methods and ideas in education, and above all, must endeavour to enter the child's mind and think from his point of view. He must get back to his childhood days and live his struggles, disappointments and triumphs all over again in front of his class. The extent to which he is able to do this is the measure of his 'lasting' success.

In this Thesis it has been shown that one important source of help in arriving at the child's outlook is to set 'psychological' questions periodically to boys and girls of various age-periods and then sift the evidence obtained and act on it. A few instances of such Questionnaires are given.

The method adopted in the teaching is not too rigid - it is alive and changeable within limits, just as Nature is seasonably changeable yet ever fundamentally unchangeable. For this reason seasonal opportunities have guided the Master in his syllabus-making, and throughout his Scheme, since the practical work, - which is considered a highly important feature of the work, - necessitates the Examination of living (mostly) material

found in Nature, and which is collected, generally speaking, by the pupil himself, - another feature which is considered highly important as having an educational value. The pupil, too, and his point of view and natural instincts occupy a far more central position than they normally do, perhaps, in our system of education. Thus, it is maintained, the pupil develops 'naturally' along the channels of his natural tendencies. In this connection, it is suggested, there could, profitably be far more co-ordination of studies within the curriculum, and far more collaboration amongst members of a Staff of a School and amongst members of the Profession as a whole.

Relation between Biology teaching and that of
Kindred Subjects.

(a) Physics.

'Life is one and knowledge is one' should underlie all teaching. The whole study of Natural Science, in particular, should be very closely interwoven.

The principles of the physiology of plants and animals cannot be grasped without a thorough knowledge of certain principles of Physics, e.g. (1) Energy must be understood before the process of Respiration - the key which unlocks the store of potential energy stored in a plant or animal - is studied; (2) Water - circulation in Nature and physical properties of, - e.g. expansion on freezing and maximum density at 4°C. - are first dealt with in Physics.

In fact the whole study of the subjects included under the title 'Natural Science' is so essentially one whole, that in no individual case can one of the subjects be said to stand on its own.

Other Subjects.

(5) English and Other Languages.

Essays on biological topics are of value to both subjects. Extracts from Poetry, such as from Wordsworth's inimitable Poems to Nature form a ~~strong~~ strong link between the Subjects and aid particularly from the cultural point of view. Extracts (couplets, etc.) written underneath mounted specimens in a herbarium or on Charts in general afford us an example of this, - a great help also from the aesthetic standpoint.

It is well for the English Master to read over Essays on biological topics sometimes, and for biological titles to be given to Essays done in English and other Languages. Limited work along these lines, in connection with the Scheme, herein discussed, has proved very interesting and profitable. Technical terms also, in the Science are referred to their respective language for derivation. In this way one subject works into and aids the other.

(f) Geography.

Plant geography or Ecology (plant) is much better understood alongside a course in pure Geography. The

flora and fauna of various parts of the world should be done at the same time as the Geography of those parts. Specimens displayed in the biological department (oils, seeds, etc) do not fail to arouse some geographical interest and vice versa - if suitable suggestions are made in the lessons.

(g) Handwork.

Training in biological drawing helps in the drawing-out of designs in Handwork. Various things have been made for use in biological experiments, e.g. shelves, stands. A good deal of handwork, too, comes into the actual biological work (as stated elsewhere) particularly in the lower Forms.

(b) Art.

A sense of the beautiful in Nature intensified by biological study has^{been} found to be of great value in the study of design and pattern in Art.

Colour and pattern in Nature is, presumably, the source of inspiration in the study of Art.

e.g. the intricate pattern of a moth's wing.

Ice crystals in a snowflake.

Art in its turn helps Biology in giving the pupil extra practice for his diagrams (which are important in Biology), and in increasing his powers of keen observation.

Other Examples could be given, in fact there is hardly a subject which could not be improved upon in its teaching by co-relation with other subjects. History, for instance,

is an excellent example of this. This subject could be made to permeate almost every subject in the curriculum, adding more real interest to the subject concerned and weaving a fine thread of inter-relationship and inter-dependence of all the subjects taught, the study of which, after all is kept apart only for the sake of convenience but which collectively goes to make up the sum total of knowledge. This binding force between the Subjects brought about by their co-relation, in whatever way this is accomplished, should be a very real incentive and guide to the learner. History in particular has been found ~~to~~ helpful to Biology in connection with the lives of the pioneers and the story of great discoveries. It plays an important part in the Historical method described in this Thesis (see Aspects) and especially in the treatment under Aspect 1. (the ~~of~~ History or Survey of the Science).

The teaching in the next place, takes its colour from the School surroundings. By the application of the principles of the teaching to local needs the effect upon the pupil - who as yet is hardly aware of any other environment - is intensified. At the same time, however, the idea must grow in the pupil's mind that Science is universal and international.

The syllabus is designed to embody sequence of thought - one topic following upon a kindred one. This is dealt with under Aspect 2 in this Thesis. In order that the pupil might gain the full measure from his accumulated experience, the time allotted to the Science increases, rather than decreases, as he proceeds up the school.

Finally, the Method advocated here is the Historical one. This embodies first-hand information gained from personal observation of living things, together with a treatment of each topic from the point of view of one or more or all of the Aspects considered. The topics are studied on the background of the achievements and struggles of great names connected with them. It has been proved that this creates much greater interest and thus the teaching comes to have a much more permanent value and result. A question as to the value of the historical method in Biology teaching, given to the VIth Form brought forth answers which may be summarised thus:-

'It is a good thing that the day is past when the student of Science sat in front of a text book and worked hard at it all day. The average boy to-day needs something far more interesting and practical to kindle his interest. Herein lies the great value of the historical Method. The point is that while the teacher is dwelling on the historical aspect, often

on matters seemingly unimportant but tremendously interesting, points of vital importance in the Syllabus are being brought in and the ^{student} ~~subject~~ in his interest can hardly fail to grasp them. For instance, in a lesson or lecture on 'Bacteria', if, instead of the student being told about the different kinds, what they do, and how big they are, he is led into the exciting story of the great pioneers who found out all these things and fought against the ravages caused by these bacteria - a battle for humanity - how Pasteur disproved the theory of spontaneous generation, for instance, - then the work is made stimulating and inspiring, original and interesting. Looking at the subject in this way shows what has been done and suggests what might be done in the future.'

