TRAINING FOR HORTICULTURE

W. J. C. LAWRENCE

GEORGE ALLEN AND UNWIN

THIRD EDITION

W. J. C. Lawrence has completely revised and renamed *The Young Gardener* which was reprinted three times. His aim is, first, to give information hitherto not generally available, and secondly, to give the facts which are basic to horticultural theory and practice and to show how they are most usefully learnt. Special emphasis is laid on craftsmanship and the practice of the scientific outlook. The needs of those who have no expectation of special training and who must rely on their own efforts to make progress, have been specially kept in view. Students taking the shorter courses at Institutes and Colleges will also find the book useful, since it covers the first three or four years of a career in horticulture.

This excellent little book is not only a student's outline to horticulture as an art, but also a guide to those who wish to follow horticulture as their life's work. From a life's experience the author writes in an eminently practical and thoughtful manner. It should be in every library, and in the hands of every biology teacher.

'It fills a very definite hitherto vacant niche and it is far more comprehensive than its modest title-page would suggest . . . from a life's experience he writes in an eminently practical but eminently thoughtful manner . . . It should be in every school library and in the hands of every biology teacher.'

School Library Review

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TRAINING FOR HORTICULTURE

by W. J. C. Lawrence, O.B.E., V.M.H.

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and Plant Culture
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BEING
A REVISED EDITION
OF
THE YOUNG GARDENER

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The Provision of Horticultural Training

The existing provisions for the training of young gardeners can hardly be described as satisfactory. The reasons for this are so important and so little understood as to demand the attention of all those who have the interests of horticulture at heart.

In the first place, horticulture as an industry or profession lacks unity. The various branches—commercial gardening, public parks, county advisory establishments, training colleges, etc.—work in water-tight compartments and have few contacts with one another. Thus the public parks tend more and more to be concerned with their own affairs: commercial growers as a whole apparently have little interest in the training of gardeners, despite the fact that the prosperity of commercial horticulture is bound up with the proficiency of its workers: the county staffs normally are little in touch with the public parks, and, from an educational point of view, they are mainly concerned with the dissemination of new scientific knowledge and not with the training of gardeners. In view of this disunity it is not surprising to find that there is no general policy in regard to training and that such facilities as do exist are scrappy and inadequate.

The existence in horticulture of highly specialized branches is, of course, natural and desirable. It should be recognized, however, that specialist establishments cannot provide the broad initial experience which is the best foundation for a horticultural career.

The composite nature of horticulture is one of the factors which bear on this question of training. There are two others: the decline of the large private gardens and the rise of scientific horticulture. With the passing of the large private gardens, what might be called *the apprenticeship system also lapsed. Probably the standard of pre-scientific cultivation reached its peak in the large private gardens. A great variety of indoor and outdoor plants was grown and the young gardener received an all-round training under some of the ablest practical men the country has known. All this has now gone; as yet, nothing so comprehensive has taken its place.*

Secondly, the lack of training facilities is a consequence of the great progress made in horticultural science in the last two decades. Scientific methods are, very properly, displacing rule of thumb, and at the same time a host of new methods, new materials and new machines is replacing the earlier simplicity. One may ask whether these complexities will result in better plants and better gardeners. The answer is that whether they will do so will depend on training.

This is where the rub comes. Most young gardeners have little hope of acquiring the new knowledge, unless their parents can afford the fees for courses at Farm Institutes, Agricultural Colleges or the Universities. A few dozen young men may hope one day to become student gardeners in Botanic gardens and similar training establishments; or to win scholarships to Agricultural Colleges and Farm Institutes. The rest must rely on their own reading or on correspondence courses. Evening classes rarely provide instruction that meets the requirements of the young gardener, and then only in the large towns and cities.

There is now reason to hope that this phase in the history of horticulture will be a short one and that the end of the war will see a determined effort made to organize horticultural education on a scale and with a method that will ensure a steady flow of well-trained gardeners into the public as well as commercial gardens. I mention these two branches of horticulture since it may be confidently predicted that in both there will be great developments.

On the one hand public gardens should become the centre of recreational and, what we may broadly call, educational activities.

Lawns, trees, flowers and water would provide surroundings where people could seek refreshment of mind; play-grounds, sports fields and the swimming pool would provide facilities for physical recreation; while the theatre, town or village hall, the museum and similar buildings would find their natural and proper setting as places of entertainment and instruction when associated with the gardens.

On the other hand commercial horticulture should have a more definite part to play in the nation's life. An all-the-year-round supply of a variety of fresh fruit and vegetables is essential to our people's health; likewise our people will demand flowers and plants to brighten house and garden alike. Concurrently with this expansion in public and commercial gardening, we may also expect considerable developments in the teaching of Rural Science in schools and of advisory work in the counties. The meaning of all this should be plain; we need young men and women competent to take advantage of the opportunities. There is clear proof that an increasing number of young men and women wish to follow horticulture as a career. There is equally clear proof that they wish to be thoroughly trained. Only by co-ordinating and extending training facilities will progress be maintained and the status of horticulture improved.

Finally, there is a wider aspect of the subject which should not be overlooked. The training of gardeners is a far bigger thing than ensuring a supply of craftsmen for a particular trade. The land does not merely supply food for our bodies; it is an indispensable instrument of education in the broadest sense. The destiny of our nation and the welfare of our people are both dependent on wide appreciation of this fact.

If our national life is to be healthy and balanced its roots must be firm in the soil. Industry must be the complement of agriculture. Instead it has become the competitor, sapping its life blood and growing to disproportionate size. The war has opened our eyes to this foolishness. If we are to profit by our experience we must see to it that horticulture, as well as agriculture, is equipped to meet *the tasks of the future, and that when the job has to be done the trained man is there to do it.*

MERTON
November 1942

Fifteen years have passed since the above pages were written. What changes have occurred in the provision of horticultural training during this time?

