Some Aspects of Biology Teaching in Secondary Schools

by

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Study No 3. This is one of several studies intended to provide an analysis of the present situation of biology teaching in schools
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Bibliography
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I - Preface

In order to discuss the significance of biology as an educational item, it is first of all necessary to realize what biology means to society. Until the end of the 18th century biology had almost exclusively been a descriptive science. There was no influence at all of biology on society, or vice versa. Around 1800, experimental biology began to develop. Ingenhousz experimented with assimilation, Lavoisier with the respiration of animals, and de Saussure with the respiration of plants. Only in the middle of the nineteenth century did a big change take place. The investigations, made by von Liebig into plant food and artificial manure, by Sachs, the founder of plant physiology, by Pasteur, Darwin and Mendel appear to have had an enormous influence, especially with respect to the application of biological discoveries for the benefit of the human society. Medical science and veterinary science benefitted most out of these biological discoveries, especially when we think of aseptic wound treatment, contagious diseases, microbiology, virus research, hormones, vitamins and antibiotics, the fight against malaria. In agriculture, too, applied biology has achieved great improvements, for example, right manuring, increased yield, conquest of plant diseases and insect plagues, hybridisation and selection, growth-promoting substances, etc. We may say without any exaggeration that contemporary society can no longer do without biology. The image of life which modern biology conjures up, is one of an admirable unity and complexity. The science of life has a message for all and plays a significant role in our society and it is the task of the biology teacher to propagate the knowledge of biology and to develop a proper insight into the subject.

II The teaching of biology

Active participation in the process of inquiry into specific problems is the best way to learn the facts and concepts of science. Scientific experimental methods are essential for the training of the student. These methods of experimentation develop the mental processes and help reasoning and decision on the part of a young citizen.
Biology in secondary schools started as a largely descriptive science, the component parts of which were: anatomy and systematics. The evolution of biology teaching beyond the purely descriptive level is relatively young and came after the evolution of the teaching of physics and chemistry. Biology had long been considered as a subject of secondary importance among the sciences. For years, attention was paid at the school to experimental physics and chemistry, while biology remained just a descriptive subject. Only recently the relationship between biology and physics and chemistry has begun to penetrate into the curriculum of the secondary schools. The present static position of the teaching of biology in secondary schools is the natural result of its remaining a self-contained subject without any references to the other branches of science. Only when the coherence of the natural sciences began to be realized by the educationists, biology could take a step forward, but even now the advance is only slight. There still appears to be a vast difference between the biology which is being taught and the desired up-to-date biology which should be taught in the right way.

This slow advance has definitely made for the neglect of biology by the schoolchildren. Very few were interested in biology, principally because of the way it was taught at the school. It was a dull science stuffing the pupil with a list of terms. Being treated hardly more than a dead version of morphology, the dry scientific characteristics of plants and animals meant little to the pupils. Moreover, these characteristics were learnt with the aid of a book and there was very little contact with natural objects. Only the lovers of nature derived some help from these terms as they were the key which disclosed nature to them. Nor could a systematic treatment of the vegetable and animal kingdoms contribute to the attractiveness of the discipline. The confrontation with natural objects themselves and the various laboratory and field experiments, - be it within the school or out of school - can only give the possibilities of an increasing interest. Only then the problems will arise in the mind of the pupils and which will be discovered and solved by the pupils.

A. The status of biology

In European countries schools are organised at two levels: a primary level (grades 1-6) and a secondary level (grades 6-12). There are great differences between schools in various countries. The age at which secondary education starts, varies. In a few countries it already begins in the fifth grade at the age of ten, in most countries in the 6th grade, at the age of eleven, while there are also a few countries in which secondary education does not start before the 7th grade, at the age of twelve. Apart from a few exceptions, we may say that the 12th grade, at the age of 17 is the last grade. This means that the secondary school takes 8,7 or 6 years and these years influence the teaching of biology. In this report we are going to consider only those secondary schools with a curriculum preparing for the matriculation or the school leaving certificate.
In about 50 per cent of the West European countries, Belgium, Denmark, Finland, France, Federal Republic of Germany, Ireland, Italy, Netherlands, Norway, Scotland, biology has the same value as physics and chemistry in the case of promotion or at the final examination. In Austria, Portugal, the Soviet Union, the United States of America, there is either no biology examination, or there is an oral examination, or only the marks obtained in a test are taken into account.

There is a difference with respect to the name of the subject; sometimes the word biology is used, then again we find a division into botany and zoology, while sometimes general biology and nature study (for lower forms) are the terms.

Sometimes it still occurs under the name of Natural History, a name which was correct at the time when biology was no more than a descriptive science. What was understood by this term was, however, not always the same thing. It often comprises botany and zoology, but sometimes zoology is also included. When people talk about biology, they are not always talking about the same subject in every country; the emphasis may be put on certain subjects, so that we cannot speak of a unity in this respect. Sometimes physiology is taught besides botany and zoology. This additional subject points out that a reform has indeed taken place, a reform which has not integrated the subjects which are taught already but as added a separate subject in order to make the whole syllabus comprehensive. In order to make room for a new course something has to be left out. This is done in two ways, partly by specialization so that the new branch viz. physiology, appears as a separate subject, partly by reducing the content of morphology and anatomy in botany and zoology. In the lower grades biology is not always taught as a separate subject. Instead of this, general science is being taught, certain subjects, for instance, energy, are being treated from the point of view of physics, chemistry and biology so that the student does not become aware of a division of subjects. From the above it appears how great the differences are. All this may be severely criticised but it is better first of all to trace what is being taught.

