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ABSTRACT

The planning of biology facilities in Asian schools is discussed in the light of present laboratory activities, curriculums, and experimenting functions. Emphasis is placed on laboratory classrooms which are described as greatly influencing biology teaching and learning. Information is given on--(1) equipment, (2) teaching methods, (3) examples of experiments, and (4) bench and work surfaces. Floor plans, photographs, and diagrams are included. (TG)

STUDY 2

THE DESIGN OF BIOLOGY LABORATORIES FOR ASIAN SECOND LEVEL SCHOOLS

ASIAN REGIONAL INSTITUTE FOR SCHOOL BUILDING RESEARCH
Sponsored by Unesco
COLOMBO
1969

ASIAN REGIONAL INSTITUTE FOR SCHOOL BUILDING RESEARCH

STUDY no.2

THE DESIGN OF BIOLOGY LABORATORIES FOR ASIAN SECOND LEVEL SCHOOLS

by

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PREFACE

Great changes are presently taking place in the teaching of biology to secondary school children. These changes are to be seen not only in new curriculum content, but also in teaching methods and techniques which now tend to emphasise problem-centred learning. This paper has been prepared in the belief that buildings and furniture contribute significantly to biology teaching and learning and suggests changes in laboratory design not only to accommodate the introduction of the new content and method, but also to provide for continuing cycles of curriculum revision as they take place. Biology teaching now emphasises guided experiments in which children endeavour to find out for themselves and in their own way, the principles or laws relating to the particular biological phenomena they are studying. Demonstration thus follows rather than precedes experimental work and much formal lecturing is replaced by ad hoc group discussion. Most science lessons now need to be held in the laboratory for, in any one period the activity may change from student experiment, to discussion, to teacher demonstration, back to experiment and finally to recapitulation. In some countries, however, with a shortage of trained teachers and of biology teaching equipment this picture has not entirely been realised and thus where these shortages continue, there will often be a heavy area of demonstration by the teacher and less experimental work by the children.

None the less changes in content and method, whether they have actually taken place or are likely to be implemented in the near future, must be reflected in the new laboratories and furniture that are to be provided for biology teaching. It is important, for example, that the new laboratories be designed not only to house laboratory benches, but also to provide space for discussions; the initiatives that are encouraged in the student by new teaching methods demand moveable rather than fixed furniture; facilities are required for group project work and there is always the need for room for display of visual aids.

/This publication endeavours to provide information on the functions, furnishing and design of spaces for the new biology teaching./ It has been framed in a regional context with the biology syllabuses of the Asian Region in mind. The study has been approached in four stages. First the educational situation, as it affects biology teaching in the Region, has been studied, secondly the common sizes of teaching groups and ranges of second level children in the countries of the Region have been considered, thirdly the changes in teaching method that are taking place in the Region have been identified and finally for comparison, standards of accommodation, where they exist, have been examined.

/The element which has the greatest bearing on laboratory design is the biology table. The table illustrated in the text has been developed in the Institute and is being studied in use in two countries in Asia. The drawings of laboratory layout shown at the end of this paper were originally produced as models before reduction to two dimensional form.

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SUMMARY

There is a change in emphasis in the new biology teaching methods in the Asian region. This change involves much more problem-centred learning for the children and substantially less demonstration and lecture work by the teacher. Future laboratories need to be designed to provide facilities for individual and group experiments, discussions, demonstrations, student project work and much greater use of visual aid material. This involves the bringing of the classroom into the laboratory and the virtual abandoning of the separate biology lecture room; it also requires easily moveable biology work benches at which the children, through group experiments, can find out for themselves, and in their own way, the principles relating to the particular biology topic they are studying. The paper indicates, from the point of view of design, the six main activities in the biology laboratory. From a consideration of these activities, essential furniture has been designed having dimensions related to body sizes of Asian secondary school children as well as to the activities in which they are likely to be engaged.

A study of the Ceylon and Philippines biology teaching schemes suggests that whilst piped water, gas and mains electricity might be useful, these services are by no means essential. In fact sufficient water for nearly all the experiments can be contained in three litre aspirators and waste water can be disposed of in portable plastic sinks. There is thus no need for fixed drainage systems inside the laboratory. Heat can be provided for the small number of experiments requiring it, by spirit lamps or primus stoves. Only one experiment requires electricity which can be provided by small dry cells. This consideration of services permits considerable economies in the design of biology laboratories for the Asian region. The laboratories shown in Chapter 3 are for teaching groups of 40 children and it is concluded that the per place requirements are about 2 square metres.

SOMMAIRE

La région asiatique a adopté le nouvel enseignement de la Biologie. Cette nouvelle méthode d'enseignement entraîne de nombreuses expériences faites par les élèves eux-mêmes. Les démonstrations et les discours du professeur sont devenu peu nombreux et par conséquent les futurs laboratoires doivent être dessinés de façon qu'ils répondent aux besoins de la nouvelle méthode. Il est nécessaire de prévoir de l'équipement adéquat pour les travaux d'expériences en groupe ou individuel, pour les démonstrations, les discussions, les démonstrations et les travaux de projects par les élèves; l'usage du matériel audio-visuel est également beaucoup plus répandu que dans le passé. Ceci entraîne le déplacement de la salle de classe au laboratoire, même la salle de conférence pour la Biologie est ainsi presque tout entièrement abandonnée. Le déplacement exige des tables portatives, ce qui permet aux élèves de faire des expériences en groupes et de découvrir par eux-mêmes les principes relatifs au sujet qu'ils sont en train d'étudier. Le tableau indique, du point de vue du dessin, les six activités les plus importantes dans un laboratoire de biologie. On a dessiné le mobilier essentiel sur la base de ces activités. L'échelle du mobilier est en relation avec la taille des élèves des écoles secondaires asiatiques et, en même temps, le mobilier est adapté aux activités et aux travaux des élèves.

Après avoir fait des études sur l'enseignement de la Biologie à Ceylan et aux Philippines on a trouvé que, quoi que l'eau courante, le gaz et l'électricité soient utiles, ils ne sont pas absolument nécessaires. L'eau peut être fournie au moyen d'un seau d'eau de trois litres, ce qui est suffisant pour presque toutes les expériences. Les eaux d'égout sont recueillies dans un bassin en plastique et jetées au dehors. De cette façon on peut se passer de tuyaux d'eau dans le laboratoire. Les expériences étant peu nombreuses, la chaleur peut être fournie par une lampe à alcool ou par un réchaud à pétrole. Il n'y a qu'une seule expérience qui exige de l'électricité, et l'usage d'une batterie est tout à fait suffisant. Cet arrangement nous permet de faire des économies considérables en ce qui concerne la planification de laboratoires dans la région asiatique. Chapitre no.3 montre des laboratoires destinés à l'enseignement en groupes de 40 élèves; on a calculé environ 2 mètres carré par place.

CHAPTER 1

BIOLOGY TEACHING AND LEARNING

1.1 Biology - the Subject

An architect who really wishes to understand the ways in which biology can be taught, the subject content, its treatment and the implications for laboratory design can best read T.L. Green's "Biology in Tropical Secondary Schools"1/ He can hardly fail to be fascinated by the teaching problems that are posed and the varied and ingenious ways in which their solution can be approached. For those unable to make such a study this paper attempts to set out some of the main aspects of the topic with special reference to the design of biology laboratories for Asian Secondary Schools.

Biology, the study of living things, is a subject of special significance in the world today. In fact the present might, without exaggeration, be described as the age of biology, in which people are becoming increasingly concerned and informed on topics such as the conservation of natural and human resources, radiation experiments, population control, quarantine and health regulations; questions such as the determination of sex, how twins are born, why children resemble their parents, how disease can be prevented, the ways in which a balance between plants and animals is maintained in nature and many similar problems. Moreover, everyone needs, at this time, to have some understanding of the elements of nutrition, pest control and sanitation. Finally, and perhaps not least important, the study of biology also gives the aesthetic satisfaction that springs from an understanding of the unity and diversity of plant and animal life.

During the present century, our understanding of biology has undergone considerable development due largely to the new techniques made available to the biologist from the fields of chemistry, physics and statistics. For example, artificial means of inducing mutations in plants and animals, the invention of the electron microscope and of methods of ultra-centrifugation and the development of knowledge about vitamins, hormones and antibiotics are but a few of the advances that are causing a change of interest in the subject from its purely morphological and anatomical to its more functional aspects. This change has, somewhat naturally, influenced the direction given to current biological studies in schools.

1/ GREEN, T.L., The teaching of biology in tropical secondary schools. Lond., Oxford University Press, 1965. (Unesco. Handbooks on the teaching of Science in tropical countries, v. 10)

A further and, in many ways, more significant shift in emphasis in the education field is, perhaps, the present realisation that, with an increasing amount of biological information resulting from the rapid advances made in recent years, teaching involving the memorisation of facts is likely to become less and less effective. Students are now, therefore, encouraged to develop a scientific approach to biological problems and this is achieved through an increase in the amount of student investigatory work in both the laboratory and the field. Science, it is now recognised, involves a way of thinking and a method of seeking answers and education reflects this through problem-centred rather than didactic teaching schemes.

Students educated in this way will, in later years, it is thought, be better equipped to acquire knowledge and solve problems for themselves and are also likely to become better scientists.

However, as with most changes, the protaganists of the new methods of biological education may sometimes be thought to have overstated their case in much the same way as in flying in a strong wind it may be necessary to oversteer to keep on course. The core of any pedagogical problem is balance. Thus, whilst there is certainly a valid case for much more investigatory work of a pupil-centred nature, the older methods of lecturing and demonstration still have their place and a good teacher will use them appropriately. What is happening in science education at the present time can thus better be described as a change of emphasis rather than a revolution.

As far as the content of the subject is concerned, there is also a shift from the somewhat narrow, albeit detailed, study of plants and animals, to concepts of much wider application. For example, greater attention is now paid to those aspects of biology which have a direct bearing on the daily lives of the students. This much is very clear from a study of the material produced by the Nuffield Foundation in the United Kingdom, the National Council of Educational Research and Training in India, the Biology Teaching Schemes of Ceylon and the Philippines and the B.S.C.S. material from the U.S.A.

These changes in approach to teaching coupled with the changed content in the material taught must have, it is shown below, a significant effect on the design on biology laboratories.

1.2 Important Activities in the Biology Laboratory

In order to identify the activities having a bearing on biology laboratory design it is necessary to analyse the schemes of work.

An approach to analysis of schemes from two Asian countries is given below. The same method of analysis is, ofcourse, applicable to any other scheme currently in use in the Asian Region.

The particular schemes studied were those for Ceylon[2] and the Philippines.[3] The analysis showed a similar and easily identifiable pattern in each case. The principle activities noted were:-

a) Work with the microscope and/or a magnifying lense such as examing the cut surface of fruit, observing the growth and characteristics of common micro-organisms and studying different kinds of plant and animal cells. This sort of work is most conveniently done sitting at a stable table with good illumination.

b) Dissection of plants and animals. Examination of the structure and functions of the main internal organs of the ubiquitous frog is common to most biology teaching schemes.

Dissection requires a stable bench at which to sit, a supply of water (dissection under water prevents drying and hardening of the specimen), a space for a microscope and stains and for a note book.

c) Miscellaneous experiments of duration not greater than one teaching period and not including the foregoing. The Schemes include for example, the comparison of monocotyledonous and dicotyledonous flowers, study of chemoreceptors in man and the determination of response to electric current of a group of paramecia.

In general these experiments require a stable table and many of them involve the use of water.

d) Miscellaneous experiments of duration greater than one period. These include, for example, the study of the ways in which plants react to environmental stimuli, investigation of starch digestion by a plant enzyme, etc.

The experiments, which may involve the use of water, require a stable bench on which they can stand, undisturbed by successive classes of children using the laboratory. Sometimes an outside area is required on which to stand the experimental material.

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[2] CEYLON. Department of Education. Syllabuses of instruction and schemes of work in Science subjects for G.C.E. classes. First and Second years (Colombo) 1963.

[3] PHILIPPINES. BSCS Adaptation Committee. Biology in Philippine High Schools: the relationships of living things. University of the Philippines, 1965 (Laboratory Manual).

e) Statistical studies involving work such as comparing populations from given data, construction of graphs of climates from data and establishing patterns of growth.

Much of this work can, after measurements have been made, be carried out in an ordinary classroom.

f) Field studies of, for example, biotic communities, the collection of material for study, as part of any of the above.

This activity usually requires only storage space for collecting nets and the like and has little effect on laboratory design, except in that several of the collections can usefully be made from a botanical garden, planted adjacent to the laboratory.

It is possible to quantify all of these activities and to arrive at a fairly precise estimate of the types of laboratory furniture required to facilitate them. The following table shows, for the Ceylon and Philippines schemes, an analysis of the experiments, arranged in accordance with the type of activities outlined above. It was prepared by making a study of the nature of every experiment in the schemes a time consuming exercise but one which is essential if the true nature of the activities in a laboratory is to be throughly understood.

TABLE I Activities in Biology Laboratories

The Ceylon and Philippines Teaching Schemes

Type of Experiment	Ceylon %	Philippnes %
a) Using microscope hand lense	9	32
b) Dissection	7	5
c) General Experiment-single period	51	43
d) General Experiment-several periods	23	23
e) Statistical Experiment	0	22
f) Field Study	14	3

Note: The % ages for each country do not total 100 for some experiments overlap, as for example c) and d).

It is important to observe, at this juncture, that the analaysis given above is made at a particular point in time. Teaching schemes, however, are constantly under revision by curriculum designers and it may be that, in the not too distant future, other ideas will change the pattern shown in the Table. More is said on this topic in the section dealing with the adaptability of furniture.

1.3 The methods of teaching and learning about biology

The title of this section highlights the two main problems facing the laboratory designer, namely, teaching and learning. There is an important distinction between these problems. If biology education was to become completely problem-centred with pupils designing, carrying out, discussing and writing up their own experiments, the teacher would virtually cease to exercise the teaching function and become a co-ordinator. A laboratory design for such a pupil-centric situation would logically provide complete facilities for the children and very little for the teacher.

The Institute's Study No.3 - The Design of Chemistry Laboratories for Asian Second Level Schools, describes the development of prototype chemistry laboratory furniture and its use in a school, initially in such a way that there was virtually no provision for the teacher, his facilities being added only as an actual need for them was demonstrated by the experience gained as the lesson proceeded. The initial imbalance in teaching, which was most evident in the early stage of the field trial, was brought about purely by the design of the laboratory for problem-centred work.