Nottingham University now offers a degree course in horticulture; Reading University a diploma course in landscape architecture; the East of Scotland College of Agriculture, Waterperry Horticulture School, and the Institute of Parks Administration diploma courses in horticulture. Of the Farm Institutes offering horticultural courses in 1942, *three no longer do so, but this deficit is more than made up by the addition of eight other Institutes where horticulture may be taken, making sixteen in all. For those, therefore, who can afford the fees, facilities for training have increased.*

For beginners who cannot afford fees there is now the Agricultural Apprentices Scheme, instituted in 1953, *"for the systematic selection and training of promising young people". At last therefore, a long conspicuous gap in horticultural training has been closed and the teaching of craftsmanship may yet be saved.*

HERTFORD
December 1957

PREFACE

Every year I receive many letters and visits from young people who wish to take up horticulture as a career, and their number increases yearly.

From my contacts with these enquirers two things emerge. First, none of these young people has more than the sketchiest notions about the different branches of horticulture, where to get a job or what subjects to study. They lack information. Secondly, they all realize the value of thorough training in the science and art of horticulture and they are all keen to get this training. For reasons I have already shown, many young people cannot expect to receive the training they would like. They lack opportunities of tuition.

My aim in writing this book has thus been twofold. First, to give the information which, until now, has not been generally available. Secondly, to give the facts which are basic to horticultural theory and practice, and to show how they may be most usefully learnt. In this respect, the book may be described as a students' outline of horticulture. The needs of the young grower who has no expectation of special training and who must rely on his own efforts to make progress, have been specially kept in view. Students taking the shorter courses at Institutes and Colleges will also find the book useful, since it covers the first three or four years of a career in horticulture.

The book falls into three parts. Chapters 1–4 discuss the prospects of a career in horticulture and make suggestions about seeking and starting work. Chapters 5–8 deal with methods of study. Chapters 9–14 outline the subjects for study. The section on chemistry and physics goes into details rather more than is necessary for the beginner, chiefly because assembling the facts is a tedious business occupying far more time than the senior student, let alone the junior, can afford.

In referring to quantities, I have, wherever possible, given figures, not so much that the student should memorize them, but that he should learn to look for, and demand, precise information in place of the vague generalities which so often pass for knowledge.

I have endeavoured to keep to statements of fact in the first and third parts. The middle section on methods of study and the chapter on examinations are in a different category. The opinions therein expressed are the outcome of my experience in training student gardeners at the John Innes Institution. In a sense, they were devised by the students themselves, since they grew out of their needs and deficiencies. I owe much to their criticism, enthusiasm and co-operation.

I have to express my thanks to Dr. N. H. Pizer of the South-Eastern Agricultural College, Wye, Kent, for the data in Table V; to Miss J. M. Jannaway for assistance in the preparation of the manuscript; and to Mr. A. F. Emarton for the preparation of Figures 18 and 19. I am indebted to a number of friends, and especially to my colleagues at the John Innes Horticultural Institution, for helpful criticism and suggestions.

MERTON

November 1942

PREFACE TO SECOND EDITION

The title of this book has been changed from "The Young Gardener" to "Training for Horticulture". The main reason for this alteration is that the book has been found to have a wider appeal than was first thought, students and trainees in various branches of horticulture having spoken of the help they have had from it. To meet this wider interest, chapters 1, 2, 4 and 15, the Addresses on pages 173–175, and the Books on pages 176–180 have been thoroughly revised. In addition the sections dealing with heat and light in Chapter 10 have been brought up-to-date.

One other matter. This book was written perhaps as much to encourage the reader to develop a certain attitude of mind to horticulture, as to impart information. This, I hope, will be clear throughout its pages. There is every sign that such an attitude is needed more than ever today.

HERTFORD
June 1952

PREFACE TO THIRD EDITION

The information on prospects of a career in horticulture, pages 18-22, has been brought up-to-date, also the details of the Royal Horticultural Society's examinations, pages 161-3, the addresses of training establishments, pages 173-5, and the list of books, pages 176-180.

HERTFORD
December 1957

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Chapter One

HORTICULTURE AS A CAREER

WHEN I left school I hadn't the slightest idea as to what I wanted to do. And when I eventually started as a gardener, it was "by accident." I didn't know what my prospects were or what I ought to do to achieve success.

Perhaps you also are undecided? In that case I want to show you what your prospects are if you make horticulture your career. On the other hand, you may have already made up your mind and started work, but now want to study to become efficient and gain promotion. First of all, however, I want to say a word or two by way of introduction.

You and I are going to spend a good many hours together in these pages. Indeed, if I am to help you as I want to, we shan't part company for long during the next three or four years. You see, you can't read this book through just once or twice and get from it the maximum benefit. By all means read it straight through at once if you like; in fact I think you ought to, to get a general idea of what it's about. But remember, this book covers all that you may be doing and learning in the next few years. So parts of it won't concern you for a long time yet. Certain chapters you may want to refer to again and again, and you won't realize the importance of some of the things I have dealt with until you re-read them in the light of your own experience.

These preliminary remarks will, I hope, help us to get our bearings. There's just one other thing I wish to say now: we must be sure we speak the same language. For instance, you want to achieve success, I want you to also. But what do we understand by success? Let's be sure, all the way through this book of the meaning we put to key words such as this. Otherwise we may find ourselves travelling in different directions instead of together along the same road.

Success

Countless books have been written on how to be successful in this or that matter, and in them you will find a great variety of definitions and directions. Our purpose is simpler: we have to decide what we mean by success in horticulture. Suppose we say that you are successful when you have:

1. The right job, one that suits you, and gives you plenty of scope.
2. Knowledge and experience wide enough to permit you to take a large part in the direction of the work upon which you are engaged.
3. Earned the appreciation of others and have an income sufficient for all reasonable requirements, professional and personal.

The above view of what constitutes success is a rather narrow one. I don't think you should be satisfied with it. Generally speaking I believe the success of the horticulturist depends a good deal on the success of horticulture. We may hope to get something from horticulture but we should plan to give something to it—new ideas, new methods, and new plants; good quality produce, good workmen, and good working conditions. But these are wider aspects of success than concern you as a beginner. I mention them so that you should not overlook them as we concentrate on *your* career.