B. Hours of instruction per week

Generally there are not more than two hours per week, sometimes only 1, exceptionally 3 or 4. The number of hours also depends on the particular type of the secondary school. Moreover there is a difference between the grades; Biology is not always taught in all grades, in the higher grades in particular it is no more taught. In some countries, however, the higher grades have 3 or 4 hours (see appendix 1).

C. The aims

Here we also find differences which are connected with the various grades at which secondary education begins. Sometimes the aims are more or less general viz.: to teach pupils how to observe
accurately and thoroughly, to describe their observations clearly and systematically, to promote a more or less detailed knowledge of the living nature through observation and to apply these observations to everyday life.

Sometimes more details are mentioned and a distinction is made between the lower and higher grades. In the lower grades, for example, the pupils should get acquainted with the typical families of animals and plants by direct observation. This implies that we introduce them to plant and animal classification, teach them the essentials of the structure of the human body and acquaint them also with the importance of conservation; describe the phenomena of elementary morphology, give an idea of the relations between the form and functions of the various parts and of the relations that exist between plants and animals and their environment. In the higher grades the primary aim is to develop a conception of life together with the understanding of the laws governing life and to foster an attitude of respect for the living world and the mysteries of creation, particularly for the human body. This may lead to discussions on the main problems of life.

The aims of secondary education are, in short, to impart factual knowledge, which may be a means but not an end, and which is necessary to obtain insight and understanding. Other aims are to teach the pupils, to detect and analyse problems, to train their intellect, and to make them cultured members of the society. Among the sciences, biology is the very subject with which it is possible, particularly in the higher forms, to offer the necessary insight and understanding within a limited range of factual knowledge.

The most important objectives of biology teaching for the elder pupils are:

1. making the pupils receptive to impressions from nature, training them to observe biological phenomena and giving them an insight into the stream of life and consequently instilling in their minds a respect for life;

2. imparting the pupils with a knowledge of man and his status in the biological world;

3. giving insight into the interrelations of the living and the non-living world;

4. preparing the pupils for a further biological studies, for which specific knowledge and general understanding of plants and animals are desirable.

Many university students need biology for their studies, for example students of biology, medicine, veterinary science, pharmacy, geology, chemistry, sociology, psychology, agriculture, forestry, etc. For younger pupils the value of biology lies particularly in the promotion of their interests in and respect for nature. This may only be done by instilling knowledge, as the pupil will only thus get familiar with
nature. Drawing improves their power of observation. Identification is of great importance as this is their key to nature. Knowledge of the human body is meaningful as a basis for hygiene. Making a herbarium (not too big) may satisfy their collecting habits.

A few aspects of teaching the elder pupils may be mentioned here:

1. teaching should be coordinated with the other sciences, particularly bio-chemistry;

2. as in the case of the other sciences, part of the teaching time should be spent on practical work;

3. encouragement of the self-activity of the pupils, which will imply working according to the inductive method;

4. an important contribution to the sex instruction of the pupils by means of discussions of the subject "propagation". With the theory of heredity, the attention of the pupils may also be drawn to their responsibilities in this matter, for which the discussion of eugenetics serves a particularly good purpose.

5. a critical discussion of the theory of evolution, in which the question arises of the first life on earth, shows the pupil that several solutions of this problem may be given but that actually evolution is an unsolved problem. It is a fact that biology cannot be replaced by the other natural sciences. While studying life, its specific problems claim our attention. It is necessary for the pupil to be informed of these. The problems in biology and the results of scientific investigation are an important contribution to the general picture of the world and to the philosophy of life. The student will learn to see that biology tries to reveal life, but that this has not been achieved so far: "the very problem of life is life".

D. The curriculum

As regards the curriculum, the differences in European countries are great too. This is partly connected with the age at which secondary education starts. Moreover, the curriculum of one country is much more detailed than that of another. It is therefore very difficult to draw up a comparative table. There appear to be differences also between the syllabuses of the lower and the higher grades.

a. Lower grades

Zoology. Usually the vertebrates are treated, beginning with the mammals, after this the birds, reptiles, amphibia, fishes morphology, anatomy, physiology, modes of life). Sometimes a few invertebrates are treated or a general survey of the animal kingdom is given. The treatment is different: sometimes monographs on common vertebrates, sometimes general classification.
Botany: Flowering plants (beginning with the simple flowers), mainly morphology, classification, general survey of the vegetable kingdom.

Human body: Elementary anatomy, function and some hygiene.

General biology: Protection of animals and plants and national parks. Study of an appropriate biological community.

b. Higher grades

Zoology: Invertebrates (morphology, anatomy), arthropods (in particular the insects), molluscs, echinoderms, coelenterates, unicellular animals.

Botany:
1. lower plants: ferns, mosses, lichens, mushrooms, algae, bacteria, viruses.
2. anatomy
3. physiology

Human body: detailed study of anatomy and physiology and hygiene (+ first aid).

General biology: a. theory of heredity of plant, animal and man;
b. evolution of animals and plants; c. applied biology;
d. ethology; e. comparative anatomy and physiology; f. topics from animal physiology; g. sexual hygiene (sometimes);
h. biochemistry; i. microbiology; j. ecology, sometimes in relation to geography and geology; k. economic importance of plants and animals; l. history of biology.

E. Non-European schools

In non-European schools the differences with regard to all the aspects of biology teaching which have been mentioned above, are even greater than in European countries. It is not possible to give a general survey of this.

In the developing countries the curricula and standardized examinations generally follow the patterns of European countries. Often the facilities for secondary education are relatively poor, compared with those of the elementary and higher education. Elementary or primary education is concentrated to reducing the number of illiterates. In higher education, however, the number of science students is very low. This has its influence on secondary education, where the lack of teachers presents a serious problem.