In fact what has to be sought in any teaching situation is a "middle way", the average teacher bringing to bear on the topic of the moment the teaching technique which is most likely to lead to its successful learning by the students. This may involve use of any of the following methods:

a) Lecture
b) Demonstration
c) Discussion
d) Individual or group experiment

The key to good laboratory design is thus in the arrangement of furniture to permit application of any one of these methods in such a way that application of the others at any other time is not inhibited.

An example of the restraint put on the use of a variety of teaching techniques is, of course, provided by the traditional laboratory, the arrangement of which creates a teacher-centric situation suitable for lectures and sometimes suitable for demonstrations but totally unsuitable for discussion of problem-centred work in small groups.

This traditional situation needs changing but the change should not be such as to facilitate the new problem-centred methods at the expense of the older lecture, discussion and demonstration methods of teaching. In short, the design must allow a balanced approach to both teaching by the teacher and learning by the pupil.

To achieve this balance through both furniture design and laboratory layout, the designer will require more precise ideas of the nature of some typical experiments in lower secondary school biology. These are given in the following section.

1.4 <u>Typical Biology Experiments</u>

a) <u>Using a microscope and/or magnifying lense:</u> A typical study using a hand lense is that of identifying the parts of a cut, soaked corn grain. The equipment required is:-

sharp knife or scalpel
hand lense
iodine solution
medicine dropper
petri dish or similar container
note book

The grain is cut in half and the parts identified with the aid of the hand lense. A large wall chart hung conveniently in the laboratory provides a guide.

A drop of iodine solution (which colours starchy parts of the grain blue-black) is put on the cut surface. The student is required to draw an enlarged view of the cut grain and to tabulate the parts indicating the presence or absence of starch. The experiment is repeated with a bean and the tabulations compared.

An example of microscope work is that involving the study:
<u>Spirogyra</u> as an example of the algae.
The equipment needed includes:-

compound microscope
slides and cover glasses
iodine solution
medicine dropper
culture of <u>Spirogyra</u>
note book

A few filaments of Spirogyra in a drop of clean water are placed on a slide and a cover slip added. The cell structure is studied using the microscope. Iodine is added at the edge of the cover slip and the location of starch determined. A drawing of the Spirogyra cell showing its internal structure, is made in the note book.

Both of these experiments are most conveniently carried out by students working singly, although where microscopes/lenses are in short supply they may be shared between two or more students. The comfortable bench area per place required for this sort of activity is about 1 metre long x 50cm. wide (Figure 1).

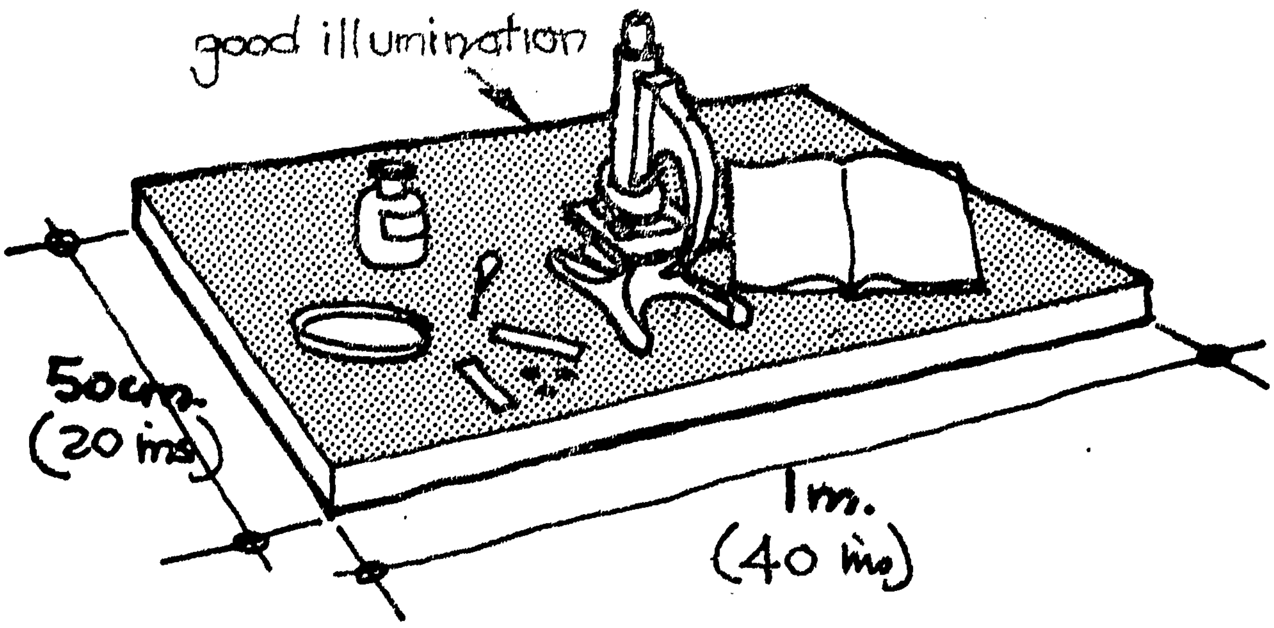


Figure 1 - Bench area required for microscope work.

b) <u>Dissection of plants and animals</u>. A common experiment involving dissection is the study of the functions of the major internal organs of a frog. The equipment required for this is:

Live frog (brain and spinal chord destroyed)
2 dissecting needles
dissecting pan
4 dissecting pins
medicine dropper
Watch
Hand lense or microscope
microscope slide
caffeine
beaker
pipette
sodium chloride crystals
distilled water
petri dish
scissors
forceps
sugar solution

heat (bunsen burner or spirit lamp)
Ring stand with ring
wire gauze
note book

The frog is turned, ventral side up in the dissecting pan and systematically cut open to expose the chest cavity, enough to study the internal structures. The heart beat is timed and the action and parts of the hearts observed. The heart is bathed successviely in cold water, warm water and caffeine solution and the heart beat rate recorded each time. The lungs are inflated using a pipette inserted into the glottis via the mouth and the lung wall texture observed. Sodium chloride is sprinkled on the intestines and peristaltic movements observed. The small intestine is detached, placed in a petri dish of distilled water and the reaction observed. The small intestines are then cut open and studied using a hand lense or microscope. Constant reference needs to be made to wall charts during the experiment the results of which are systematically recorded in the note book, stage by stage.

This is an experiment in which two students can usefully participate, sitting on opposite sides of a 1m. x 50cm. bench top with the frog in the dissecting tray between them. The table would be arranged so that light falls on it from the ends and neither student casts a shadow on the tray (Figure 2).

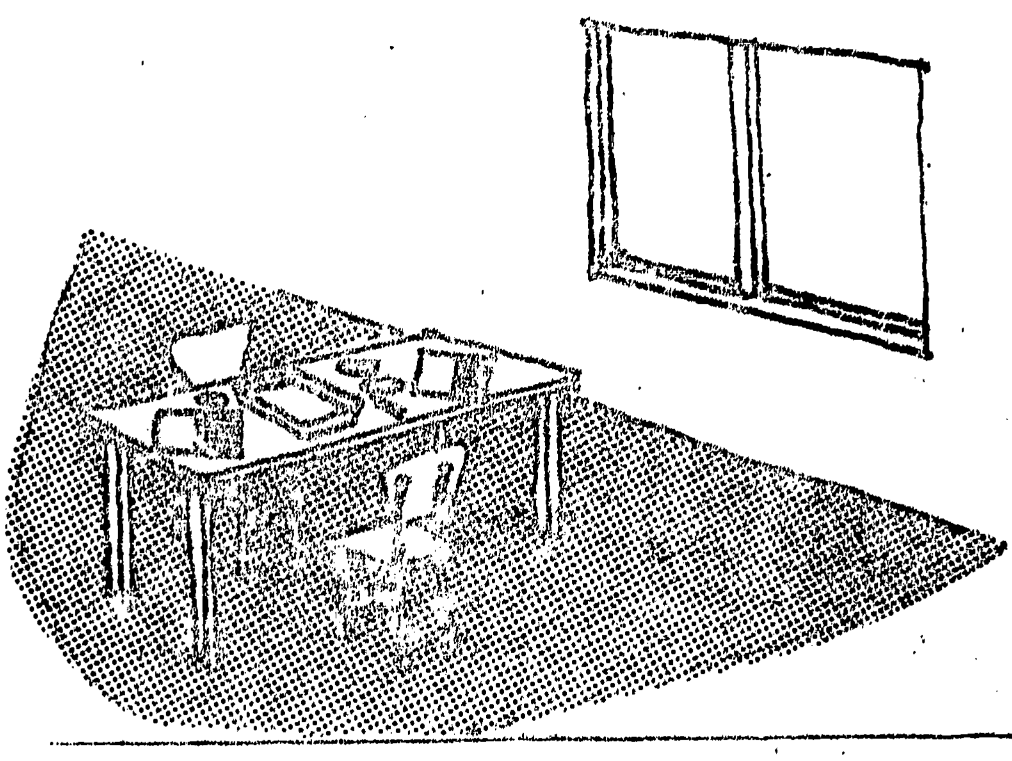


Figure 2 - Bench arranged with light falling from the ends. - Student's not working in own shadows.

In an experiment as complicated as the frog dissection it is likely that a teacher will precede the student activity by a discussion and possibly a demonstration, whilst, at the end, those students who have been engaged in the experiment may have a group discussion at which a number of questions are asked to develop further ideas on structure and function.

c) Miscellaneous Experiments of duration not greater than a single laboratory session (and not including the foregoing). A study of osmosis or the passage of water by diffusing through a membrane is a typical experiment involving a group of three students and capable of completion in one session in the laboratory. The equipment required comprises:

2 pieces of cellulose tubing each 15cm. long
2 pieces of 5mm. glass tubing each 1m. long
2 ring stands with screw clamps
2 split corks with holes
sugar solution
ruler, graduated in millimetres
clock or watch
2 wide mouth jars, 500ml. capacity
note book

One student holds the cellulose tubing tied at one end vertically, the second pours sugar solution into it, the third inserts the glass tubing into the cellulose tubing. The second student makes a liquid-proof junction between the two tubes and the cellulose tube is rinsed in running water. The glass tube is then clamped to the ring stand. A second set of tubes is prepared in the same manner using water instead of sugar solution. Empty jars are placed under the tubes, the heights of which are adjusted so that the cellulose membrane tubes cause the liquid to rise in the glass tubes. Mark the heights of liquid in the tubes and at 5 minutes intervals, measure the height of the liquid levels, recording the results in graphical form. The results are then discussed.

This sort of experiment can best be carried out by students standing on opposite sides of a 50cm. wide bench. (Figure 3)

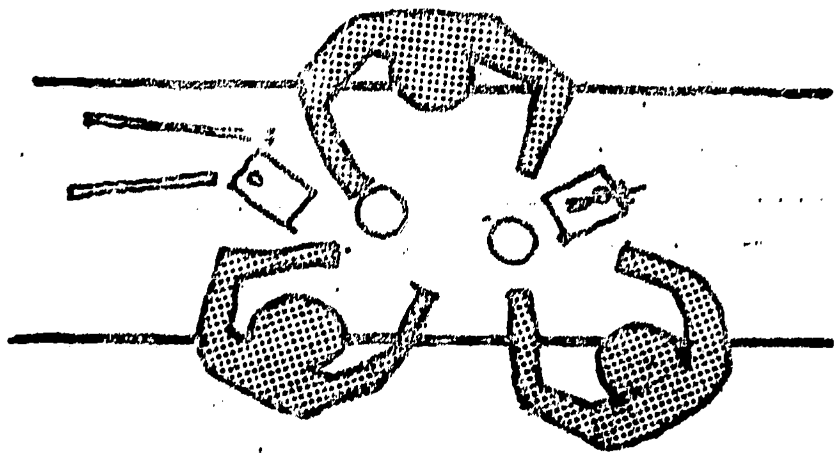


Figure 3 - Students working in groups of three across bench

After the experiment the various groups carrying it out (and the entire class will not necessarily be engaged in this work) will assemble by a convenient chalkboard for discussion with the teacher.

Miscellaneous experiments of duration greater than one period. A feature, as will be seen from Table I, of much biology work, is experiments that continue for several days and sometimes for weeks. For the laboratory designer these experiments are of great significance as they require space which cannot be used for any other purpose whilst they are in progress. A further feature of this type of experiment is that it is often "environmental" in character. That is to say, it may involve exposing plants or animals either to the extremes of light and dark or heat and cold.

One such experiment to investigate phototropism in plants examplifies this.
The equipment required includes:-
Radish seedlings in 3" pots
2 cardboard shoe boxes

Cut a square, 3 x 3cm. opening in the end of one shoe box. Place pots in each of the two boxes and place them side by side with the end of the box having a hole next to a window in the laboratory. Mark each pot and the base of the box so that after the pots are taken out for daily watering, they can be replaced in exactly the original place.

Both boxes should be sealed to exclude light from the covers.

After several days, notes are made on the differences in direction of growth of the seedlings in the two boxes.

Although the boxes can be prepared on any bench there must be:

i) Somewhere to place the pots whilst the radish seedlings are germinating and growing (possibly in the biology garden outside the laboratory)

ii) A place at the window at which the boxes can stand undisturbed yet remain accessible for daily watering.

e) Statistical Studies. Some of these studies involve work requiring laboratory facilities, as for example that of the effects of light and gravity on the behaviour of fruit flies. Other studies as of, for example, the inherited ability to roll the tongue or an effect of population size could be undertaken in a classroom or even outside under a shady tree. No special laboratory facilities seem necessary at least for Philippines statistical experiments.

f) Field Studies. A good example of this type of experiment is the field and laboratory study of a pond community, involving work in both the field and laboratory. The study is also of interest as it involves group work as well as the provision of a pond in the biology garden (a local pond would be equally useful if very close by).

The field work requires three groups. The first collects nine bottles of plankton, the second group collects six bottles and six plastic bags of submerged and emergent plants, whilst the third group collects anything up to 30 bottles of animals such as fish, larvae and the like. All bottles need to be stored in a cool place out of direct sunlight in the laboratory.