In order to achieve success, there is a great variety of things you must learn, some much more important than others. If your progress is to be unhampered and rapid, you must know from the start which are the essentials and how to master them with the least delay. You have your target: now you want to know how to score a bull's-eye every time. Perhaps you haven't left school yet, so let's start from the beginning.

ATTRACTIONS OF HORTICULTURE AS A CAREER

What special attractions are there in growing plants for a living?

Firstly, it is a healthy occupation, physically and mentally. If you are successful in your career, you may eventually spend a good deal of your time in an office, but before you get there you will have spent much more time in fresh air and sunshine.

Secondly, in the office you may have to cope with a lot of routine affairs, but meantime every day will bring interesting tasks or facts to be learnt, so you shouldn't be bored.

Thirdly, you have to pit all your skill and knowledge against the vagaries of the British climate, and there is nothing like a fight for adding spice to life!

Fourthly, you will never have done learning (which should keep you humble); you will have to deal with new plants, new methods, new knowledge. This will prevent you from falling into a rut as regards routine and it will give you a lively and enquiring mind.

Fifthly, however hard the work may be, it is creative, and there is hardly anything that brings greater satisfaction than creative work, intelligently brought to a successful conclusion.

There is another side to the picture, of course. It is not likely that your working day will be much shorter than 8 a.m. to 5 p.m. and sometimes you may have to work through week-ends. You will have to do rough and dirty jobs and you must face up to hard study for a number of years.

PROSPECTS OF HORTICULTURE AS A CAREER

This is a most important question to which you want a clear and definite answer. At this stage it is not necessary for you to make up your mind as to what you want to become, but you should know the opportunities that are open to you. There are four branches of horticulture, each quite distinct. I have made a table of them so that you can compare them at a glance. Other details are given below. The salary scales are for 1958 and are given in general terms.

Commercial Gardening

If we take the mixed nursery with a fair number of glass-houses as an example, the order of promotion would be gardener, charge hand, foreman, assistant manager, manager. A glass-house foreman would get £500-750 a year, possibly with a house as well. Managers receiving the lower salaries (i.e. in the smaller establishments) are sometimes paid a bonus of 5 per cent on profits. Superannuation is not arranged for as a rule. It is not unusual for a good manager to go into partnership with someone who lacks expert knowledge but has capital to invest. The chance of becoming one's own master is a strong incentive for many aspirants to commercial gardening.

Public Gardening

The order of promotion is apprentice (or boy), improver, journeyman, sub-foreman (or charge hand), foreman, technical assistant,* assistant superintendent, superintendent. Boys often serve as apprentices for three years, during which they receive general instruction in gardening practice. Superintendents not infrequently give lectures to their own staff and to others, so the young gardener has an opportunity to receive some

* Large departments also engage a growing number of technical assistants, well trained either in landscape design or in decorative horticulture, to cope with specialised tasks. These men are usually drawn from Kew, Wisley, and the Institute of Park Administrations School of training at Lyme Hall, and are eventually promoted to deputy superintendents and superintendents.

TABLE I

	Commercial	Public	Private	Advisory
Salary ..	Manager, £600–1500	Superintendent, £575–£2,000 and house, etc.	Head Gardener, £500–600 and house, etc.	Advisory Officer, £615–£2050
Kind of work	*General Nursery*—Trees, shrubs, herbaceous, alpine, bedding and pot plants, fruit trees, cut flowers, etc. *Glasshouse Crops*—Tomatoes, cucumbers, flowering pot plants, bulbs, cut flowers, ferns, etc. *Market Gardening*—Vegetables and salads *Fruit Farming*—Tree and soft fruits *Landscape Gardening*—Designing and laying out of gardens and estates	Pleasure grounds (public parks), sports fields, children's playgrounds, open spaces, street planting	Pleasure grounds, glass house plants, vegetables, outdoor fruits, indoor fruits	Information and advice given to all types of growers—especially commercial
Qualifications that may help	N.D.H.	D.P.A., N.D.H.	R.H.S. certificate, N.D.H.	B.Sc. Hort. or N.D.H.

theoretical as well as practical instruction. Young men are also encouraged to attend evening classes, to take horticultural correspondence courses, and to sit for the Royal Horticultural Society's General Examinations. All grades from journeyman (twenty-one years of age) and upward join a superannuation scheme if medically fit (retiring age sixty-five). It is usual for a superintendent to be provided with a house, coal, light, and a car allowance. There are some four hundred superintendencies in Britain. Openings for women apparently do not exist. The security offered by municipal gardening is not the least of its attractions, and there is plenty of scope for creative work.

Private Gardening

It is probable that the days of the large private garden are numbered. The average salary of a head gardener would be £500–600 with house and perquisites (vegetables, etc.). Many establishments have been turned into commercial gardens, the manager of which receives commission in addition to his salary. The insecurity of private gardening has been its chief drawback.

National Agricultural Advisory Service

The Ministry of Agriculture has set up the N.A.A.S. to provide farmers and growers with technical advice and instruction on agricultural and horticultural matters. The service is organised on a county and provincial basis. Counties are divided into districts, each in charge of a District Officer. The County staff provide day to day general advice and the Provincial staff specialist advice.

Salaries start at approximately £600, depending on responsibility of duties. Officers enjoy the benefits of a superannuation scheme.

Candidates must normally possess a University Degree in agriculture or horticulture, or the appropriate natural sciences, or a National Diploma in appropriate subjects, or a qualification accepted by the Civil Service Commissioners as of equivalent academic standard. Since most of the work of the County Officers is to assist growers in problems of cultivation, it is highly desirable that they should have a sound understanding of commercial growing, including management.

COUNTY COUNCIL INSTRUCTORS

The County Councils employ horticultural instructors or superintendents, at those Farm Institutes offering courses in horticulture, and at other centres. These officers act in an advisory capacity for "domestic" growers such as private gardeners, allotment holders, as distinct from commercial growers dealt with by the N.A.A.S.