In one country the teaching of biology has already reached a higher level than in another. In Ghana, for instance, scientific methods are emphasized. Much attention is paid to demonstration and laboratory work.
In South American countries there are likewise great differences in the teaching of biology. Sometimes, as for instance, in Argentina, there is a basic course and an advanced one. The latter, takes 1, 2 or 3 years; this depends on the type of school in which it is given. The subjects in the advanced course are: anatomy and physiology of the human body, hygiene and general biology.

In Japan biology teaching in lower secondary schools constitutes the second part of the single science subject, according to the new course of Study since 1962. In the 7th grade, environment and the living things are taught when ecological representatives of animals and plants are dealt with. The internal structure and function of plants and animals (centering on human beings) and their food (including their chemical nature) are also taught. In the 9th grade reproduction, breeding, heredity, evolution (fossil animals and plants), and the systems of classification are taught. In lower secondary school a more systematic treatment of biology is given. In the upper secondary schools since 1963 biology teaching has been started according to the new Course of Study. Its salient features are as follows: It is intended to have the students grasp the function of animals and plants on the basis of metabolism and energy relationships. Accordingly, there is a tendency to place more emphasis on theories of formonts and nucleic acid at biochemical molecular level. The content is treated from the viewpoint of general biology instead of division into botany and zoology. It is designed to provide the students with an understanding of the forms (internal structure included) of the animals and plants in relation to their functions. Emphasis is placed on the integration of an individual and his maintenance of homeostasis. Through the adaptation of modalistic contents one is led to the progress of new ecology, the concept of ecosystem and to the production and consumption of biological materials.

F. Summary and critical analysis

Most of the biology programmes are essentially informative. There is a lack of emphasis on the experimental methods. The classwork programmes are rigid and there is no connection between theory and practice. Moreover there is a lack of coordination with other subjects. They fail to acquaint the student with the great unifying principle of biology.

In broad outline there is some resemblance to be found in the curriculum in the various countries. In the lower grades the stress is laid, in general, on morphology and anatomy and a knowledge of the species. In the higher grades the emphasis may rather be put on the physiology of organisms (also comparative physiology). It is also fascinating to discover the laws of nature. Not all the topics mentioned under general biology are of course dealt with.
Each country lays the stress on particular parts, but the possibilities are many. On one hand, this is very advantageous for biology, but on the other hand, this may be a disadvantage and at various types of schools in one country the teaching of biology may lead to great differences. With a uniform final examination this may give rise to difficulties.

In the curriculum we sometimes see that attention is drawn to practical work which is to be done (descriptions, dissection of animals, excursions, etc.). The accent on the practical work and field work ought to be more firmly laid down in the curricula than has been done so far. Only then is there a chance for the teaching of biology to be organised as an experimental science. Modern subjects are gradually appearing in the curricula, such as biochemistry and ecology.

III. Reforms in the field of teaching

Many countries are bringing the teaching of biology to a higher level by means of reforms. Not much documentary information from the various countries is available at the present moment. Important work has been done by BSCS in the USA and work is proceeding in the United Kingdom.

The study of the Biology curricula in the USA

This study was begun in 1959 by the A.I.B.S. "to seek the improvement of biological education". The BSCS materials are the results of a large-scale project in which there has been close co-operation between research biologists, mainly from universities, and high school teachers. The aims and objects were "to prepare first high school biology courses, suitable for a wide use in the average high school, to give students a basic understanding of science and of scientific processes". Student work is centred in the laboratory, where real problems are explored. "The central position of the laboratory reflects the view that a student will begin to understand science much better when he takes an active part in it, than when he serves as a bystander who only reads about science, watches demonstrations or follows patterned work outlines as a routine". BSCS has produced three alternative courses; the blue version, with a preference for molecular biology; the yellow version, with a preference for molecular biology; the yellow version, with a more cellular approach, and the green version, which emphasizes biology and biogeography. There is no saying which version is better or more suitable and the choice is left entirely to the individual school. Each version comprises a Teachers' Guide, a Teachers' Handbook, a Student Text and a Laboratory Manual. Additional material includes "Laboratory blocks", which can be used for six weeks' experimental work. The courses have been made flexible by including in them far more than could possibly be taught
or learnt in that time. Before the three versions reached their final form, they were tested by about 1000 teachers with 160,000 pupils. Classroom testing has shown that 70 to 80 percent of 15 year-old pupils are able to use BSCS material in a satisfactory manner.

In the United States of America general biology is studied by most pupils of the 10th grade level (age 15-16). Recently there has been an increase in the number of students taking biology in the 9th grade (age 14-15). An increasing number of senior high schools are now offering a second course in biology to higher selected students in the 12th grade (age 17-18), usually 5 to 6 periods a week.

The impact of the Biological Sciences Curriculum Study upon the teaching of biology in the secondary schools has been tremendous. More than 250,000 copies of the textbooks have been sold during the past school year. In many instances this also required the establishment of modern secondary biological teaching laboratories. Four six-week Block Programs are now available commercially and six others are in the process of completion. Two volumes, each with forty investigations. Research Problems in Biology-investigations for students are now available for individual work with highly gifted high school students. For the past two years the BSCS has been doing experimental work with the second higher course on biology. The current revised edition is titled "BSCS Biology—Second Course, The Interaction of Experiments and Ideas". Another area of experimentation has been the BSCS program in dealing with special materials for the slow learners, (about 20% of the 10th grade group).