The three teams then work at 3 tables identifying the organisms - the work being divided up among team members. Charts are prepared and the information obtained carefully recorded.

The facilities required for this sort of activity would thus be, possibly a biology pond, cool storage away from direct sunlight and tables for groups of at most eight students. (Figure 4).

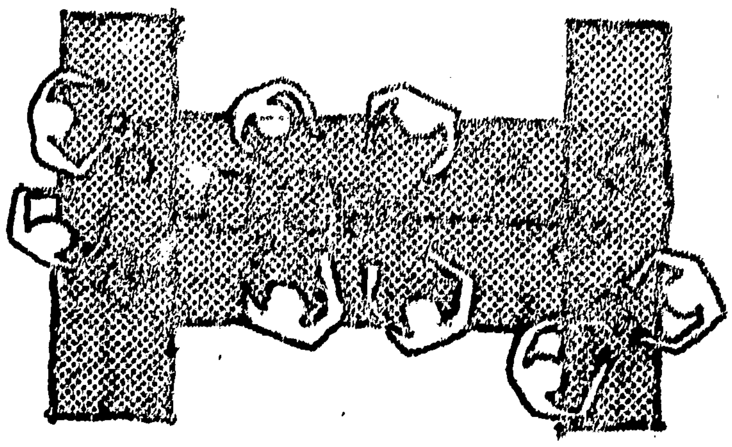


Figure 4 - **Biology** Benches joined together for large group work.

1.5 Other Situations and other Needs. The situations described at some length in section 1.4 are of importance as from them it is also possible to assess the needs in situations other than that for Ceylon and the Philippines from which the examples given are drawn. In India, emphasis tends to be placed on dissection and morphological studies and in this context, therefore, subsections 1.4 b) and 1.4 c) would be relevent.

In a laboratory for the Indian situation the need for the exceptionally good daylighting required for dissection and microscope work would be reflected in furniture layout and in the design of fenestration. Dissection of one specimen may also extend over several periods and it would in such a situation, therefore, also be important to provide adequate storage space for the dissecting pans. In India, students are encouraged to make herbarium collections and space is needed for these as well as for the collection of skeletal material required for other morphological studies. Again in India and in other countries of the region aquaria for fish and pond life and vivaria of various types ranging from "wormeries" for worms, cages for animals, are, commonly included in the requirements for biology teaching and form the basis for much pupil-centred project work, often of several weeks duration.

The other needs common to all biology laboratories include:-

a) Good storage facilities; (Annex I is the Unicef list of equipment for biology teaching and provides a good idea of the nature and quantity of material to be stored).
b) A small biology library, containing books for "quick reference" during periods of laboratory work.
c) Storage for students' books and bags in which those books not actually required for note-taking, can be stored.
d) A museum. In most schools, with the passage of time, a collection of material on general biological, zoological and botanical topics will slowly be built up. The museum is used as a teaching aid and many of the specimens will be in regular use by the students. It should thus be located in the laboratory and easy of access.

1.6 Services

Architects will need, finally, to know whether water, heat, electricity and drainage are required in a lower secondary level biology laboratory and if so, on what scale provision should be made. A study of the detailed teaching schemes for Ceylon and the Philippines shows the following:-

a) Water requirements

Ceylon	The Philippines
The range of water requirements per teaching group, per lesson is from ½ to 4 litres. Only one experiment requires 4 litres; one requires 3 litres; 12 require 2 liters; twentysix require 1 litre and three require ½ litre.	The range of water requirements per teaching group per lesson is from 1 to 6 litres. Only two experiments require 6 litres; three require 4 litres; seven require 2 litres and thirteen require 1 litre.

From this it may be concluded that a three litre aspirator, filled from a well or tap once per lesson for each teaching group will provide adequate water except on one or two occasions when an extra bucket of water will be needed. There is thus no absolute necessity for running water although it will be more convenient, where a supply of water and the money to pay for a piped installation is available.

b) Heat

Ceylon	The Philippines
Four experiments require heating of liquids in test tubes. Three require heating in beakers.	Two experiments require heating of liquids in test tubes.

A small spirit lamp will heat liquid in a medium sized test tube conveniently and quickly. A small primus or oil stove is more convenient for heating water in a 500ml. beaker.

There is no case at all in these schemes for the installation of a piped gas supply.

c) Electricity

The only requirement for electricity in a single Philippines experiment is for two, 1.5 volt dry torch cells. The Ceylon schemes require no electricity. It is assumed in this connection that daylight will provide the illumination required for the microscope and for dissection.

d) Drainage

By and large the waste liquid requiring disposal is the water mentioned in a) above. This can be thrown out by hand into a convenient drain. In one Philippines experiment, some 24 litres of pond water requires disposal and this can be bucketed out to the nearest drain. There is no case for permanent, fixed drainage arrangements in a biology laboratory.

CHAPTER 2

LABORATORY FURNITURE

2.1 The Standard Bench

The analysis of experimental work given in Chapter 1, suggests several criteria for the design of benches for biology laboratories:-

a) The bench top should be at much a height as to permit ease of working, both sitting and standing. This implies the provision of suitably sized chairs;
b) The bench should permit students to work on one or both sides, the width being such that the student can comfortably reach across to the other side of the bench;
c) The bench should be easily moveable so that it can be located in darker or better illuminated parts of the laboratory or joined together with other benches to form a large working surface of convenient shape;
d) Provision should be made at some of the benches for the convenient storage in either cupboards or drawers for commonly used items such as hand-lenses, microscopes, test tubes, petri dishes and the like;
e) Generally the bench must be stable and of materials that will resist wear. This study makes no recommendations on materials as most Asian countries will use what can be afforded and not necessarily ideal materials such as some of the tougher plastics.

For 14 year old children in the Asian Region a suitable bench height for standing work is 76cm. (30 ins.). A bench top at this level requires a seat height of 54cm. (21 ins.) with a foot rest at 15cm. (6 ins.) above the floor (Figure 5). The length of bench that can sensibly be used by one pupil studying biology is a metre (somewhat shorter bench lengths per place are practicable for chemistry and physics). The comfortable forward reach for a 14 year old is somewhat over 50cms. but, if benches are to be sensibly joined together for group work then there is much to be said for restricting the bench width to 50cm. (20 ins.)

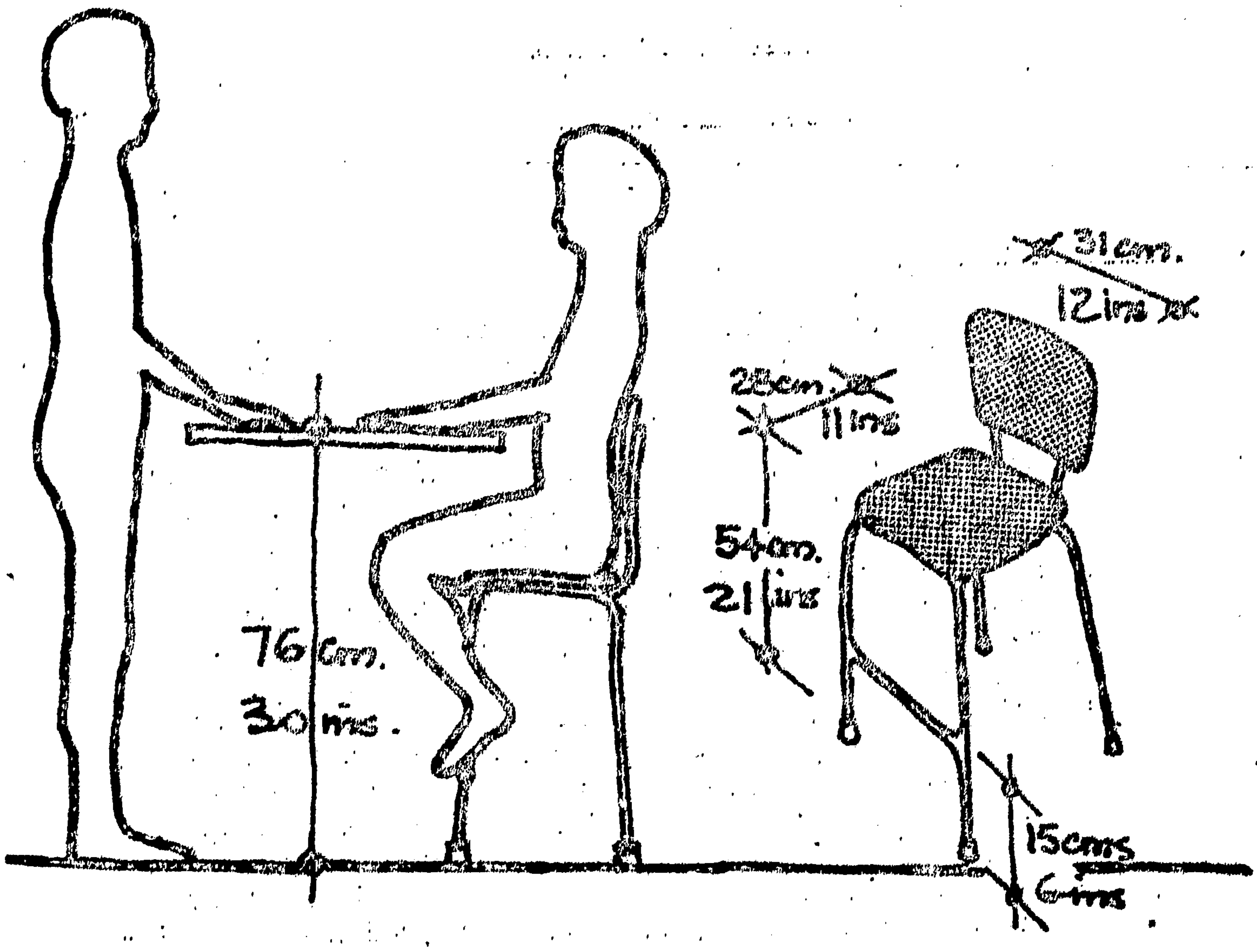


Figure 5 - Bench height and seat sizes

The resultant basic bench is illustrated in Plate I.

2.2 Bench Storage

Storage may, as has been explained in Chapter I, sometimes be required at the bench. Two units are suggested, one a cupboard for microscopes and similar large items, the other drawers for smaller pieces of equipment.

Depending on the nature of the work programme, these storage units may be required either at the bench or away from it. For exmaple, if the students have an extended programme involving sitting at the benches, then bench storage units will be inconvenient as they will prevent the knees from being placed beneath the bench. Again, if it is desired to move benches into fresh positions for group work then, with under-bench cupboards and drawers they may be too heavy.

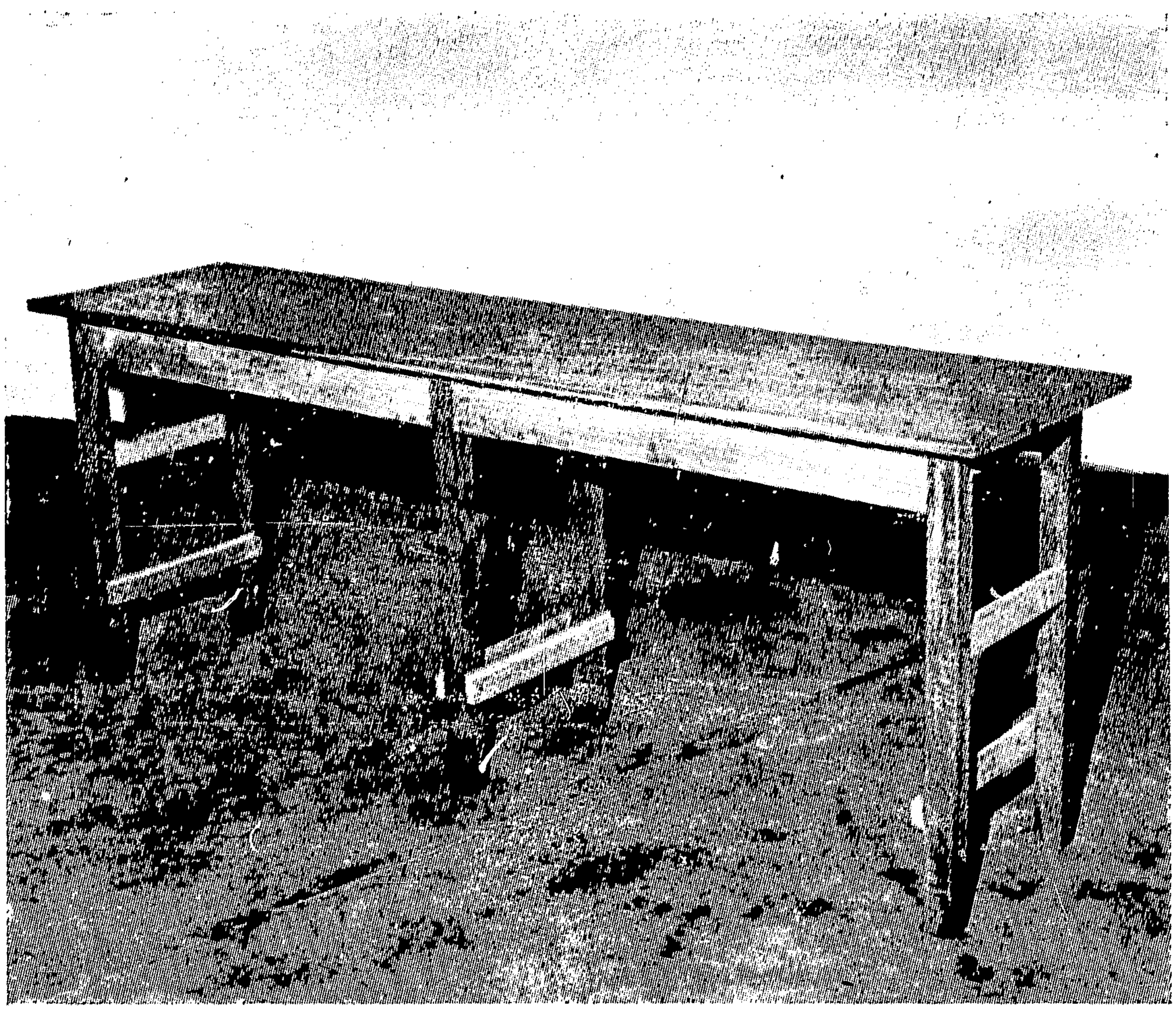


Plate 1.