School Instructors

Home Office Approved Schools appoint Horticultural Instructors at salaries ranging from £500–£700 per annum for candidates who are substantially but not fully qualified, and at the Burnham scale plus four increments for those fully qualified, i.e. holding a degree or the National Diploma in Horticulture plus teachers training qualifications.

WOMEN GARDENERS

In view of the increasing number of women entering horticulture, brief particulars of the positions open to them are given below:

Private Gardens

Single-handed gardeners, companion-gardeners, assistant and head gardeners.

Commercial Gardens

Under-gardeners, charge hands, etc., in market gardens, nurseries and fruit farms; jobbing gardeners, landscape gardeners. A number of women manage their own establishments.

SCHOOLS AND INSTITUTIONS

Gardening mistresses, demonstrators, head gardeners.

ADMINISTRATIVE AND RESEARCH

Advisory Officers, lecturers, research workers.

Chapter Two

PREPARATION AT SCHOOL

PERHAPS you are asking, "Can I do anything special, whilst still at school, to prepare for my career?" For example, "Will the Advanced or Scholarship level of the General Certificate of Education help me?" We shall find the answer to these questions by taking a long look ahead to the time when you are well on the way to the top of the ladder.

First, you must be able to handle the arithmetic of everyday figures with ease, since accounts will have to be kept, estimates prepared, budgets balanced and so forth.

Second, you may have to deal with a considerable number of letters, keep records, and prepare reports clearly, therefore, you should be able to express yourself in a simple and lucid manner and in a clear hand.

Next, it is an advantage to know something of elementary botany, physics and chemistry, since each of these subjects contributes information that is vital to a satisfactory understanding of how plants grow and how their growth may be regulated under various conditions.

Lastly, a grower often has to deal with problems concerning carpentering, plumbing, building, hot water engineering and electricity. He may never have to do the work himself, but if he is a "handy man" he will be in a far better position to estimate what needs doing, how it should be done, and the time, labour, and cost involved.

To summarize. Facility in arithmetic and English (letter-writing); an elementary knowledge of botany, physics and chemistry; and some training in manual work all bear closely on the grower's job. I do not say these things are essential to success. Men have succeeded without them in the past, but few will in the future.

We can now return to our questions about the Advanced and Scholarship level of the General Certificate of Education. Do they confer no special advantage where a horticultural career is concerned? Let us be clear what we are asking. We are not really discussing education at all. Education is what fits us to be intelligent and useful citizens of the world. We are concerned with a much narrower issue, namely, what is the best preparation for a career in horticulture? I have tried to indicate the answer. Much of what you must learn in horticulture it is not the business of day schools to teach. Many young people, once they have passed through a secondary school and given a good account of themselves, will lose nothing by "starting work". If, however, you are one of those folk who can pass examinations with ease, it may be worth your while going on for Advanced or Scholarship level, especially if you take botany, physics and chemistry as your main subjects. These may be essential, of course, if you intend to get a University degree.

Don't think that starting work brings your schooling to an end. You are really only just starting. What has gone before has been preparation. Now you are ready to get down to the most interesting work of all—winning a place for yourself in the competitive world of business.

Essentials for Success

I have been talking of some qualifications necessary for success. Are there others? Yes, the most important of all. And that is why I have left them till last. In the main you have to be born with them though training can help a lot. Here they are. *Imagination*, *judgment*, *determination*.

IMAGINATION is of tremendous importance. We find it in everyone who succeeds by his own efforts. It is the hallmark of the man for whom "plants grow," who has "green fingers," though he may be quite unconscious of it. His imagination enables him to see life from the plant's angle and to adjust its environment to perfection.

Imagination will help you to be adaptable. Men who cannot adapt themselves to new requirements rarely exhibit any imagination. They have learnt a certain routine and dislike or fear changing it, often to the point of obstruction. They suffer from mental inertia: their minds are closed to progress. In a rapidly changing world it is most important that you should be able to change with it as circumstances direct. If you don't, you'll be left behind.

Imagination, then, is the power that enables you to seize an opportunity to keep ahead of your competitor and to develop an organization that is both flexible and efficient. Without it you can neither take the initiative nor be bold. With it you can surmount almost any obstacle to progress.

JUDGMENT. Imagination alone is insufficient, however. It is a good servant but a thoroughly bad master. We may compare it with a spirited horse, ready to take flight in any direction, no matter where. We need a rein to guide this restless energy, and that rein is judgment. Imagination may call up prospects so alluring that you are in danger of acting rashly unless you can regard your ideas with some detachment and with nicely balanced judgment.

To discriminate wisely you must know all the important facts that bear on the point at issue. *Facts are indispensable to sound judgment*. By practising intellectual honesty you must learn to distinguish facts from opinions and prejudices—not always a welcome discipline.

DETERMINATION. Imagination and judgment are the essential equipment for progress. Determination is the power that enables you to drive forward. It is easy, at the beginning of your career, to make up your mind to be determined. It is still easier, once study and work lose their novelty, for your initial drive to lose its power. The fuel that is essential to keep determination going at full power is *interest.*

How can I develop and maintain interest, you ask? By bringing your imagination to bear on everything you have to do, so that pricking out seedlings, weeding a plot, or learning about fertilizers become, not dull tasks, but gateways to a world crammed with things waiting to be discovered—new facts, suggesting new ideas. Be curious, be observant. For example, when you are weeding, identify at the first opportunity all the weeds you come across; observe the frequency with which they occur, how their seeds are dispersed, the types of root systems. Note to what extent different plants of the same species (e.g. shepherd's purse) differ from one another.

Collect the creatures that live in the soil (e.g. centipedes, wireworms), learn their names and look up their life histories. In particular, notice the relation of one thing to another (e.g. type of soil, and kind of weed; weather and soil condition). By persistent and accurate observation you will not only make your work more interesting, but a large store of knowledge will be at your command, when later, by putting two and two together, you have to draw conclusions and make decisions.

Let me summarize what I have said. Your success will be proportional to your imagination, judgment and determination; these are essentials. But you should also be able to calculate and write with facility and know something of the elements of physics, chemistry and botany. If you are a handyman that too, will help. So much for the equipment for your career. Now we must draw up your plan of campaign.