The Nuffield Biology Project in the United Kingdom

In December 1961 the Trustees of the Foundation agreed to lay aside £ 250,000 for the development of a comprehensive programme to improve the teaching of science in schools. The first biology materials has been tried out in about forty selected schools from September 1963. It is hoped that the course will evolve aims to serve three purposes:

1. To provide a sound introduction to modern science for those children who will leave school at the age of sixteen.

2. To contribute a suitable background for more advanced specialist work.

3. To provide a basis for further courses of science at Sixth Form level for non-scientists.

A set of documents will include:

a. A text for students written from a much more experimental point of view. But although the BSCS student texts and laboratory guides are published as separate volumes, theory and practice should occur side by side in the Nuffield Programme in order to emphasize the importance of their inter-relation.
b. A guide for teachers (also with respect to the preparations and conduct of laboratory demonstrations and practical work in class)

c) A book of projects intended for the most gifted students and for those who show a particular aptitude and enthusiasm for experimental work.

d) A set of good visual aids.

As in the case of the American scheme the course will be built round a number of fundamental concepts. An aspect of biology teaching which will receive much attention is its integration with physics, chemistry (very particularly and mathematics.

The aims of an elementary course are:

1. To develop an understanding of man's place in nature.

2. To further a realization of the variety of life.

3. To encourage a respect and feeling for all living organisms.

4. To develop a contemporary outlook on the subject.

5. To develop a critical approach to evidence.

6. To show what is meant by experimentation and proper use of controls.

7. To encourage and develop an attitude of curiosity and enquiry.

Two main trends can be detected in the changes taking place. The first concerns the content, where a more functional approach is becoming accepted, modern material is being introduced and the need to relate the school course to the human biology and to the world problems of food, disease and population pressure is being increasingly recognised. The second concerns the method, where more attention is being directed towards developing a thoroughly scientific attitude in appropriate situations and to stimulating powers of critical thought in a biological context.

In general, the reforms should cover various aspects of teaching:

A. **The lessons.** The number of lessons and their distribution vary in the different countries. In many countries however, no biology lessons are given in the mathematical-scientific type of schools. It will be necessary:

a. that this number of hours is at least equal to that for physics and that for chemistry, especially in the higher grades of secondary schools.
b. that biology is taught in the two highest grades.

c. that the number of hours is sufficient to give ample opportunity to practical work, as a result of which a sense of observation is developed.

It is impossible to develop correct conception without experiment and observation. Therefore practical work and fieldwork together with the theoretical lessons are indispensable - just as in the case of the other fields of science - and time should be allotted for that.

B. The lay-out of the scientific classroom. The teaching of modern biology requires well equipped laboratories and other facilities (gardens, greenhouses). The ideal situation should offer the possibilities for comprehensive laboratory work. There should be, if possible, two separate classrooms for the teaching of biology, situated one behind the other, the first for the lessons and the second for practical work. Under such circumstances a laboratory assistant will be able to prepare the laboratory work without losing any time. Moreover, it is desirable that there is a room in which the educational aids for the teaching of biology can be placed in dustproof cupboards. A school garden next to the school building is desirable. In this garden will be those plants which are used most - in the broadest sense of the word - selected from the trees, shrubbery and herbaceous plants. This makes it possible to have living materials at one's disposal during the biology lessons, an important fact from a didactic point of view. It is recommended to have the biology department on the ground floor, so that the rooms overlook the garden and teacher and pupils have a direct access to it.

C. Educational aids. The teaching of modern biology requires a good equipment. Necessary materials are: the various models, the skeletons, liquid preparations, stuffed animals, wall pictures, bioplastics, aquaria, terraria, microscopes, projectors, slides, filmstrips and if possible films, records and a record-player.

D. The subject-matter.

For the purpose of modernisation of the subject-matter, less attention should be paid to morphology, and anatomy, and more time be spent on physiology, microbiology, molecular biology, genetics, evolution and ecology. All these subjects give biology a wider background and the contacts with physical sciences will be increased. The scientific way of thinking will be developed.

In many developing countries the following factors form an impediment to the revision of the biology curriculum: lack of surveys of local flora and fauna, lack of ecological data, lack of biological supplies and lack of reference books and materials.
It is important here to discuss the principal points of view which characterize the teaching of biology. The morphological and anatomical approach is the classical approach and this is being more and more replaced by the ecological and the cellular approach. On the one hand, there are the biologists who think that the ecological approach is the one and only method. On the other hand, there are those who think that biology must be taught from molecule to man. These two approaches are found in the reforms but in many countries particular stress is laid on the ecological approach. The manner in which the ecological approach is to be realized varies from country to country, taking into consideration the particular environment which is ready for study.

An ecological approach has certain advantages from both educational and biological points of view. This kind of approach will make it possible to give an integrated view of nature and contribute to the pupil's physical, intellectual and social development. It also provides a more natural motivation for teaching the basic elements of taxonomy, anatomy, physiology, the molecular nature of life, genetics, and the great socio-biological problems which face mankind. These subjects may otherwise tend to be too formalized and traditional in approach.

The ecological method offers undoubted advantages, by putting students directly in contact with the biosphere under all its aspects. Through the study of ecosystems, students have an opportunity of acquainting themselves with biological mechanisms. The concept of ecosystems is the best means of explaining the real position of living beings in nature. The organism shall not appear alone; it is shown to be subject to the effect of living and non-living parts of the ecosystem, and in turn at on them (see the Green Version of the BSCS). The cellular approach begins with the fundamental basis of life which is centred on the properties and organization of matter, then it moves to the activities of these organizations as seen in the capture and use of energy and then to the organs, and thence to the level of the whole organism and of the populations. Genetics is couched in terms of the conservation and modification of molecular organization from generation to generation; evolution is the basis for long term changes in the development of diversity among living organism (see the Blue Version of the BSCS).