The Basic Laboratory Bench

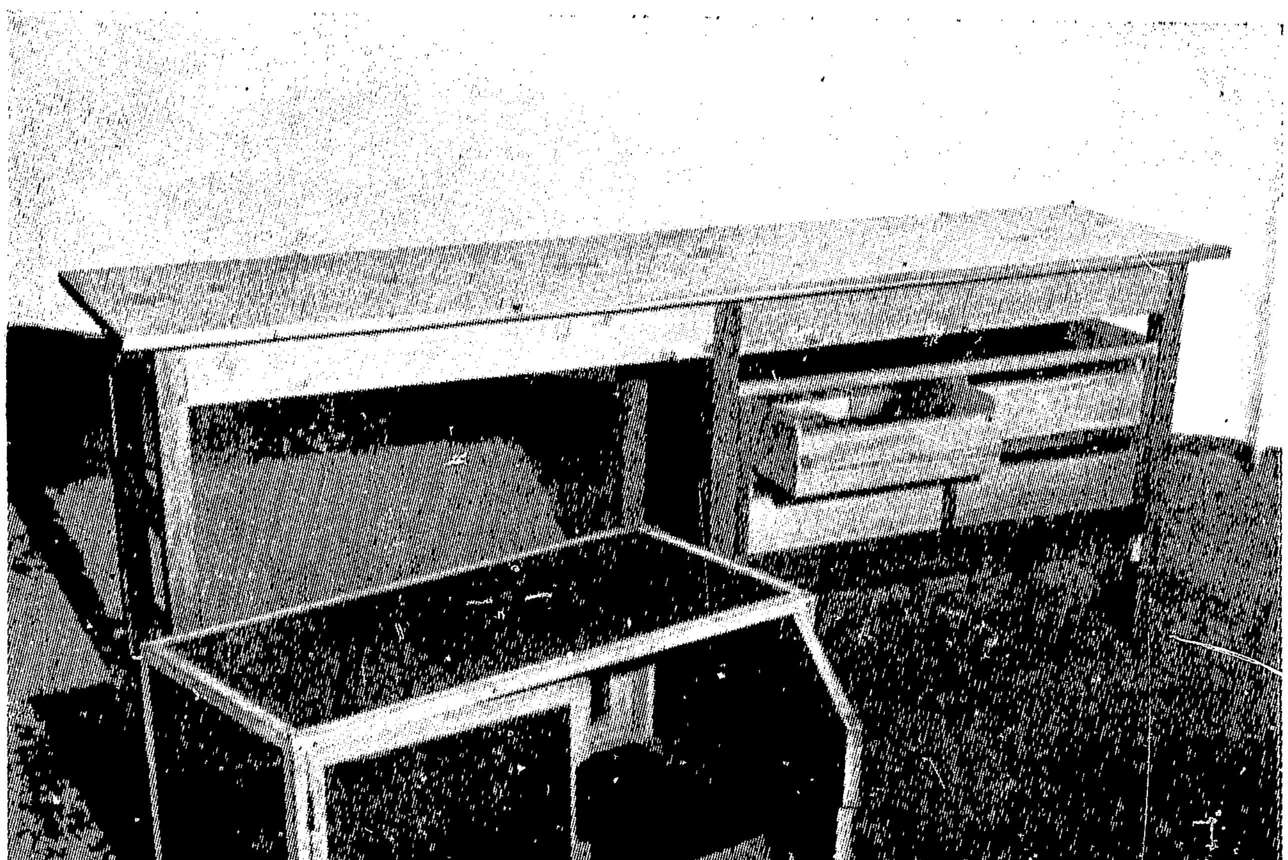


Plate 2.

Slide-in, Slide-out under Bench Storage Unit

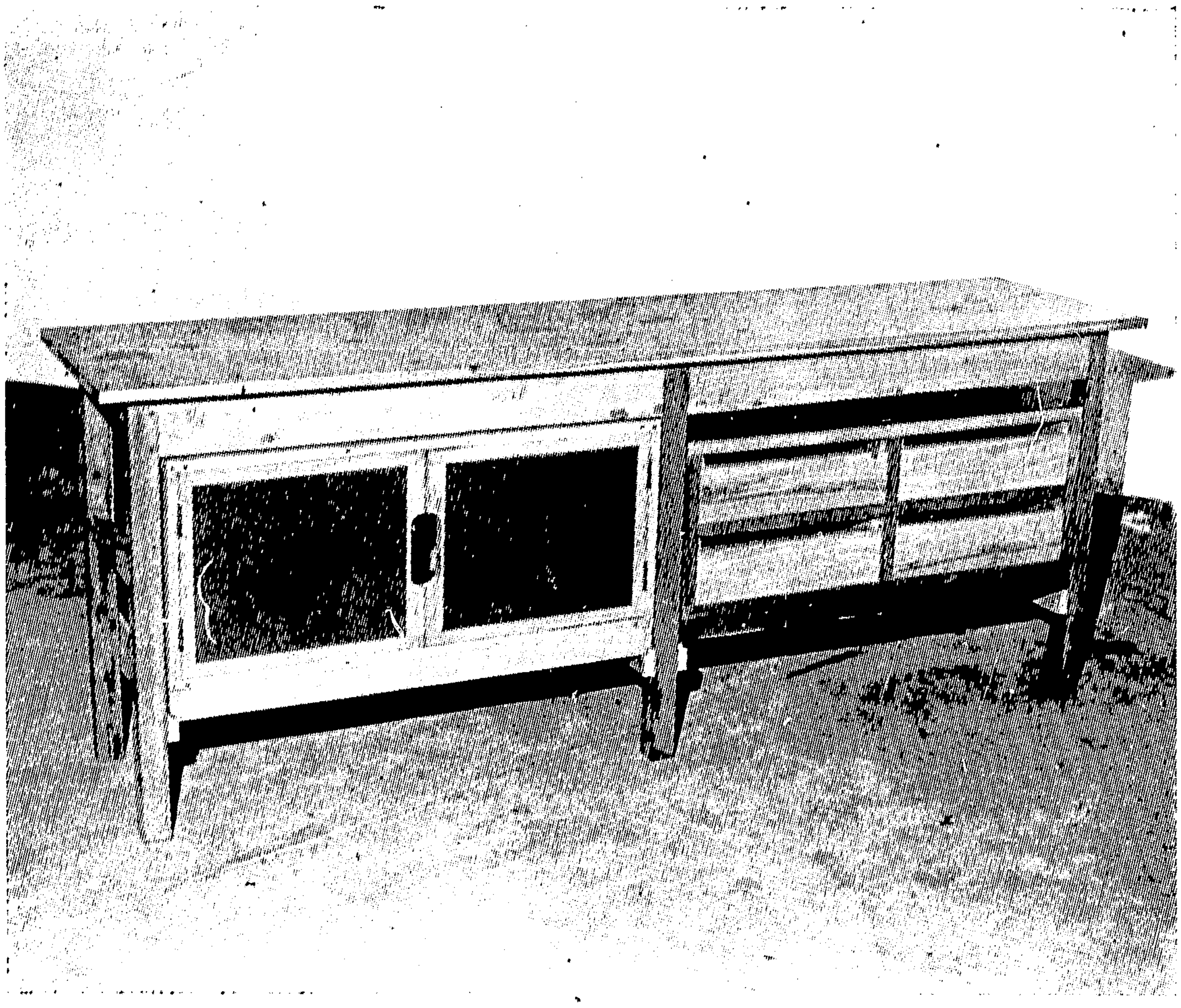


Plate 3.

Bench with Storage Unit

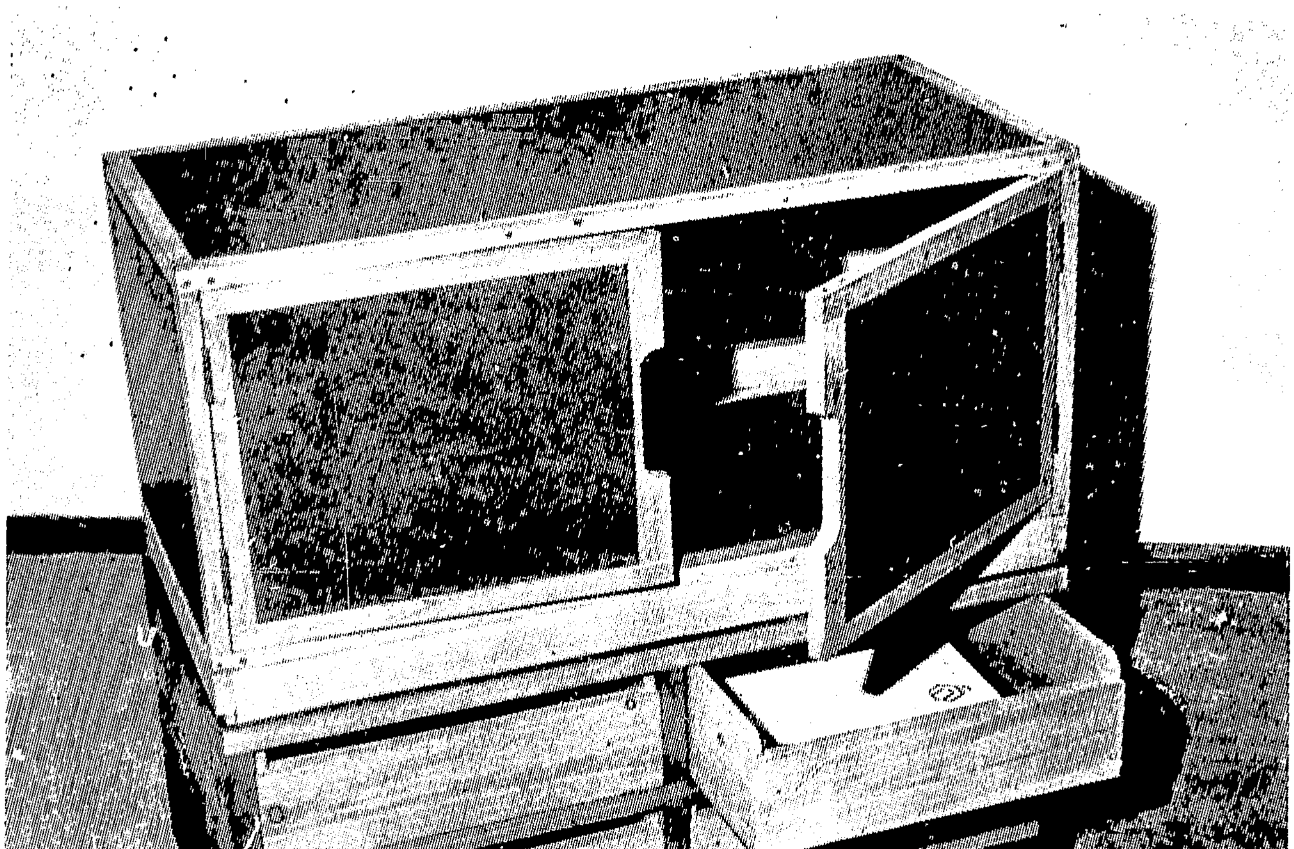


Plate 4.

Storage Units arranged to form Work Top

A solution to the problem which provides for a high degree of flexibility involves the provision of slide-in, slide-out storage units (Plate 2). These can be arranged in any desired combination with two cupboard units, two drawer units or one unit of each at each bench and, moreover, as the units slide in easily from each side, the bench can be used from both sides with storage units facing, if so desired, in opposite directions (Plate 3).

When the storage units, which are quite light and easy to handle, are not required in the benches, they can be slid out and placed one on top of the other, to form a separate work-top suitable, among other things, for experiments standing for longer than one lesson (Plate 4).

The advantages of small storage units are not, however, confined to their portability. Studies have shown that far more energy is involved in bending to the ground than in bending (in case of a 14 year old) to about 39cms. (15 ins.) above floor level. The storage units under the benches are thus fixed with their bottom shelves at about this height. Underneath, there is a clear space which not only provides easy access for floor clearing, but which also allows regular inspections of furniture for white ant attack - a danger common in ground floor laboratories with immoveable cupboards standing on the floor.

2.3 Allocation of under-bench cupboards and drawers

The number of items that might be kept in under-bench cupboards and drawers will determine the provision of these units. Considering the equipment in the UNICEF Guide List, EVE (Appendix 1) it will be seen that cupboards are essential for storing the following:-

93 beakers	24 bottles
18 graduated cylinders	8 conical flasks
41 glass preserving jars	6 microscopes
18 support stands	12 tripods

Six under-bench cupboards, each containing the items listed below, would distribute a readily accessible amount of material around the laboratory:-

Contents of 1 cupboard

(internal dimensions L 94cms; W 38cms; H 38cms; - L 37ins; W 15ins; H 15ins.)

1 microscope	3 supporting stands
2 tripods	6 glass preserving jars
1 conical flask	3 graduated cylinders
4 bottles	15 beakers

The drawer units present a more complex problem as the number of items that might be kept in them is considerable, whilst the size of most items is small. As much of the equipment is supplied in multiples of six units, e.g. 12 rubber bulbs; 18 clamp extensions; 24 wire gauze etc., it seems likely that six drawer units - which would certainly provide sufficient volume to contain all the items - could be located at strategic points around the laboratory under the benches.

For a class of 40 places, 12 benches would be needed, under six of which would be central storage locations comprising cupboard and drawer units. The remaining benches would have spaces beneath.

It should be emphasised at this stage that the foregoing is a theoretical approach to the problem, based on the equipment in the EVE list. Local situations, local equipment lists and perhaps most important of all, the decision of the teachers on what is to be kept in the laboratory and what is to be kept in a locked central store, will govern the actual requirements for underneath storage.

2.4 Water and Waste Water at the Benches

As was shown in Chapter I (1.6 - Services), whilst piped water is a convenience, it is certainly not a necessity in a biology laboratory. A simple means of providing water is from a filled 3 litre aspirator and of waste water collection, a plastic sink. When the lesson has finished, or at other appropriate intervals when there is a need to dispose of waste water, the sink can be lifted out and the water poured down a convenient external drain. An arrangement for the sink between two benches showing the sink and aspirator is given in Plates 5 and 6, whilst Figure 6 gives a detail of a sink support linking two benches. This support can easily be lifted out if it is desired to move the benches to other positions.