Chapter Three

STARTING WORK

WHERE shall you start work? How are you to decide the respective merits of this or that establishment? Where can you get good experience?

First, we must decide what we mean by "good" experience. I suggest it means two things: (1) sound instruction on how to do jobs, (2) working acquaintance with a fair variety of plants. The first of these is clearly important. Practice makes perfect only if you start by doing things in the right way. Secondly, no young gardener wants to become an expert in one thing by concentrating on that thing alone for a whole year. That is specialization, and specialization should be left until later in your career. Your immediate aim should be to get all-round experience in the basic jobs. Good experience, therefore, means *sound instruction and adequate practice in basic horticulture.*

With this in mind, we may now consider the respective merits of the different establishments open to the beginner. These are of four kinds, commercial, public, botanical, and private. How are you to get to hear of openings?

In the first place, it is probable that you will have to live at home for a year or two, simply because you will not earn a wage big enough to enable you to live in lodgings. This means that your future place of work must be within a 10 miles' radius of your home, preferably less. Locating the commercial establishments is easy. In the classified telephone directory to be found in any Branch Post Office, there is a section headed "Nurserymen and Seedsmen". Write down all those nurseries within a radius of 5–10 miles. You can then go to look at them whenever you please. Locating public and botanic gardens should cause you no trouble, but it is not always easy to get to know of openings in private gardens. You should watch for advertisements in the local press and in such journals as *Gardeners' Chronicle*, *Gardening Illustrated* and *Amateur Gardening*. If there is a local horticultural society, the secretary might be able to help you. The Youth Employment Bureaux (or Service) will also assist you to find a post.

Now, having made a list of establishments, you can hardly march up to the manager, superintendent or head gardener and say "I might like to work for you if you assure me that I shall be given sound instruction and ample experience in gardening." Clearly, however, you *do* want to be satisfied that you will get good experience, so what should you do? If you know someone who can give you a professional opinion on the establishment in question, that will be a great help. More probably you'll have to find things out for yourself. In that case, try to get a look at the place. If it appears well managed and in a reasonable state of repair, if the plants are healthy and well grown, if they are varied in kind, then you are pretty safe in putting that place on your list of prospective employers.

Assuming that the standard of cultivation is more or less equal is there anything to choose between commercial, public, botanic and private gardens as training grounds for the young horticulturist? It is not easy to give a direct answer to this question, as so many factors come into play. Nevertheless, it is probably true that practical experience will be gained most quickly in a commercial establishment, especially in a "mixed nursery". In the other three types of establishments, the pressure of competitive business is not felt and the "garden boy" may be kept longer crocking pots and performing similar menial tasks, than in a nursery. Mass production nursery methods call for help from anyone who has ability to render it, simply because there is so much to be done and so little time to do it in, consequently the beginner gets an earlier chance of doing responsible work. By the way, it does not follow that mass production methods encourage slipshod work. On the contrary, if the plants aren't grown well, they won't sell well.

In this matter of the respective merits of different establishments a great deal depends on the time and interest the foreman or other supervisor spends on his staff. A good man will satisfy himself that their training is not neglected. The beginner's progress may depend as much on the personal interest of the foreman as on any other factor I have mentioned.

Chapter Four

SPECIAL TRAINING

It will be greatly to your benefit if, fairly early in your career, you can take advantage of the facilities for special full-time training provided by certain establishments. These fall into two classes: where a fee is required, where training is free.

Fee required

Full-time Training

1. *Country Farm Institutes.*—The certificate course lasts one year. Fees for board-residence and tuition range from £120 to £265 a year.
2. *Agricultural and Horticultural Colleges.*—These provide courses usually of two years' duration for a Certificate, or Diploma in horticulture. Tuition and board residence, £225–275 a year.
3. *Universities and University Colleges.*—There are two main types of university courses in horticulture:
   (*a*) courses for Pass and Honours degrees in horticulture,
   (*b*) Post-graduate Diploma courses in horticulture.
   Tuition and board residence, £200 to £215 a year.

Scholarships

Scholarships in horticulture are offered by the Ministry of Agriculture and Fisheries, the Department of Agriculture for Scotland, and Local Education Authorities. Particulars may be had on application to these bodies.

Part-time Training

1. *Evening Classes.*—In places where evening classes are held, courses in such subjects as botany, physics and

chemistry, and land surveying are sometimes provided. As a rule these courses are not designed for the gardener, therefore much of the ground they cover is of no great importance to him. Nevertheless, the classes may be of considerable value especially to those young gardeners who have no immediate prospects of receiving full-time training.

2. *Correspondence Courses.*—Coaching for the R.H.S. examination is a special feature of these courses.

Free Training

1. STUDENT GARDENERS

Free training, covering a period of two years, is provided for working students (men) at

(1) The Royal Horticultural Society's Gardens, Wisley, Surrey.

(2) The Royal Botanic Gardens, Kew, Surrey (and women).

(3) The Royal Botanic Gardens, Edinburgh.

Students are paid a subsistence allowance. They take part in the routine work of the establishment, but also attend lecture courses and demonstrations in the science and art of horticulture. In general, applicants must be between twenty and twenty-six years of age, single, and have had three to four years of good practical experience. The number of these studentships is not large, therefore selection is rigorous.

2. APPRENTICES

An Agricultural Apprenticeship Council was established in 1953 in consultation with the Ministries of Agriculture and Fisheries, Education, and Labour and National Service. The main purpose of the council is the improvement of agriculture and horticulture in England and Wales by means of Schemes for the systematic selection and training of promising young people of either sex who enter the industry before the age of 18.

The minimum age of entry into apprenticeship is 16 years and the period of apprenticeship is for three years. Training is given on approved holdings and may be undertaken on more than one holding during the period of apprenticeship. During the first two years, apprentices are released for attendance at day time courses of instruction. A certificate is issued to an apprentice who satisfactorily completes his term of apprenticeship.