E. Laboratory work

Moreover, there is a general tendency to spend more time on laboratory work. The pupil becomes more familiar with the scientific way of thinking in the course of setting up an experiment and performing it; thus we get problems raised at the mental level of the pupil. These problems must be solved with the help of experiment; in the following stages: arranging the experiment, carrying out the experiment, observation, conclusion. The conclusion from various experiments,
related to one object, e.g. the respiration of the plant, can then be linked up with one another. Mental assimilation creates a synthesis, which is built up by the pupil himself. Physiological experiments should especially be chosen from the field of botany (respiration, assimilation, food, transport, evaporation, growth, movement) and the functions of the human body (sense-organs, digestion, respiration, blood and blood circulation, etc.).

From the above it appears how important it is for a pupil to do physiological experiments himself. Experiments on bacteriology are very important too. Besides, we may point out the meaning of microscopical work (laboratory) in which subjects from the anatomy of the plant, lower plants protozoa and insects may be studied during microscopical work and zoometry. The internal and external structure of a starfish, a mussel, an earthworm and a lobster, etc. can be examined. Through these observations the pupil will get a better understanding. A proper development of his conception is impossible without experiments and observations. The same applies for genetical work (practical), in which the crossings of Drosophila are carried out to make the pupils discover (rediscover) the laws of Mendel themselves (see the Laboratory Blocks of the BSCS).

F. Fieldwork

In general, the purpose of these activities will be to provide the pupils with first-hand experience over a wide range of biological phenomena. Plants and animals can be studied in their inter-relationships and in relation to physical conditions. Observations made in the field - in large towns, a corner of a garden, waste ground or town park - and the materials collected there will lead to the laboratory work and further study. An analysis of ecosystem leads to a definition of the most varied aspects such as:

1. Competition between various species and elimination of a large number.
2. Dynamic balance of ecological groups with the climate and the substrate.
3. Food chains, energy and chemical cycle, productivity.
4. Study of climate, soil, water.
5. Selection of the best adapted individuals among a population (variability of a species and evolution).
6. Reproduction, scattering and accessibility of the environment.
7. Productivity and its present importance for mankind.

The study of the landscape, from many points of view, form an essential part of the ecological approach at all levels at school. Frequent
excursions and field trips will be of great importance. In planning these kinds of experience the teacher has to face many problems of a technical and more practical nature. When can field trips most conveniently be arranged? What kind of habitat will give the best output at different times of the year? What sort of field work will give the maximum information and at the same time the greatest educational value? The value of field study centres equipped with the necessary material and apparatus for making biological work through long term excursions is to be stressed here.

The earliest studies will be largely descriptive and designed to familiarise the pupil with a wide range of common plants and animals, their general characteristics and taxonomic relationships. Problems of identification and the use of dichotomous keys will be encountered and the pupils must be led to regard the naming of an organism as a first step towards a deeper understanding and not as an end in itself. Later field studies should be more analytical and related wherever possible to experimental work in the field or in the laboratory.

G. Didactic research

In the secondary schools didactic research gradually begins to assume form and substance. In various countries books and publications in the field of biology teaching have appeared. At present, there is a great deal of research in the field of teaching methods. There are various approaches for the teaching of botany, zoology, knowledge of the human body, genetics, ecology, psychology, the classical experiments and their significance for education, laboratory work and field work. It would carry us too far afield to pursue the subject any further. There is yet a vast field open for didactic researches, which may ultimately produce a catalytic function in the further development of biology teaching.

Various Institutes of Education have departments for the teaching of biology, at the head of which we find a didactician. Various reforms have already been introduced. One example of didactic research is the following.

Teaching methods: One has to start from some material – preferably living – which nature offers in the vicinity of the school. In view of the questions asked by the teacher, the pupil can find the answer by observing the material. The pupil can get acquainted with the plants and animals from his surroundings and in this way it is possible to enlarge his interest, and at the same time, his respect for nature. Attention will have to be paid to the treatment of the topics in the period that the organisms are available, so that there is a connection with the seasons. This especially holds good for the lower grades, where knowledge of the species is most important. Working material and problems to be investigated should be found "on the spot". The experimental approach has been mentioned before, the application of
mathematical methods (variation of form and rates of reaction), field studies of principles of ecology and some examples of types of approach need greater emphasis in a modern biology course. It is agreed that biology is best taught and learnt through the medium of laboratory exercises and field work. Theoretical instruction will always be an integral part of a biology course. Visual aids, models and organisms and above all, the living organism itself should form part of each lecture-demonstration. An improvement of the teaching method will also come about by using the information given by research on the psychology of the learning process. The morphology of a plant can therefore only be well understood if the pupil himself examines the plant during the lesson and if full account is taken of the various stages which can be distinguished during the process of study.

a. The information. After the plant has been given to the pupil the teacher begins to inform himself of the pupil's present knowledge of the plant by means of questions, such as the name, place of its growth, flowering time, etc.

b. Guided observation. Now the teacher asks questions on the external structure of the parts of the plant (root, stem, leaf, flower). Those questions are answered by the pupil while he is observing the plant. Only after the question has been answered correctly and each pupil has acquired the necessary information, another question is asked. So at this stage the pupil is subjected to a rigid system as to the study of the material and the gathering of information.

c. The explanation. At the previous stages various parts are observed and it will often be necessary for the teacher to mention botanical terms. Stage c is then at once joined to stage b, and can hardly be separated from b. The stages a, b and c will appear during one lesson.

d. The free observation. In a following lesson another kind of plant can be discussed, while use is made of knowledge acquired. The pupil can now get a few tasks at the beginning of the lesson and while using the material, he can then find the answers to the questions asked and write them down. So he is now more free with regard to the material, which, however, does offer him valuable information. The tasks require more initiative on the part of the pupil himself. Sometimes a task may be executed in various way, sometimes a task may be a stimulus for the process of invention. The pupil learns to vary his actions according to the purpose. This fourth stage is, therefore, indispensable to arrive at a real control of the subject-matter.

e. Integration. Finally the pupil has come to a complete understanding of the procedure. When comparing plants, he will then discover relations which occur frequently. Being confronted with a certain solution he will suddenly discover them. Therefore this stage forms
the conclusion of a process of study? For each item of the subject-
matter those stages will re-appear. It may also happen that during
the free observation another item is discovered as well. This
coincidence enables us to repeat things, which is ever so important
and necessary in education.