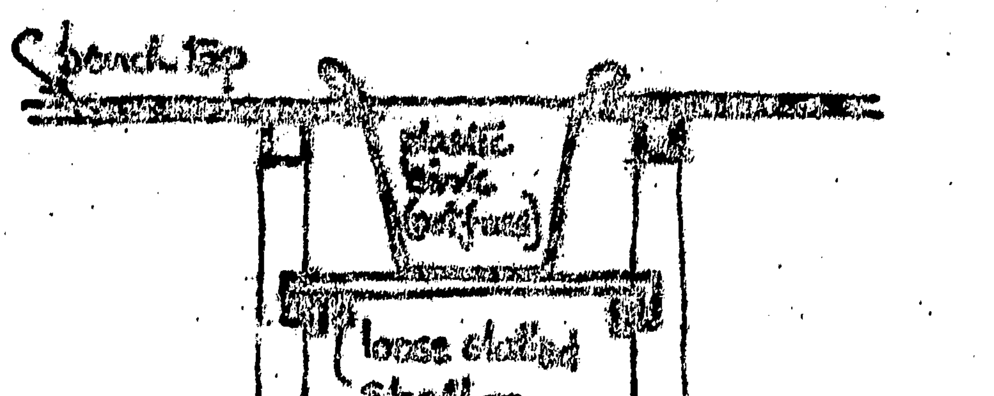


Figure 6 - Detail of sink support linking two benches

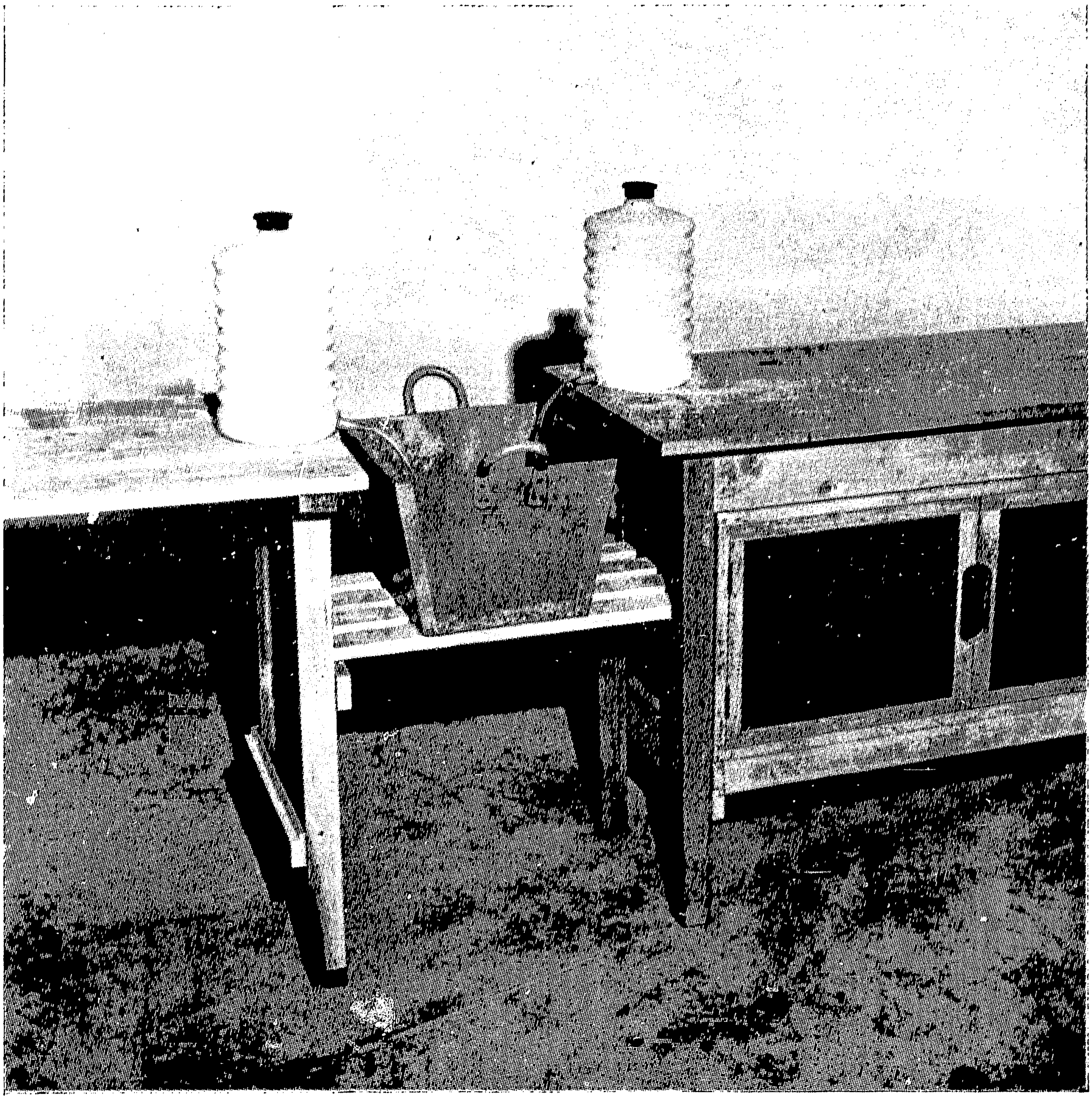


Plate 5.

Sink Between Two Benches

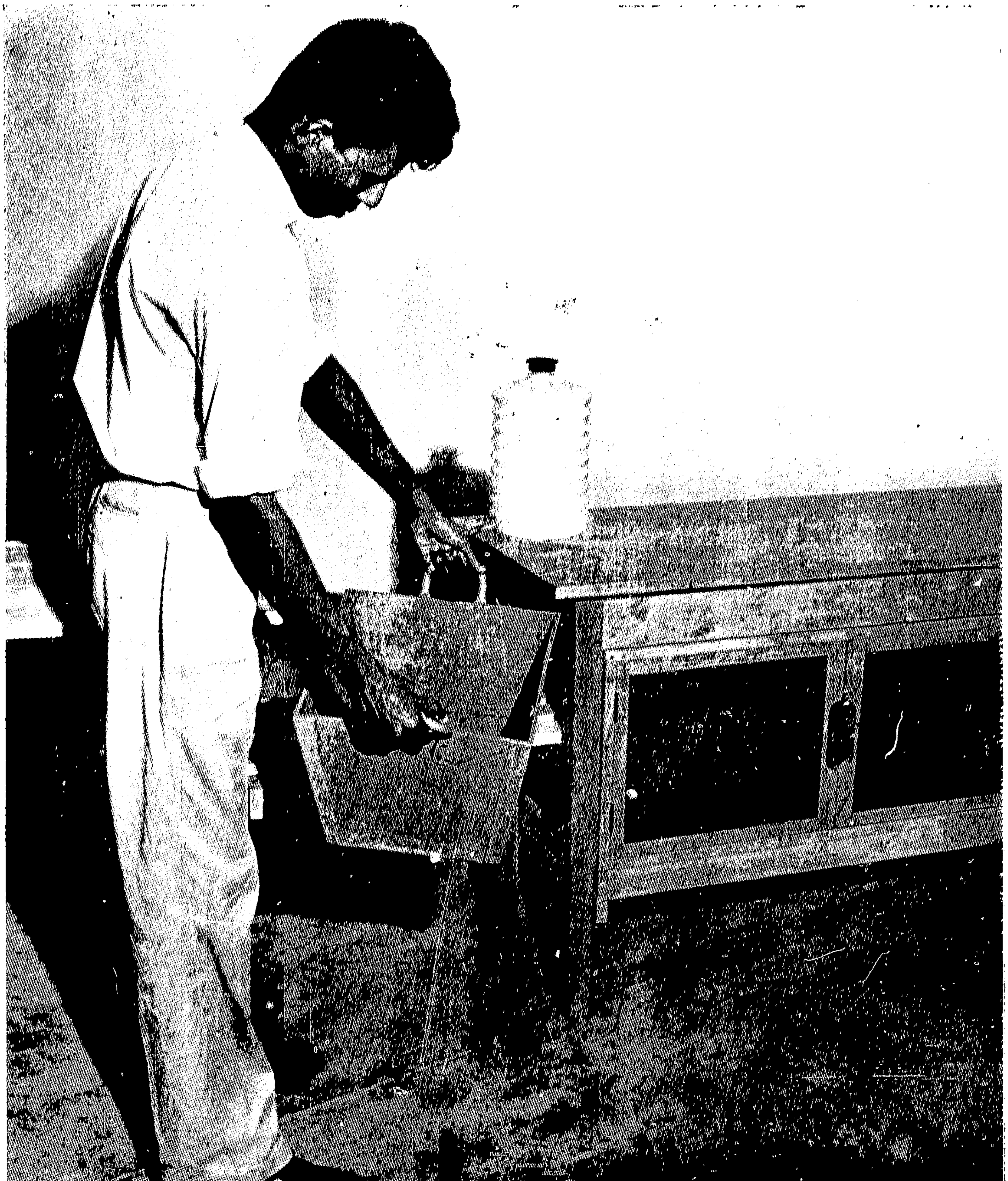


Plate 6.

Sink removed to throw away waste water

2.5 Central Storage

A number of less frequently used items such as sand and water baths, dessicators and bell jars can most usefully be stored in a small room adjacent to the laboratory. Some 6m. (18 ft.) of strong shelving, 30cms. (12 ins.) wide, fixed to the wall will be found adequate for this equipment and for the limited supplies of chemicals that are needed in biology teaching for lower second level children. Sand trays should be provided on the floor for the storage of acids and strong alkalies.

2.6 The Biology Library

Figure 7 illustrates suitable shelves for a small collection of books and for a few periodicals.

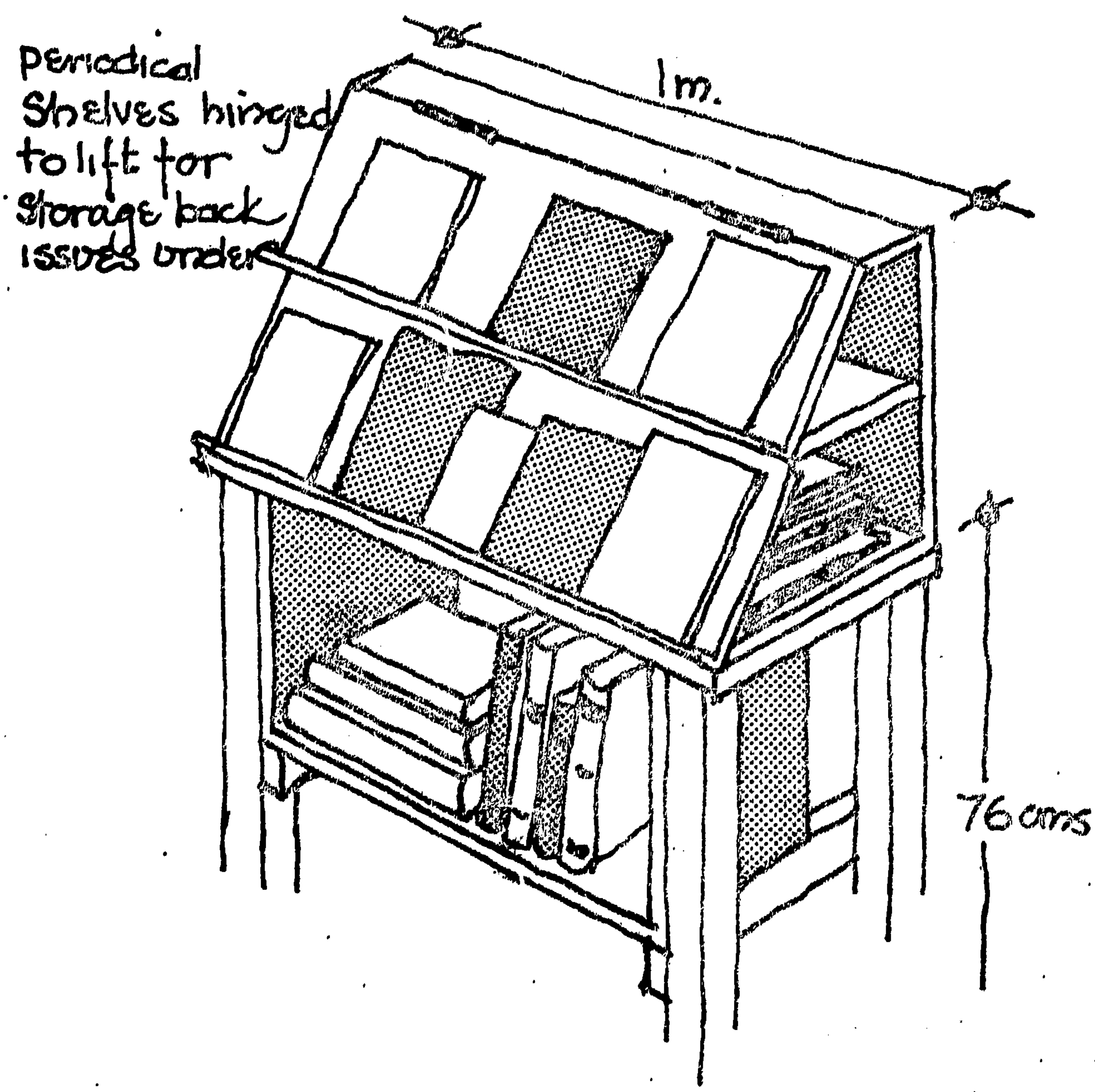


Figure 7 - Library unit

2.7 Students' Book and Bag Storage Rack

The work benches described and illustrated above are of the minimum size necessary to permit students to experiment and to make notes. There is no space for the piles of books and cases or bags that many students commonly carry with them from classroom to laboratory and back. Unnecessary cluttering of the bench impedes efficient execution of the experimental work. A unit is thus required in which the students can place those of their books not actually in use whilst the lesson proceeds. This unit is shown in Figure 8.