Apprenticeships may cover all or any of the following horticultural branches of the industry:—

1. Commercial production of fruit.
2. Commercial production of vegetables in the open.
3. Cultivation of hardy bulbs, flowers and foliage plants.
4. Cultivation of fruit, flowers and vegetables or other crops under glass.
5. Propagation of plants for sale or the commercial production of hardy plants for sale.
6. Production of vegetable and flower seeds.

Full particulars of apprenticeship may be obtained from: The Agricultural Apprenticeship Council, Agriculture House, Knightsbridge, London, S.W.1.

FURTHER PARTICULARS

Valuable information on the qualifications, training and prospects of employment in horticulture will be found in *Agriculture and Horticulture*, No. 3, in the Choice of Careers series of booklets issued by the Ministry of Labour and National Service, and obtainable from Her Majesty's Stationery Office, London, price 5d., post free. Particulars of the facilities available at centres of agricultural and horticultural education will be found in a leaflet obtainable from the Ministry of Agriculture, London, under the title "Full-time Agricultural Education in England and Wales".

Chapter Five

USING BOOKS

IT is hardly possible for me to exaggerate the importance of books to the young horticulturist, and I have no patience with those people who profess to despise "book knowledge". Instead of bothering about this noisy minority you will find it more profitable to consider how books may help you, now and all through your career.

First, they bring to you the *heritage of the past;* all the wealth of knowledge and experience which men have won from countless experiments, by much labour and through many mistakes. Your predecessors started from scratch and often had an uphill task. By reading what they have to say you are given a long start over ground that has been smoothed out and is easy going.

Second, books bring you into *contact with the expert.* It is not very likely that you will meet the leading authorities in horticultural science and practice at your place of employment; and still less likely that you will be able to question them and learn their views on this or that. But in their books you may, at any time you wish, meet them and learn their mature and considered opinions.

Third, by reading you can immensely *broaden your knowledge.* You can travel to other gardens, landscapes and climes and learn of other people's methods and experiences. You can visit the research worker in his laboratory, watch his experiments and have explained to you the "how" of a hundred questions. Or you can follow the construction of a rock garden, from the preparation of the site to the last few plantings. Your work may confine you to an acre of ground: but your reading may make the world your garden.

Fourth, books help you to *keep up with new discoveries.*

These are being made at an ever increasing pace, and the grower who wants to succeed must keep himself informed about them.

We can put all this in a nutshell. Where horticultural practice is concerned book knowledge is supplementary to experience; it cannot replace it. But where principles are concerned books are the main source of information for the average young grower.

How to Read

I expect you, like me, have often picked up a book, say a "thriller," read it straight through in one evening and put it aside—probably for ever. *That is not the way to read books on horticulture.* For this reason. A text book is like a wide panorama seen from a high hill. As your eye travels over the view, you are aware of innumerable fields and woods, a range of low hills here and some bigger ones there, a gleam or two of water, villages, roads, houses, a railway—far more than your eye can take in. You get a *general impression* of the landscape. Now general impressions may be very edifying when viewing a landscape, but they are highly unsatisfactory when it comes to solving cultivation problems or answering examination questions. Your business as a horticulturist is to collect clear-cut *facts*, not vague impressions. How should you set about this?

Systematic Reading

The first thing is to *plan your reading*. Avoid the pernicious habit of dipping into books as fancy pleases. Assuming you are acquainted with the elements of physics and chemistry, you should start by studying the two most fundamental subjects. Plant Growth and Reproduction (botany) and Plant Nutrition (soils and manures). My chief reason for recommending these two subjects is that they are largely complementary, the one throwing light on the other. There is another reason, however, which prompts my recommendation. To study one subject to the exclusion of all else for weeks on end is an excellent way of boring yourself to death. Your studies, if they are to be interesting, need to be varied. I suggest you read botany, say, one half of each week and about soils the other half.

Be Thorough

Remember, you're collecting not impressions but facts. You may not find them all in one book. One author may explain a given point better than another; or his illustrations may be more helpful. For example, suppose you are studying the germination of seeds. Get hold of two or three modern books on elementary botany; compare what they have to say about seed germination; make your own summary of the facts. Do this as far as you can in all your studies. Collect the facts from different sources and sift out all that is not basic. You should then have left only the fine gold.

General Remarks

Be clear in your mind that your chief reason for reading is to learn the basic facts. Keep this in mind when you read books or journals other than text books. A text book should contain facts, and if for any reason the author gives his opinion he almost always states that it is only an opinion, not a fact.

This does not necessarily apply to the daily papers, trade journals, and weekly or monthly periodicals on gardening. Articles in these journals by recognized authorities are substantially reliable. But most journals contain letters from correspondents and sometimes articles over pseudonyms in which opinions are presented as if they were facts. The writers may be perfectly sincere in believing what they say is true; or they may be quite unconscious that they are dressing up their opinions as facts. Moreover, these writers are not usually in a position to judge what is a fact and what is not. For instance, a correspondent might state that cyclamen grow best if the corms are not covered, but rest on the surface of the soil. This statement may be made because (1) the correspondent grows them that way, (2) he tried partly covering them and they did not do so well that year. It is highly improbable that he has made carefully arranged tests, varying soil, temperature, etc., and thus proved that his general statement is true.*

Please don't think I am running down popular garden books or journals as sources of information. On the contrary, you can learn a great deal from them, especially from the excellent diagrams and illustrations which often grace their pages. What I am putting you on your guard about is the uncritical acceptance of everything you see in print as being true. Listen with respect to what men of experience have to say: but *never let respect stifle your critical faculties.*

* It isn't.

Chapter Six

MAKING NOTES

MAKING notes is an inevitable part of your studies, so we must give it some consideration. What is a note? The dictionary says it is "a brief record"; something "to help the memory". These are the qualities which should characterize all your notes: they should be brief records to help the memory. Or to put it another way, to be effective notes should be (1) concise, (2) adequate.

Conciseness

This is more important than it may seem at first sight. If you make notes merely to refer to them in the distant future, you will have missed half their value. Make notes for future reference by all means, but don't overlook the fact that the chief value of so doing is that it is as good a way as any of impressing facts on your memory. Most of us have to treat our memories with some deference. They let us down if we ask them to do too much, or if our impressions are confused.