H. Textbooks

The writing of new books will have to keep pace with the renewal of
the curriculum. Modern trends in biological thought must find a
place in our texts and manuals, but the descriptive material will
have to have its place as well. Historical introductions can
establish the reason for the exercise that is described. The style
of writing and the accuracy of facts must be of first quality. The
topics that are presented can be organized in many different ways.
(see the three versions of the BSCS). The memory type of questions
so often used for review purposes might come immediately after an
introduction to a chapter or section. Bibliographies should be
present at the end of each section. One glossary in an appendix is
sufficient. Besides textbooks more and more field and laboratory
manuals are appearing in the market. These books give more
opportunity for self-activity. In a workbook a pupil can find certain
tasks as/or experiments which he has to carry out and write a report
about. Some teachers prefer one single volume of text and laboratory
work incorporated together.

A series of questions might guide our thoughts about the best way to
design a laboratory manual. Is the method of observation explained
carefully? What approach is followed to explain the research methods
of a biological science, such as physiology? Is any mention made of
the fact that vast numbers of subjects must be experimented upon and
then that the data obtained must be analysed statistically before
any sort of conclusions can be drawn? Is the equipment or the
material to be used listed carefully? Are the procedures, descriptions
and questions concerning observations to be made accurate and
informative? Is there a bibliography cited so that the student can
confirm the historical details or reasons for certain procedures?

The format of a manual should not be different from that of a textbook.
Not only a revision of the text is important, the lay-out will also
have to be modernized. No matter how excellently the subject matter
is presented a book having very thin paper, very small print with
little spacing can be most discouraging for the student. A textbook
must be so attractive that the pupil will be eager to read it and
will become fascinated by the illustrations, a large part of which
must be in colour. Drawings must have captions to tell what the
object is and to explain how it is being viewed. The approximate
magnification is also important. Without details as to the view
and size of the object a diagram might be difficult to interpret.
The labels on a drawing should be placed very carefully. Whenever
a diagram or photograph is used in a text its placement and text reference to it are most important.

IV. Difficulties and proposals for solution

1. Difficulties.

A. Educational administration. In the countries with a highly centralized educational system, changes might be easier to effect than in countries with different systems of educational administration. If a new curriculum has been drawn up by the Board of Education, no difficulties will arise and every school is obliged to introduce this curriculum.

B. A new curriculum. A new curriculum also means, however, that the teacher will have to get acquainted with the new themes which it contains. Particularly in the case of biology, the science is developing rapidly. The teacher himself may not have studied these topics during his own student days, because they were completely unknown insufficiently known (see III, D).

C. The scientific classroom. In order to be able to teach biology as it should be taught, it is absolutely necessary for the school to have a special classroom for biology at its disposal. This room must be able to hold at least 24 students for lectures and practical work. Financial difficulties often form an obstacle.

D. Educational aids. As the modern teaching methods require that the visual material is the starting point for a lesson, the schools must be able to draw on an ample supply of all sorts of educational aids, necessary for the teaching of biology (see III, C). As with the previous items, the provision of the necessary money often forms the greatest difficulty.

E. The number of hours. The number of hours which has been allotted to biology teaching in the various countries, is usually too small. The difficulty in obtaining more hours often lies in the fact that a certain number of hours will have to be taken from another subject, and a replanning of the teaching time-table is necessary.

F. Laboratory work. The importance has already been explained (see III, E and F). It does, however, take time and this too is a reason to increase the number of hours for biology. But laboratory work and fieldwork also demand good equipment: microscopes, binocular lenses, magnifying glass, materials for collection and physiological dissection, etc. Besides, it is
necessary for the biology teacher to have a technician at his disposal, who should spend the whole time working on biology and who should not be expected to assist the teachers of physics and chemistry, as is often the case. Moreover there are countries in which there is no technician present at school and where the teacher has to arrange everything himself. Sometimes this is made possible by reducing the number of hours. Actually, 15 is the maximum for the Biology teacher to instruct properly, who should be assisted by a technician for the practical classes.

G. Fieldwork. For field studies no serious problems arises in schools with suitable areas close at hand. The ordinary pattern of lessons of comparatively brief duration does not lend itself to longer field expeditions such as will be regarded in many urban schools. There is a need for field study centres.

For the teacher the situation creates problems. Will he be paid properly for the great amount of work involved in leading a field camp of 24 to 30 pupils. This can be a 24-hour job as he has to be ready to help with any problems that might arise.

H. Textbooks. For an effective reform it will be necessary for the textbooks and the manuals to be continually modernized at least once in five years, (see III, H), not only as far as the text is concerned but also with respect to the illustrations, which have to be made by means of modern printing techniques. Manuals will have to appear for laboratory work as well as workbooks. In many countries these are urgently needed, but several reasons delay their being published; fewer authors to compile them; "Aren't there already far too many books"? Are the expenses justified from a financial point of view?, etc.

I. Teachers. In most countries there is a shortage of qualified biology teachers. The present university students usually take a greater interest in research work and in industries than in education, the latter also offering less remuneration than other professions. In developing countries there are also the difficulties of the lack of knowledge of the local plants and animals, and of local health and hygiene.