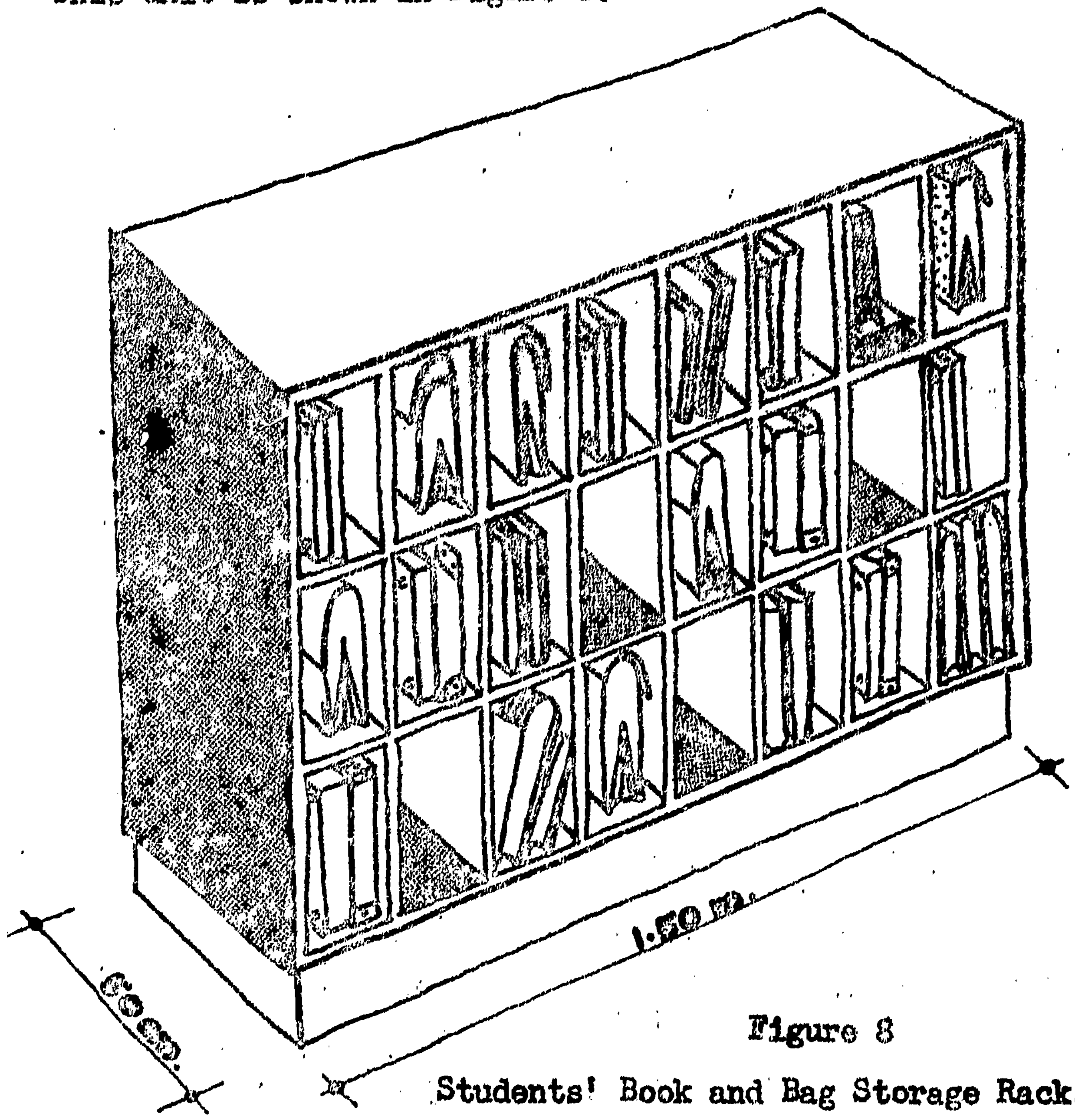


Figure 8

Students' Book and Bag Storage Rack

2.8 Museum Storage

Museum storage needs are virtually unpredictable. In one Asian school the students, having found a dead camel nearby, enthusiastically recovered the skeleton which was mounted and used for morphological studies. Much museum material, usually smaller in scale, is collected in this way and there is thus a need for a unit, the shelves of which provide a variety of lengths and are adjustable vertically. Some material needs to be kept in locked glazed cupboards, whilst others can most conveniently be stored in drawers. Figure 9 suggests a flexible unit that might meet these varied storage needs. Additional units can be provided as the museum grows in size.

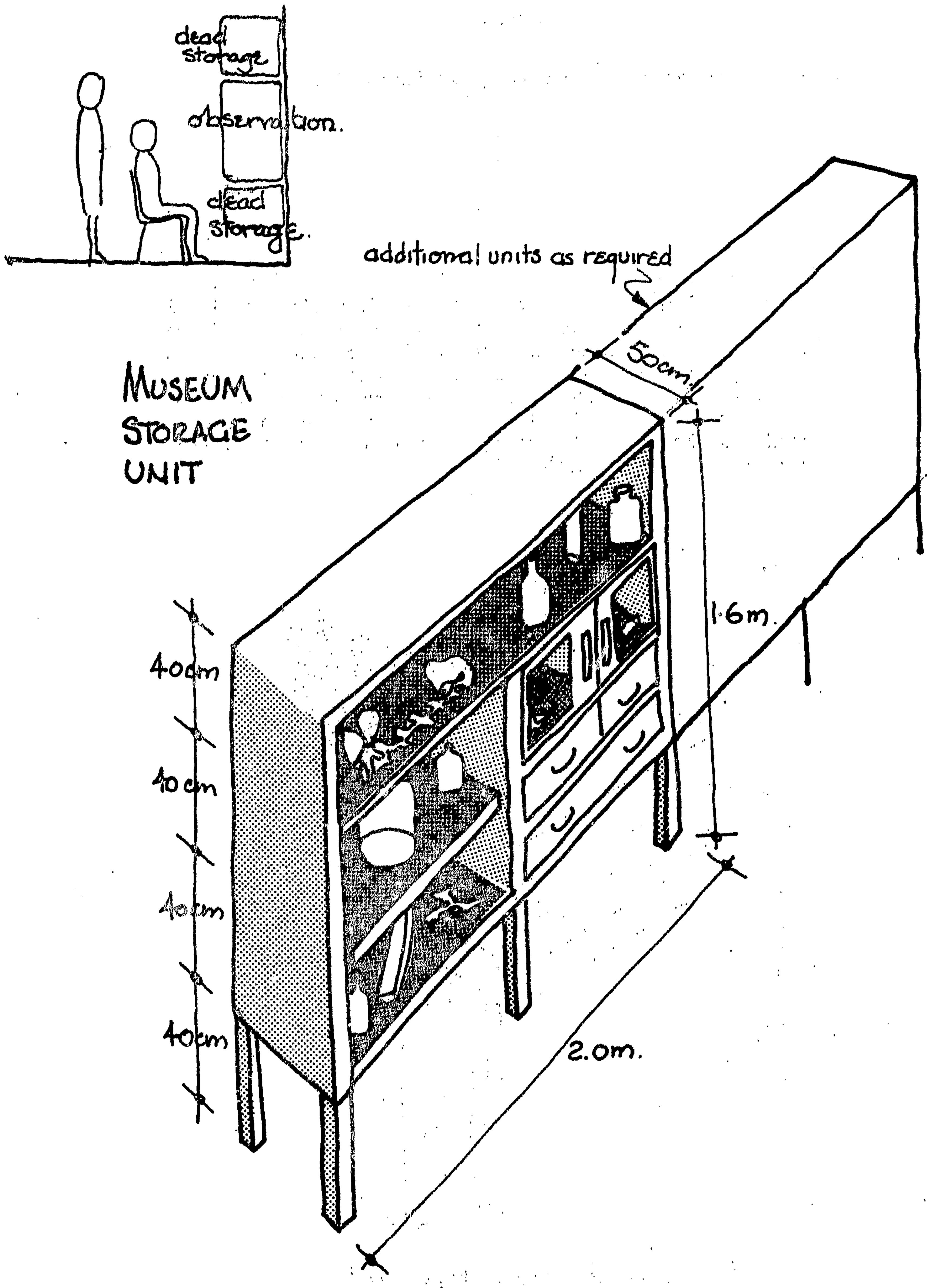


Figure 9 - Museum Storage Unit

2.9 Teacher's Demonstration Bench and Chart Store

The teacher's demonstration bench can be precisely the same as that of the students - 2m. (79 ins.) long with one cupboard and one drawer unit underneath. The only difference in the design of the bench would be its height which should be 86cms. (35 ins.). As with the student benches there is no real need for running water, waste, gas or mains electricity. The sink would stand on a separate small table beside the teacher's bench and should be emptied from time to time in precisely the same manner as the students' sink. Adjacent to the teacher's bench is a chart storage unit in which can be hung the large variety of illustrative material that is necessary for biology teaching. The chart rack should be dimensioned in relation to whatever size of charts are available locally. A convenient storage arrangement for charts is shown in Figure 10.

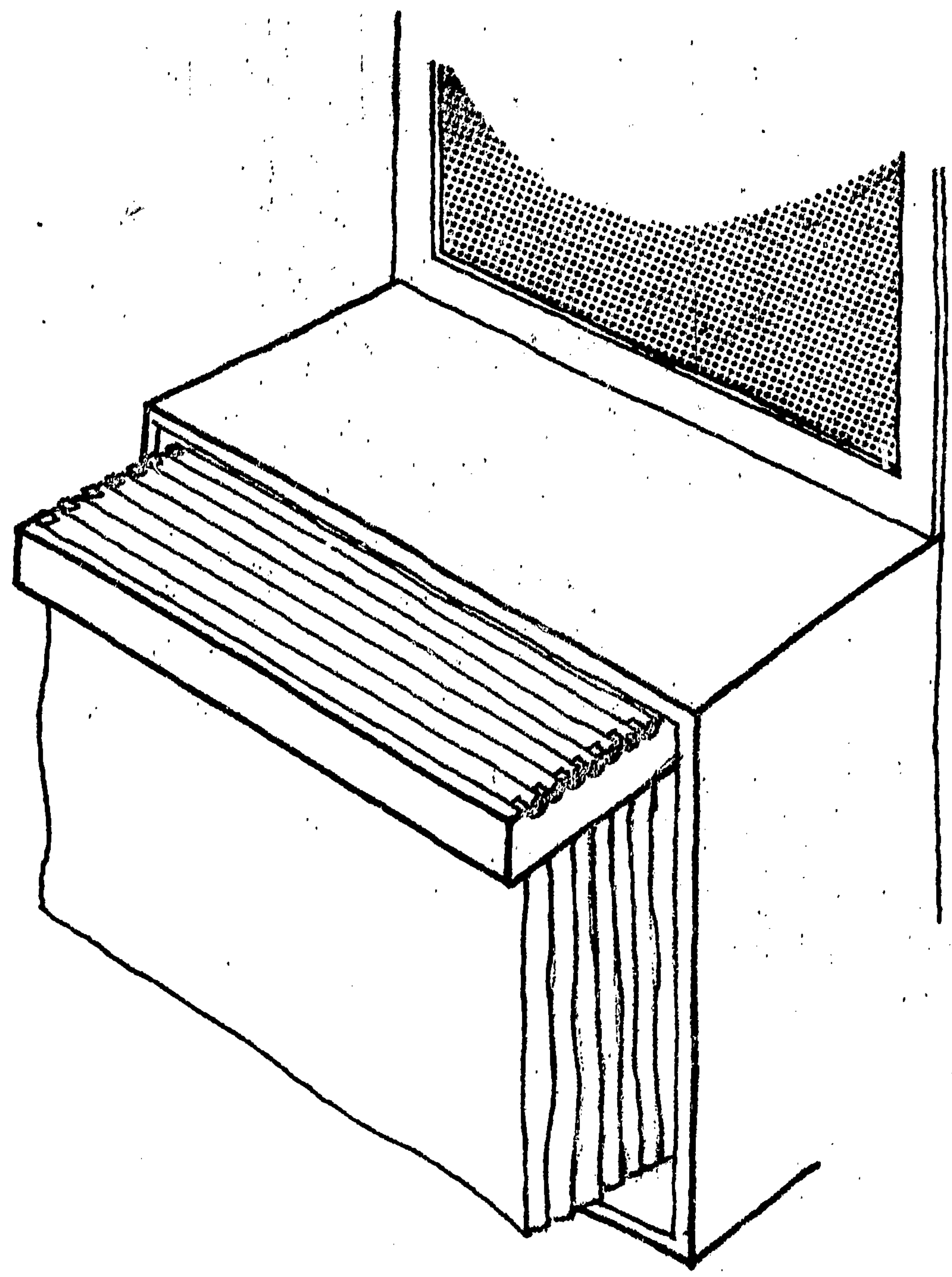


Figure 10 - Chart Storage Unit

2.10 Chalk and Pin-up Boards

The importance of an abundance of chalk and pin-up boards in the biology laboratory cannot be over-emphasized. It will be recalled that, in the first chapter, mention was made of the changing character of biology teaching with the teacher increasingly assuming the role of co-worker with student groups. The chalk boards thus need not only to be provided in the traditional position behind the teacher's demonstration table for use in a formal lecture, but also to be distributed around the laboratory so that wherever the teacher happens to be working, he has ready access to a chalk board to assist in explaining a particular point. Where doors to the laboratory are flush panelled, then it is a good idea to paint the doors as a chalk board so that they too can be used for this purpose.

CHAPTER 3

DESIGN OF LABORATORIES

3.1 General

A good environment for biology teaching and learning involves not only the provision of functional furniture, but also of adequate space in which to re-arrange it in a variety of ways depending on the various activities that are to be housed. Suitable illumination and thermal comfort must also be provided and there should be a separate space for either the teacher or a laboratory attendant to prepare the material required for each lesson. Adjacent to the laboratory facilities should be an area for growing the plant material and housing the animals that are needed for observation and experiments.

In this chapter a design for laboratory for 40 students is outlined making use of the furniture elements described in Chapter 2. A similar design approach would be followed for either larger or smaller classes. In general, the larger the class the lower the per place area required and thus, the lower the cost. It seems likely, however, that a laboratory for classes smaller than 40, whilst slightly more expensive, may make both teaching and learning somewhat easier.

3.2 Laboratory Furniture

The furniture which is required for a biology laboratory has been described in Chapter 2. It may be summarized as follows:-

a) Fixed Furniture

i) Teacher's desk and sink;
ii) Chart storage cupboard;
iii) Book and periodical shelf (library);
iv) Students' book and bag storage rack;
v) Museum storage unit;
vi) As many chalk boards arranged around the laboratory as possible.

b) Moveable Furniture

i) 12 biology benches;
ii) 6 under bench cupboard units;
iii) 6 under bench drawer units.