By making concise notes, your mind is presented with a vivid, sharp picture and has a reasonable chance of remembering it. That is why all through this book I have been urging you to summarize all that you read; to condense it until the basic facts alone remain, bold and clear to the mental eye.

The secret of making notes that are clear at a glance lies in their *arrangement*. But whether you make notes to impress the facts on your mind, or for future reference, their arrangement is all-important for a more subtle reason. Good arrangement is conducive not only to tidy habits but to *tidy thinking*. The key to good arrangements of notes is *the proper use of headings*, of which I shall have more to say in Chapter 15. A last word about conciseness: *the best note is often a table or diagram.*

Adequacy

In making your notes concise, there is one danger to avoid: don't go to extremes. While listening to a lecturer or reading a book, you will be tempted to imagine that a *very* brief note, perhaps a single word, will remind you of all that has been said about that part of the subject: it is so vivid and fresh in your mind. But in six months' time, that single word will probably fail to stimulate your memory, or even if it does, only in a rather uncertain way. Therefore, in making your notes concise, you must also be sure they are adequate, and encompass all the basic facts.

Lectures

In the great majority of cases, the student will find it best first to make rough notes in pencil, then to go through them to polish them up and see how they can best be arranged, and finally enter them in permanent form in a book. This means a little extra work, but you will be amply repaid by the improved results.

A good lecturer will announce and sum up each part of his lecture in such a manner that note-making for the listener is easy. Not all lecturers are good at presenting their facts, however, and you will then have to be on the alert in order not to miss the essentials. If any point is not clear to you never go away without asking the lecturer or a fellow student to explain it.

A final word about making notes on lectures. *Do write them up on the same day* while they are still fresh in your mind. It is surprising how what seemed crystal clear during the lecture becomes uncomfortably hazy twenty-four hours later, especially if, in the meantime, you have listened to a different lecture.

Chapter Seven

PLAN OF CAMPAIGN

ONE of the difficulties about making a plan is that it can't be done really well unless you know all about the subject for a start. By the very nature of things, the beginner can't plan for himself: he must rely on someone with experience to do it for him. And that is what I want to try to do. I'm sure it won't be a perfect plan, but I'm equally sure that you'll do better to follow it than have no plan at all.

Training for horticulture, as in other vocations, is chiefly a matter of learning and doing. You have to learn facts: you have to do jobs. Let's look at these two things more closely. Notice how I've arranged them below:

You must

Know the basic facts
Know where to find other facts
Be able to do basic jobs
Know how other jobs are done

Learning the Basic Facts

Let's take the facts first. You should know them so that when faced by a problem, you are able to decide what is the correct thing to do. *Your progress will largely depend on your ability to make sound decisions.*

Which are the basic facts? Those that underlie conditions and work which frequently recur. They are the foundation of a balanced knowledge of the principles of horticulture. Beginners, in their initial enthusiasm, often try to learn too much, and get a lopsided or patchy knowledge of horticultural principles. They don't discriminate between facts of first and third importance, and start collecting all sorts of bric-à-brac instead of the really valuable pieces of knowledge. Once you have a good foundation, you can erect on it the many other facts which go to build up the grand structure of horticultural knowledge. But first you must get the foundations right: the later chapters of this book will tell you how to do this.

What method should you use to learn the facts? Well, why do you want to learn them at all? *So that they may assist you to make correct decisions*. Clearly then you want to learn the facts in such a way that they will be of the greatest possible use. And what is this way? It is the method of *grouping related facts*. Don't try to cram your head with dozens of isolated or loosely connected facts. Always group them. Unless you do you will never be able to remember them clearly or use them logically. Let me illustrate what I mean.

Here are some facts about a sandy soil:

Sandy soil—too loose (for roots), holds too little water;

and here are some facts about a clay soil:

Clay soil—too dense, holds too much water.

If you have picked up these two sets of facts (along with others) on separate occasions, or if you have never related them, you are not likely to recall them in a useful way. Now let's bring them together, that is, group them:

Sandy soil	*Clay soil*
Too loose	Too dense
Holds too little water	Holds too much water

At once the bearing of these four facts on future decisions or work becomes apparent. You can see that if a sandy soil is mixed with a clay one, then their opposite and undesirable qualities cancel out and you can get an improved soil mixture (sandy-clay or "loam", as we call it) which is neither too loose or dense, nor too dry or wet.

To this nucleus we can add other related facts:

Sandy soil	*Humus*	*Clay soil*
too loose	granular and springy →	too dense
holds too little water ←	large capacity for water	holds too much water

Clearly, humus improves both soils. It "opens up" or loosens the heavy clay soil, allowing air to penetrate and *excess* water to drain away: it improves the water holding capacity of the sandy soil.

The above illustrations are simplified and incomplete. What I am trying to impress on you is that each new fact you memorize or make notes about should be fitted into that group of related facts which form a logical whole. Build up a picture in your mind of this group of facts, then in recalling any one of them you will see it against its proper background and thus be able to use it to the best advantage.

Now almost any book on horticulture that you read, even the most elementary, will contain many more facts than you need to remember in the early stages of your career. Moreover, though these facts will be presented in an orderly sequence, they will not necessarily fall into the kind of groups I have been talking about. This means that, in reading, you must do two things. First, select the facts of major importance; second, relate them to one another in their natural groups. Always summarize the facts of your study. *If possible make them into a table or diagram.* You will then have a picture in which the main facts stand out so clearly that you will recall them with ease.