2. Proposals for solution

By opinion, related with the opinions in a number of countries is

A. Concerning the number of hours. A possible solution with regard to this matter might be the following: a division into key and optional subjects, in particular for the higher grades or in other words: some compulsory subjects and by the side of these some which may be chosen by the pupil from a series of subjects, but which must then be followed. A disadvantage of this system
is that a number of pupils will not follow biology lessons in the higher grades, an advantage is that for those who do choose biology, the number of hours can be increased.

B. **A new curriculum.** It is desirable to divide the subject matter into a number of topics which are important for the pupil because they are of immediate interest to him and are suited to his intellectual capacity and to his stage of development. Any syllabus for biology should be planned in accordance with the corresponding syllabuses for chemistry and physics, especially for the higher grades. In the lower grades too, the teaching of biology will need some physical and chemical foundation.

The advanced course will give suitable elementary laboratory studies in physiology, microbiology, cytology, biochemistry. Here the unified view of biology will replace botany and zoology (see the three versions of the BSCS).

C. **Laboratory work.** The school should possess a well-equipped laboratory and workshop facilities (for the construction of simple apparatus). Sometimes it seems advisable to split up a group of pupils if their number is more than 20. Actually, 15 is the maximum number who can be supervised individually by a teacher, assisted by a technician.

D. **Field work.** The school should possess a garden with vivaria (aquaria, terraria, insectaria) and animal houses, and a greenhouse. The main problem is the location of a field camp. There are three ways: the school may purchase a building which can also be used as a holiday camp, the school may jointly buy some farm buildings, the full biology class goes to a youth hostel.

The biology lessons of the younger classes should be given in the latter part of the day so that the field work can go on after school hours, if necessary. Five or six excursions in the course of a year to provide all the data and material needed are sufficient. At a later stage longer expeditions at week-ends, during schoolweeks or holidays, and at longer intervals, will be more appropriate. The authorities must give grant to centres for field study, houses with library (reference books and experimental guides) and instruments for investigation.

Because the field work is so essential it must be compulsory and therefore we recommend that the expenses for the journey of the pupils are paid by the authorities (state).

For the teachers who have great responsibility for the pupils day and night must be paid an insurance and also for every pupil.
E. Didactic research. The more research we have and the more results are being achieved the better biology can be taught. It is not only a matter of inventing new experiments for laboratory work, but first and foremost a matter of an excellent didactic structure of the entire biology teaching. Certain methods and experiments will have to be tried out at some schools in the same way as in the case of the High School Biology of the BSCS and also of the Nuffield Biology Project. If the results appear to be favourable they may be generally introduced.

F. Biological Advisory Council. It is "desirable" that in each country, as in the Netherlands, an education committee is established, consisting of some professors interested in secondary education (who have been perhaps teachers themselves), a professional didactician, an inspector (of biology or natural sciences), some principals of secondary schools (biology) and some teachers. The task of this committee will be to advise the Board of Education on all matters concerning biology teaching at all types of secondary schools and on the relations between the secondary schools and the universities.

G. National Institute for the Teaching of Biology. In several countries institutes have already been established which organize courses for teachers who are in service, and which have a large professional library at their disposal. Each country should have such an institute. This institute must preferably be situated in a university laboratory or institute. In any case it must establish close contact with the university for the following reasons:

1. the subjects of secondary education cover a large field, the treatment of these subjects should not go beyond the pupils' competence to understand. Those engaged in research on education should always be in close contact with a specialist. This will only give good results if the specialist and the didactician regularly keep in touch with each other.

2. this institute has to establish close contacts between the university staff and the school teachers. As a result there should be a close contact between the institute and university laboratories.

3. being a didactic department, the institute may attract a scientific staff and assistants.

4. this institute may profit from the experience obtained from lecture demonstrations and experiments in practical work. On the other hand, it is sometimes possible to obtain a useful suggestion for practical work or lecture experiments, from an investigation which was set up for secondary education but which did not give a positive result in the schools.
5. use can be made of the library of the laboratory (or institute).

The tasks of such an institute should be:

a. To give advice to the authorities and the teachers of a school, on, among other things, the furnishing of biology classrooms, the purchasing of educational aids, the equipment for practical work.

b. To test educational equipment.

c. To give advice to authorities which organize training courses for a particular purpose (e.g. to obtain or to increase professional skill) and also to train laboratory assistants.

d. To do research work with regard to biological education, to evaluate new educational aids, to give teachers an opportunity to realize and test experiments planned by them.

e. To organize courses for teachers in service, in particular to learn new themes and techniques (genetics, physiology). There are many fields about which the teacher has to acquire knowledge after his university studies. For most teachers this is an almost impossible task. An outsider usually underestimates the difficulties connected with this. Very few people can realize how difficult it is for a teacher who has lost contact with his university to keep ahead with the modern development in the subject. It actually means that the teacher has to read many magazines, a number of which he probably cannot get hold of. After that, he has to understand the development to such a degree that he can decide what will be suitable for his lessons. The scientific advances have to be reduced to a level which his pupils can grasp. Only then will the biology teacher be able to fulfill his responsibility, provided that he has been able to obtain the necessary facilities and guidance. This purpose is served by the institute. The older teachers too, who have lost contact with the university after a few years of teaching, will choose to visit this institute as they will find understanding and patience there. The teacher has to be helped by a system of re-training and application courses, organized by the institute.

f. This institute can also be used at the university for the training of biology teachers. In this institute the students, guided by the lectures on methods of teaching biology, can train themselves in demonstration techniques and in guiding the practical work done by the pupil. In connection with the above, a few things have to be said here about the professional skill of teachers who have already been in function for a long time. One essential requirement of secondary education
is that it prepares the young students for the society in which they will live as adults. Therefore the science teacher has to acquaint his pupils with those fields of his subject in which developments of great social and technical importance are taking place.