Note: When not actually in position in the benches, the under bench drawer and cupboard units may be stacked one on top of the other to form six work places suitable for standing experiments.

The above items of furniture, which may be arranged in any number of ways, now require to be fitted into a laboratory space.

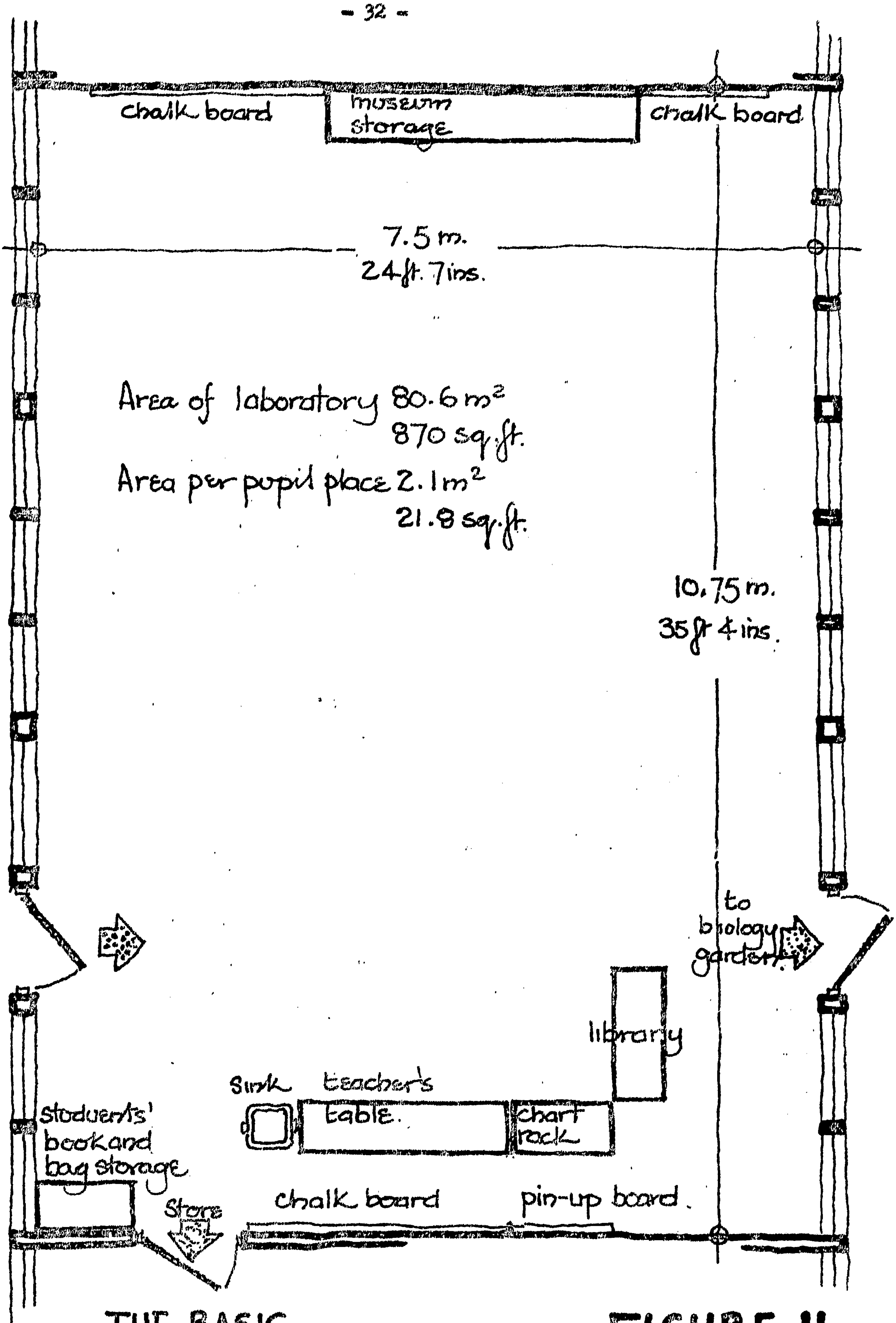
3.3 The Laboratory

To arrange the furniture, outlined in 3.2 above in a variety of ways requires a space about 7.5m. (20ft. 7ins.) wide and 10.75 metres (35ft. 4ins.) long (Figure 11). The space should have windows on the long walls and on the other cross-walls as much chalk and pin-up board as possible should be arranged. In the long walls access will be provided on the one side from the corridor and on the other side to the biology garden. On one cross-wall there should be a door leading to a store and preparation room, about which more is said below. The environment in the laboratory will be comfortable if the long walls have as much window as possible. In hot humid climates the windows should be openable. In hot dry climates there will be no need to open the windows for ventilation and, indeed, if they are shut, they will exclude hot air. Windows should be, in hot humid climates, fully sheltered from the sun. Shading should be such that in the winter, low angle sun can penetrate into the room in the early hours of the morning and later hours of the afternoon. This will assist in warming the room during the periods in which the temperature is very low.

In order to obtain maximum advantage from the illumination available from the wall windows, benches should be placed either along the windows or, when in the middle of the floor at right angles to the window. In this way no student will be working in his own light.

A series of arrangements of furniture for each laboratory activity are shown in the figures that follow. (Figure 12, 13 and 14).

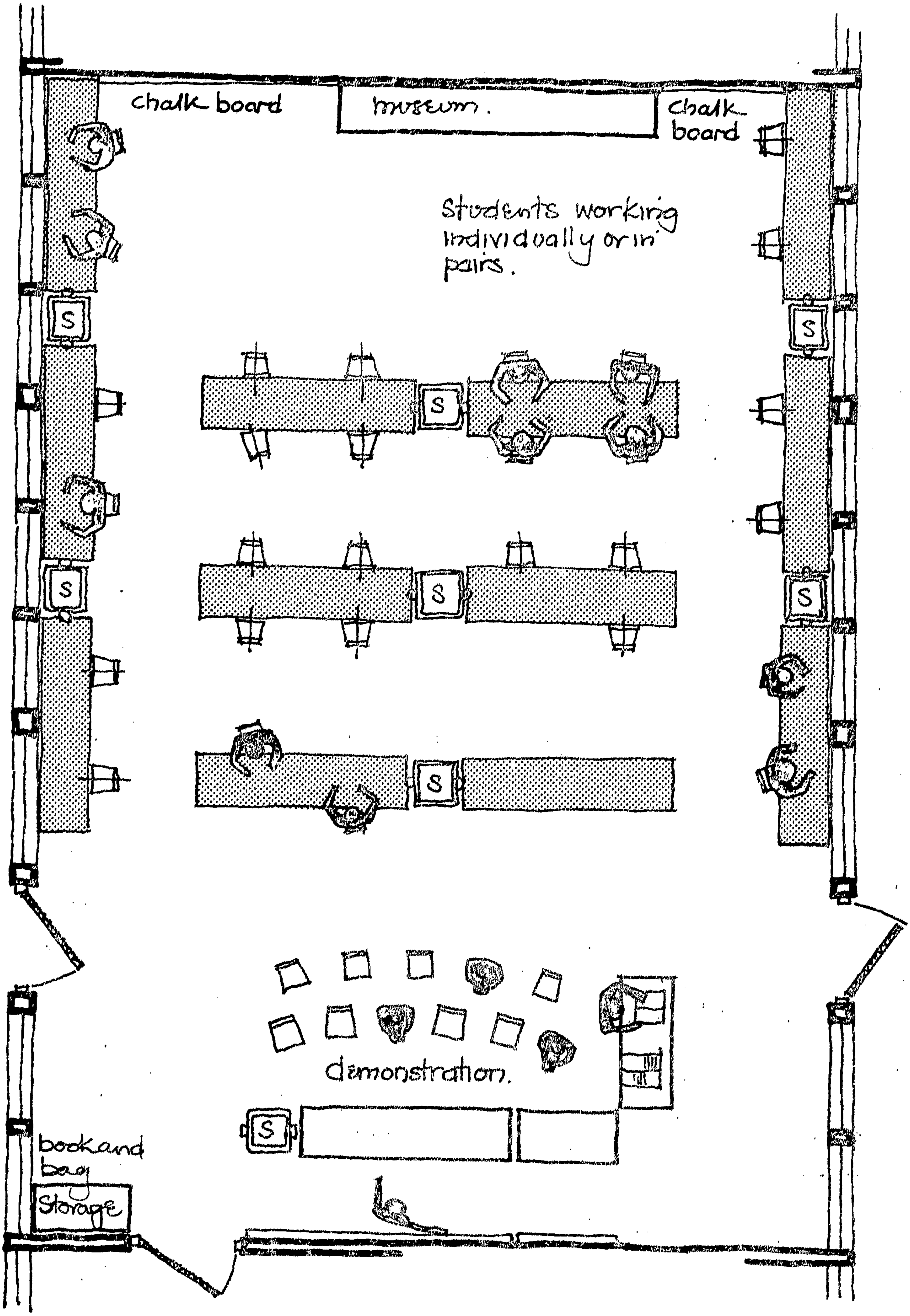
The point to be noted about these arrangements is that the furniture will not be moved for every separate class. Biology teaching is normally arranged in "blocks" or "units" of duration 4 to 8 weeks each. During each block or unit of teaching the same sort of activity continues. Thus, for example, there may be a 5 week block of microscope work during which the benches will be arranged for maximul illumination near the windows. This may be followed by a 5 week block of project work during which the students would be studying the ecology of a nearby pond. For this project work benches may be arranged for group work for a period of a further 5 or 6 weeks. The furniture has been designed to permit of this re-arrangement monthly or bi-monthly as the activities change.



THE BASIC LABORATORY - showing fixed furniture.

FIGURE 11.

Figure 11 - The Basic Laboratory



furniture arranged for MICROSCOPE & DISSECTION WORK (individuals & pairs) FIGURE 12.

Figure 12 - Laboratory with furniture arranged for microscope and dissection work

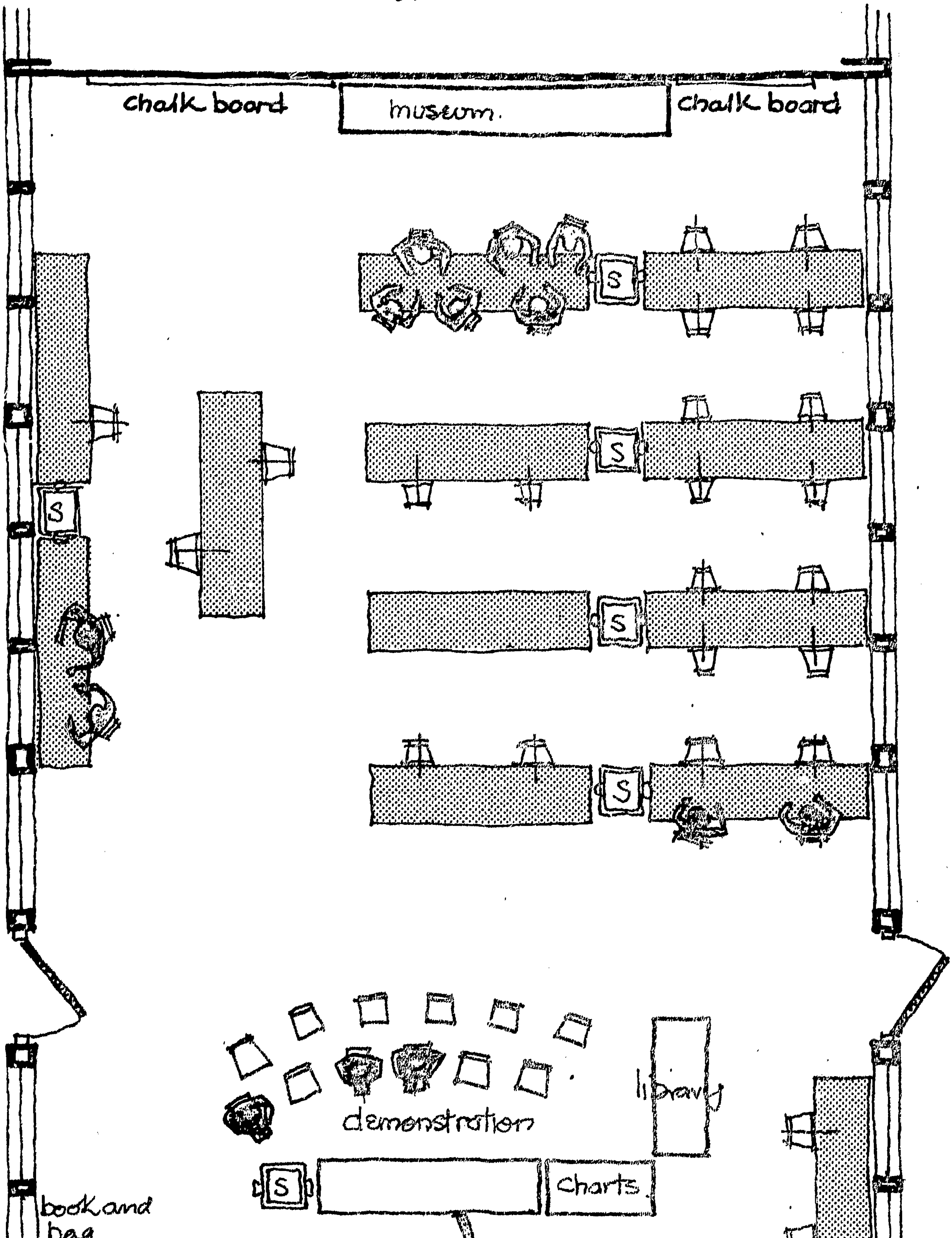
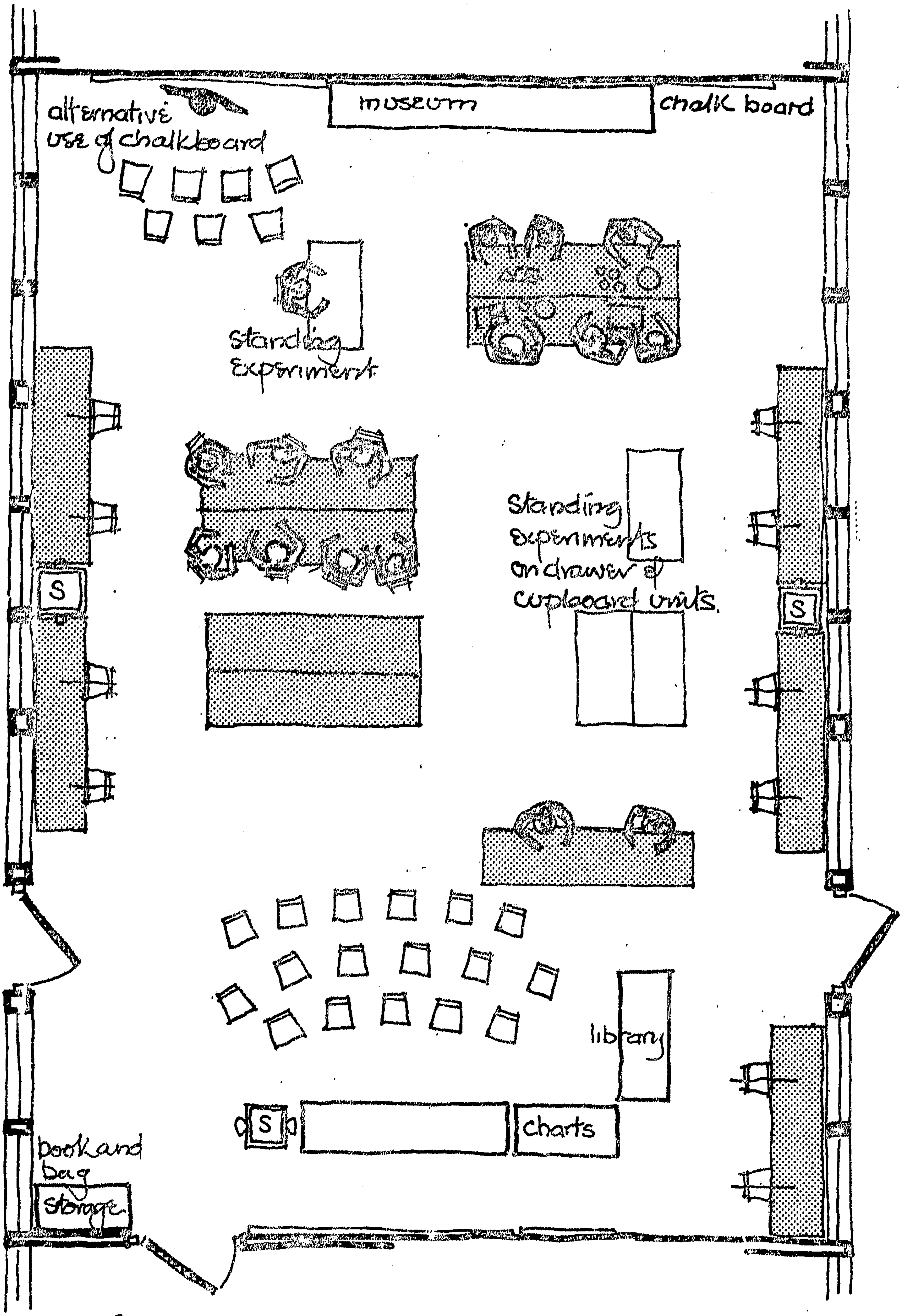