It seems that by taking into account the ever-present link which binds us to the past, continuity of thought is best attained. Early biological training is also essential in this connection.

It has been found profitable, on every occasion possible, ~~in~~ when dealing with great men in Biology, to compare and contrast briefly their intimate everyday lives with those of great men in other spheres, e.g. Literature, Art, Music. For instance, Archimedes and his bath, Darwin keeping his engagements with his earthworms.

Throughout it has been shown that when the Subject is taught historically in the manner discussed, the attention of the pupil is riveted. This blend of Science and History seems to attract and focus concentration (just as a reference to Sherlock Holmes does in connection with powers of observation). The text book becomes a 'guide' or a help only (and this is encouraged).

The historical treatment, however, when worked out properly, means more than this. It is considered in this Thesis under six different Aspects.

The syllabus is drawn out historically (i.e. in sequence as to kindred topics). These topics are dealt with from the standpoint of the great personalities connected with them, and the sum total of the knowledge gained follows naturally from this. A history of biological events throughout the ages forms a background for the whole treatment. Then each topic has its own history, e.g. a plant or an animal, and finally there is the psychological Aspect - the effect that the treatment (or teaching) of each topic has on the mind of the pupil - how it helps him in his own achievements, triumphs, struggles and disappointments, and views on life and on his own future.

It is suggested, therefore, that this treatment gives the pupil the fullest benefit from the teaching of the subject.

Thus the Method is based upon:-

(Practical Work (to cultivate powers of observation
(by ~~making~~ collecting first-hand
(information)
(
and (History (to make interesting, rivet the attention,
and produce a craving for knowledge)

There are other ways of approach to life's problems - by which truth can be reached - among them being Poetry, Philosophy, and Religion, and Science does not dispute the conclusions they arrive at, but claims the right to seek the truth in its own critical scrutinous way amongst the myriad mysteries of the Universe. The man of Science humbly gazes into the unknown and is content to say with Shakespeare -

"In Nature's infinite book of secrecy a little can I read", and he has learnt that dogmatism can have no place in the Temple of Truth.

Neither do we dogmatise about the Method herein advocated, but humbly submit it to those who, in the great work of Education, may care to see it.

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I L L U S T R A T I O N S .

PHOTOGRAPHS AND DIAGRAMS :

- Fig. 1. Diagram - Evolution.
 2. Laboratory, General View.
 3. Museum (Lower) (Portion)
 4. Museum (Upper) (Portion)
 5. Insect cases from Wall.
 Skulls from Museum.
 6. Digestive Tubes - Comparative Work V1 Sc.
 7. Rabbit Embryo; - Snake swallowing Mole.
 8. Heart and Brain - Comparative Work V1 Sc.
 9. Chart - Cigarette Cards.
 10. Greenhouse (Portion) General View.
 11. Greenhouse (Portion) General View.
 12. Department Plan.
 13. Garden (Winter) General View.
 14. Chart - Gardening.
 15. Aviary.
 16. Rock Vegetation (Side of Snowdon) - Plant Habitats.
 17. Reeds (Phragmites). (Oxfordshire) Plant Habitats.
 18. Aquarium.
 19. Vaucheria - Specimen
 To show fertile filaments.
 20. T.S. Stem - Mistletoe.
 To show Morphology of Hysterophyte.
 21. L.S. Stem of Saxifraga.
 To show growth of bud in axil.
 22. T.S. Ileum of Frog.
 To show Villi
 23. Skin of Frog (~~Abdomen~~ from Abdomen)
 To show blood vessel and pigment cells.
 24. Bacteriological Work V1 Sc.

CHARTS (Small)

1.	A. _____	Lister.	Bacteria - Theory. Form 11.
	B. _____	Yeast + Bacteria.	Practical. " "
2.	A. _____	Soil + Bacteria - Lister + Pasteur.	Form 111
	B. _____		
3.	A. _____	Bacteria (Theory)	" V
	B. _____	Yeast (Practical)	
4.	A. _____	Bacteria (Theory)	" Remove
	B. _____	Pasteur's Work (Practical)	
5.	A. _____	Bacteria (Theory)	" V.
	B. _____	" (Practical)	(Lower)
6.	A. _____	Bacteria (Theory)	" V.
	B. _____	" (Practical)	Upper.
7.	A. _____	Lister's Fight V. Gangrene	" V1S
	B. _____	Bacteriological Work - (Practical)	"
8.	C. _____	Heart-beat after Death - Frog.	"

CONTINUED.

- | | | | |
|------------|----|---|------|
| <u>9.</u> | D. | Leaf Structure-Modifications. | VIS. |
| <u>10.</u> | E. | Great Scientists - 19 th Century | " |
| <u>11.</u> | F. | " GENIUS - " " | " |

VIS. Form Charts in general, show accumulative effect of Method. — Concentration & Application — Something akin to the true spirit of enquiry.

CHARTS (Large)

-
- | | | | |
|----|----|-------------------------------------|-------------|
| 1. | A. | History of Biology, — HEREDITY. | VIS Form. |
| 2. | B. | The lives of Some Great Biologists. | V. Upper .. |
- 2.
-

Contd.

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