V. **Summary of new trends and conclusions**

A. **New trends**

Biology is now a well integrated science. The content of its teaching includes the following unifying topics.

a. Diversity of type and unity of pattern in living beings.

b. Relationships between structure and function and organization and activities.

c. Relationship and symbiosis of the individual and his environment.

d. Mechanism of regulation and homeostasis.

e. Biological basis of behaviour.

f. Genetic continuity of life.

g. Evolution of life in time.

h. Man and the biological balance of the earth.

i. History of biological concepts.

j. Science as a means of investigation and inquiry.

The pupil has to get acquainted with the workings of his own body and the needs of health in connection with them, man's place in the world of nature, man's influence in this world and how much man's welfare depends on a sufficient production, and on the control of diseases.

B. **Divided opinion**

It will appear from the previous pages that there are differences in the treatment of biology as a subject of general education in the schools. First, these are found in the age-levels at which secondary education begins, and connected with this is the division of the subject in the different grades. Sometimes there is a difference in the number of teaching hours per grade. But this is connected with the entire system of education in a country and
only a biology education committee may be able to have any influence on this. There is also the argument about which new trend is to be preferred and where the emphasis should be put. Is the ecological approach the best method or is it the genetic one which starts from the molecule? Opinions generally agree that morphology and anatomy can be reduced, and that physiology will have to become more important. This implies, however, that there must be possibilities for experimental work. All this is connected with the age at which secondary education starts and connected with this is the distribution of the subjects over the various grades. If we want to start from the molecule it will be necessary for the student to have some knowledge of chemistry, and also the name of the chemical substance should have some meaning for him. Therefore many teachers think that it is recommendable not to work from molecule to man but rather the other way round. The importance of laboratory work and field work is not always appreciated either. This also holds good for the experiments. There are still many people who are not convinced of the great importance of them.

The teaching methods and the approach often depend on the training of the teacher (both his scientific and his didactic training) and the same holds good for the time spent by him on laboratory work (this sometimes depends on the possibilities for this work too). Excursions and field research are also dependent on the teacher's initiative and on the possibilities offered by the place where the school is situated.

C. Suggestions for Cooperative action

a. More attention should be paid to didactic research.

b. New textbooks and teachers' guides for both the teaching methodology and the field and laboratory work should give and insight into the unifying principles of biology, with illustrations appropriate to the text and to the characteristics of the country for which they are intended. The textbooks will encourage the students to engage in experiments. The technical terminology must be reduced to an absolute minimum. Selections from classical authors will give the student an appreciation of the development of ideas in the field of biology. Bibliographies for the guidance of teachers and students are desirable. A series of books on the fauna and flora of each country are also desirable.

c. The establishment of a national institute for the teaching of biology in every country will contribute greatly to solve the educational problems of biology teaching.
d. A national biological advisory council should be established to prepare recommendations for the consideration of the Board of Education and the educational authorities in general. There should be close cooperation between this Council and the National Institute for the Teaching of Biology to coordinate the various tasks. (see IV.2.F.G.). Attention should be paid to the relationship between secondary schools and universities. Other tasks of this committee should be:

(I) promoting formation of libraries and their use.

(II) expanding public knowledge of biology by disseminating information on the biological subjects relating to public health and welfare through pamphlets, radio and television programs.

(III) compiling information on the modern methods of teaching biology.

(IV) negotiating with government authorities on the teaching load and salary-scales for teachers, giving special considerations to self-improvement activities and establishing categories with different rates of remuneration in direct ratio to lesson-hours.

(V) initiating any other activity that might help to improve the teaching of biology, such as students conferences, exhibitions, competitions, science clubs, circulating libraries reading lists, and museum services.

e. Steps should be taken to appoint didacticians at the Universities where the training of teachers should preferably be completed. An ideal university course should consist of a foundation of general nature, covering the most important aspects of biology, followed by more specialized courses. The minimum duration of the university training must be five years. Different universities have "second subjects". Physics, chemistry, geology and geography are appropriate, perhaps mathematics too. The minimum duration in the case of two subjects will be six years. A university training on a broad basis should be completed by a pedagogical training at the university level, (lecture in pedagogy, psychology, methods of the teaching of biology and practical work in secondary schools), in the institutes for the Training of Teachers, during the last two years of the university training in biology.

f. The retraining of biology teachers.

In this field there are many possibilities: self-study by means of review articles and monographs, periodicals on biological education, translation of books and of new instructional materials. Training courses by teams of
university biologists, planned in consultation with teachers and school authorities. These courses should include some consideration of classroom utilization of the new knowledge, including adaptation of practical work to school situations. The courses can also serve as "laboratories" for developing and testing new presentations of biology. They can be organised during long vacations, or in the evenings or during holidays all through out the year.

g. International cooperation, for which some essential features may be mentioned:

(i) advanced training courses for selected teachers, who upon returning to their countries, should organise national and local courses.

(ii) for the benefit of teachers: production of teaching materials and organizing their distribution, preparing teacher's guides to methodology and laboratory practice, establishment and distribution of national and international scientific journals in collaboration with associations of biology teachers, and obtaining information on the teaching of biology from the national committees.

(iii) with the cooperation of the governments of the various countries: inter-relating the national retraining courses, each country contribution technical guidance and financial assistance for mutual participation.
### HOURS PER WEEK INSTRUCTION IN BIOLOGY IN SELECTED EUROPEAN COUNTRIES (SECONDARY SCHOOL)

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**CODE**
- **V** = Variable time allotment
- **G** = Integrated with geology
- **O** = Not taught
- **E** = Elective

**NOTES**
1. The data show maximum hours in biology required per week.
2. The data hold good for "typical" high schools of the country or one from which a student may get credit to go in for college examinations.