Figure 13 - Laboratory arranged for general experiments.



furniture arranged for
GROUP EXPERIMENTS

FIGURE 14.

Figure 14 - Laboratory with furniture arranged for larger group experiments.

3.4 Laboratories for Curricula involving substantial microscope/ dissection work

The preceding laboratory arrangements show the arrangement of furniture in a somewhat conventional rectangular laboratory. In situations where there is a considerable amount of microscopic and dissecting work, as for example, in India, then it would be desirable, in situations where artificial illumination is not available, to provide more window/wall space at which students can work with the microscopes under conditions of good illumination. In this case a slightly less conventional laboratory plan emerges (Figure 15) which has the advantage of including a small rectangular space which can be used as a biology garden.

3.5 Laboratories in buildings with Central Corridors

In the preceding section it has been assumed that artificial illumination is not available and, moreover, that daylight can enter the laboratory from both sides. This is the best condition for illumination by natural lighting. However, in the hot-dry areas of Asia, where ventilation is not required for thermal comfort, as for example, in most of West Pakistan, Northern India, Afghanistan and Iran, it is common to arrange teaching spaces on either side of a central corridor. This is called "double-banking" of rooms. In terms of illumination it has the disadvantage that daylight is available along one external wall instead of two. In such a situation it is virtually impossible - without designing a very long, thin laboratory - to arrange for every student to have a place for microscope work at the window. Of course, in countries where equipment is issued on the EVE scale, there will be only 6 microscopes per class and there will be more than enough window stations for these in a laboratory lit from one side only. 16 places for microscope work can be found in the laboratory with the biology garden intruding into it (Figure 15 above) and, where single-storey, double-banked buildings are planned then this design will be most suitable. Such will usually be the case in rural areas where electric lighting is not available. In urban areas with power in the laboratory any of the other plans can be used and each microscope provided with its own, built-in-lamp.

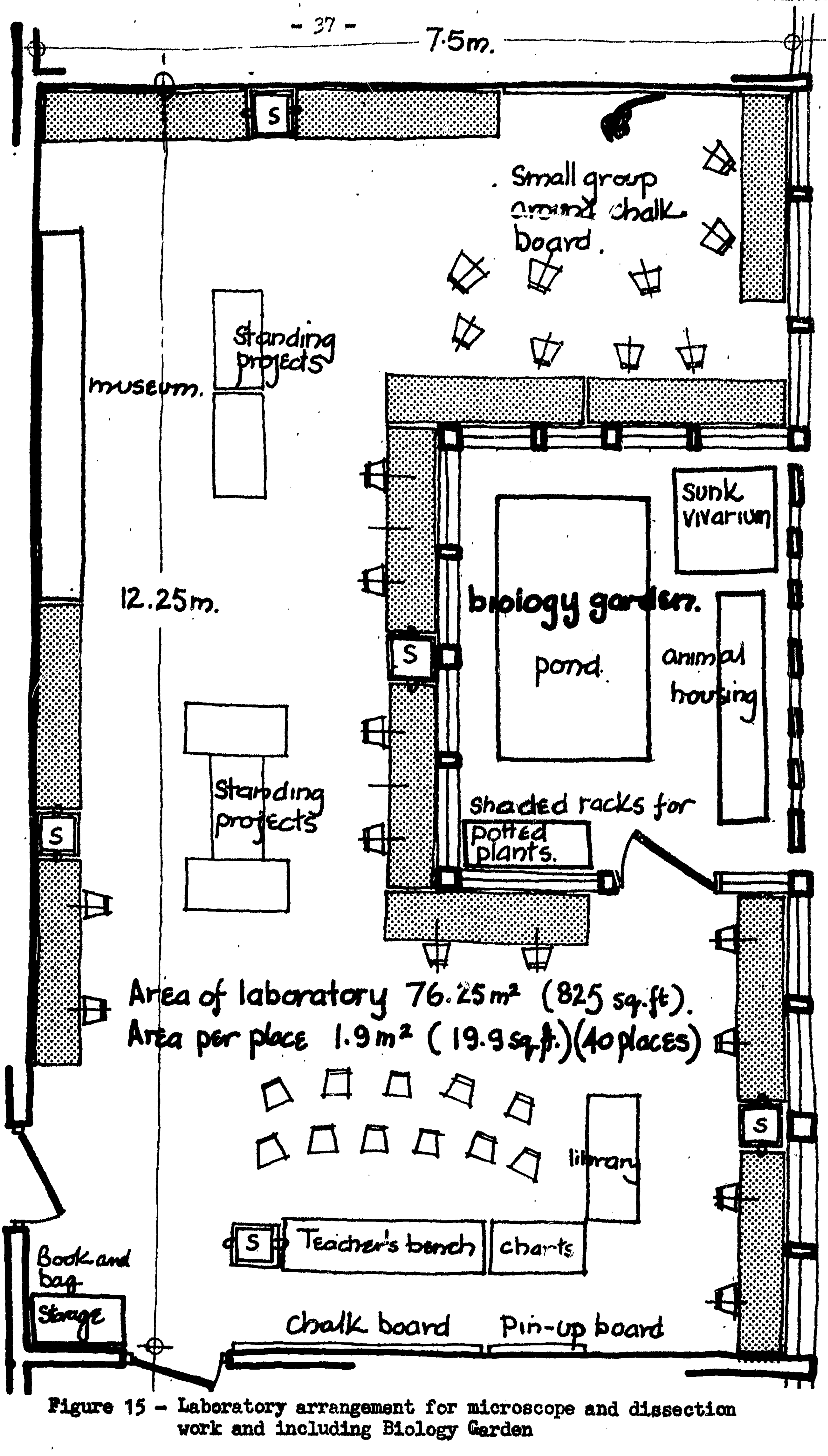


Figure 15 - Laboratory arrangement for microscope and dissection work and including Biology Garden

3.6 The Biology Garden

The essential elements of the small biology garden, whether arranged as shown in Figure 15 or independently in the school grounds, include a pond, a water tank, a raised concrete slab on which to stand pots of germinated plants, a small animal house, a vavarium and an area of ground in which materials suitable for use in the laboratory can be grown. Of these elements, the vivarium and the animal house may require special care in detailing. The vivarium would comprise a sunken pit with over hanging edges to prevent escape of the animals to be kept in it. The extent of the over hang of the pit will depend on the type of animals kept. The house for cages of animals such as rats, mice, rabbits and the like should be well ventilated and particular care should be taken to design it in such a way as to be inaccessible to snakes. This can be arranged by providing the cages with a very fine wire mesh.

ANNEX I

UNICEF GUIDE LIST EVE

Secondary School Biology Equipment

Description - Basic	Quantity
AQUARIUM: (38 litres) - 50 x 25 x 30cm.	1
BALANCE, TRIP, Laboratory	2
BATH, SAND: diameter 15cm.	6
BATH, WATER: diameter 12.5cm. x 7.5cm. deep	1
BEAKER, Laboratory, 150ml.	24
BEAKER, Laboratory, 250ml.	40
BEAKER, Laboratory, 400ml.	24
BEAKER, Laboratory, 600ml.	5
BORER SET, CORK	2
BOTTLE, WIDE MOUTH, 60ml.	12
BRUSH, TEST TUBE: Large	12
BRUSH, TEST TUBE: Small	12
BULB, RUBBER: Size 5	12
CLAMP, EXTENSION: Laboratory, Large	18
CLAMP, TEST TUBE: Stoddard	8
CORK, SHEET: Compressed; 30cm. x 15cm. x 6mm.	16
COVER GLASS: Microscope Slide Box	2
CRUCIBLE, Porcelain	2
CYLINDER, GRADUATED, Laboratory, 100ml.	24
CYLINDER, GRADUATED, Laboratory, 500ml.	1
CYLINDER, GRADUATED, Laboratory, 1000ml.	1
DESICCATOR, VACUUM, Scheibler, internal 25cm.	1
DISH. CULTURE, PETRI 100 x 15mm.	6
DISH. EVAPORATING, Porcelain 70ml.	36
DISH. EVAPORATING, Porcelain 120ml.	6
DISSECTING SET	1
DISSECTING SPIKE	8
FLASK, CONICAL: Erlenmeyer 250ml.	8
FLASK, VACUUM: 1 pint ½ litre	3
FUNNEL, LABORATORY: Glass, Ribbed 175mm.	1
FUNNEL, LABORATORY: Glass, plain 65mm.	6
FUNNEL, THISTLE HEAD, - stem - 25cm.	18
GAUZE WIRE, 15 x 15cm.	24
HOLDER, EXTENSION CLAMP	24
JAR, BELL: I.D. 13cm. diam. x 25cm. high	2
JAR, GLASS, ½ pint	12
JAR, GLASS, 1 pint	12
KNIFE BLADE, SURGICAL: Detachable	12
KNIFE HANDLE, SURGICAL	12
MAGNIFIER, DOUBLE FOLDING	36
MAGNIFIER, on Adjustable Stand	2
MICROSCOPE: Student's	6
NEEDLE DISSECTING	4
PAN DISSECTING, 185 x 285 x 32mm.	3
- WAX, Dissecting Pan Filler	3
PINS: Entomological	2
PLATE, GLASS, 30 x 30cm. 6	6

Description - Basic	Quantity
PLATE, GLASS, 75 x 75mm.	1
PLATE, GLASS, 100 x 100mm.	8
PUMP, FILTER, Laboratory	1
SHARPENER, CORK BORER	1
SLIDE, MICROSCOPE: Box of	2
STOPPERS, CORK, XXX Quality, Assortment A	1
STOPPERS, CORK, XXX Quality, Assortment	1
STROP, RAZOR	1
SUPPORT, Laboratory Apparatus, 125 x 200 x 25mm.	18
TANK, GLASS, 6 litres	3
TEST TUBE, 150 x 16mm.	2
THERMOMETER, Laboratory	18
TILE, PORCELAIN, white, 10 x 10cm.	12
TONGS, CRUCIBLE, 225mm.	12
TRIPOD, LABORATORY, IRON, 75mm.	12
TUBE, SPECIMEN, Glass, 50 x 12mm.	1
TUBE, SPECIMEN, Glass, 75 x 19mm.	1
TUBING, CAPILLARY, FLINT GLASS	1
TUBING, FLINT GLASS: Assorted	1
TUBING, FLINT GLASS, 20mm. O.D.	2
TUBING, RUBBER, 6.3 x 3.17mm.	10
WATCH GLASS 76mm.	3
WEIGHTS, STUDENT'S BALANCE	4

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Description - Optional	
AERATOR PUMP UNIT	1
- TUBING LATEX RUBBER	1
ANATOMY CHART	1
BOTTLE, ASPIRATOR, Polyethylene, 5000ml.	1
JAR, GLASS (Preserving Jar) 0.24 litre	2
JAR, GLASS 0.47 litre	2
JAR, GLASS 0.95 litre	1
KNIFE, Pruning, 8cm.	1
MICROSCOPE ILLUMINATOR	6
MICROCULTURE, SLIDE	1
PARCHMENT PAPER	1
SHEETING, PLASTIC, 91cm. wide	1
TIMER, INTERVAL	1
75 VASCULUM	1
WATCH GLASS	8

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FILMSTRIPS or SLIDES	1
CHARTS	6