One more thing before we finish with this question of learning the basic facts. Facts are much easier to memorize if you can form a mental picture of them, no matter how crude. We might call it "picture thinking". I mentioned a heavy clay soil just now. See it in your mind's eye, the mass of densely packed, microscopic particles of clay; wet and sticky in winter, dry and cracked in summer. It is so close in texture that neither air nor water can penetrate it easily, and it won't break up into crumbs of soil in which seedlings will grow. You will learn later that lime causes the tiny, clay particles to clump together to form crumbs. Fit this

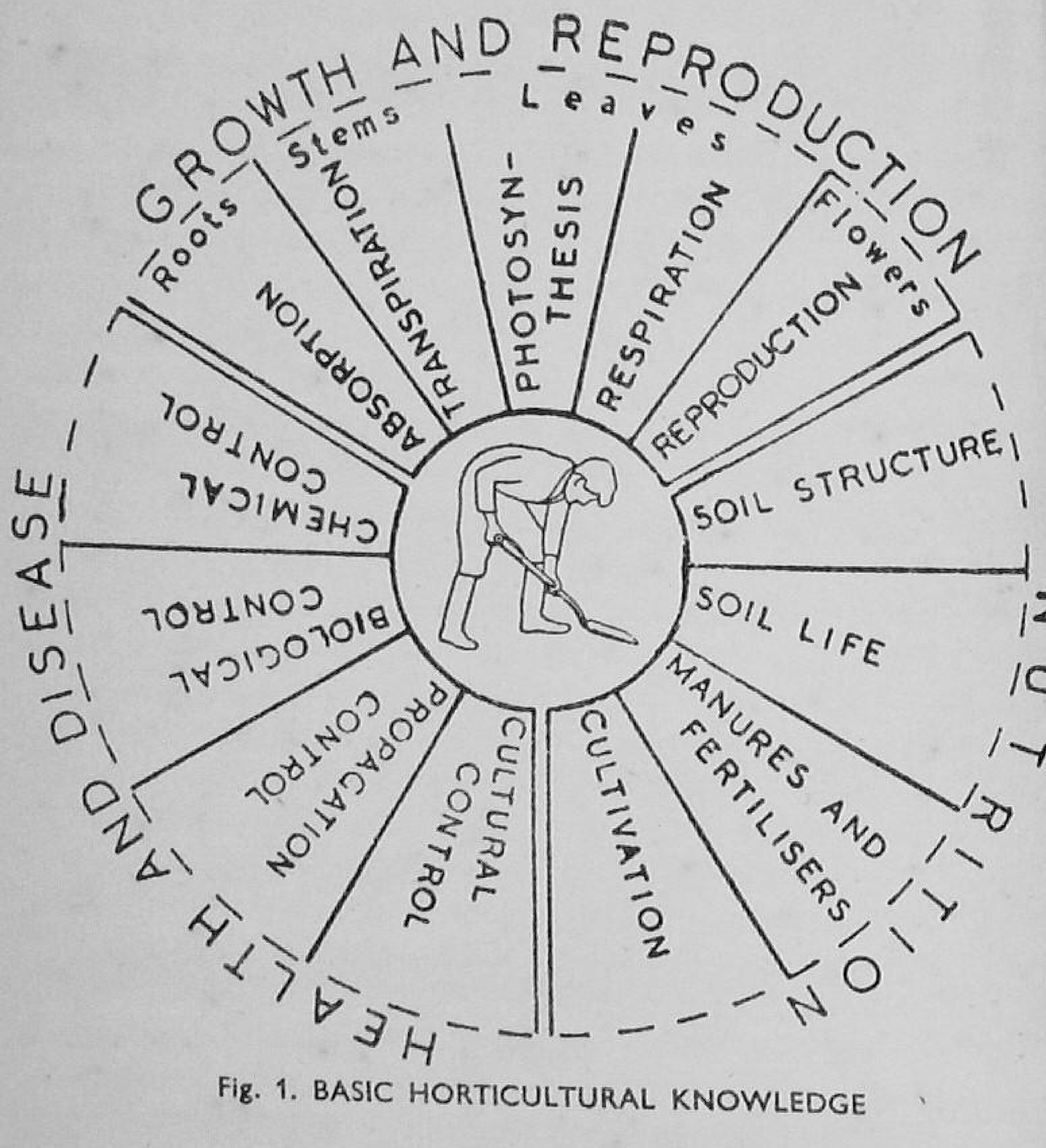


Fig. 1. BASIC HORTICULTURAL KNOWLEDGE

fact into your picture. Grit and sand mixed with the clay would also hold the particles apart, and so would organic matter, such as rotting leaves or other vegetable matter. Try to get a really vivid picture of all this. The more vivid it is the more certain you are to recall it. There is hardly anything you will have to learn that cannot be turned into a picture: parts of the plant, the way it works, the pests that attack it, and so on. Even if you are one of those people (and there are many) who are not "visualizers", you can memorize related facts in the form of a summary.

Let me summarize in three words all that I have been saying: ORGANIZE YOUR KNOWLEDGE.

One further word about horticultural knowledge. For the moment think of it as being contained in a vast library of books. The books are arranged in shelves which radiate away from a common centre, those which should be read first being nearest to the centre. At this centre stands the young horticulturist. Around him in all directions radiate the avenues of knowledge. The library is divided into three main groups: growth and reproduction, nutrition, health and disease. Each of these groups is divided into smaller sections concerned with one special aspect only (Fig. 1). The young horticulturist has to start at the centre and get to know his way about the library—first the central parts and then the more distant. The library is always growing (outwards); there are no limits to its boundaries. Confronted with such an immense and attractive array of books, one feels tempted to wander hither and thither, dipping into this book, browsing on that, curiously examining the pages of one volume and admiring the illustrations in another. Once in a way this is all right, but the wise man builds up his knowledge systematically. He organizes his knowledge.

Finding the other Facts

I have called the basic facts those that underlie horticultural work which frequently recurs. But horticulture is so varied an occupation that it will not be long before you will find yourself carrying out a piece of work that is out of the ordinary. If you are keen you will want to know something about it, especially as it may be a long while before the opportunity presents itself again. Examples of the kind of work I mean are, laying a tile drain, constructing a rock garden, stub-grafting a fruit tree, steam-sterilizing a tomato house, and so on. So I have compiled a short list of publications (p. 176) containing facts, which, though not basic, are certainly worth getting to know should you have the good fortune to observe or take part in jobs requiring special knowledge.

In the first two or three years of your career you will, of course, be carrying out orders rather than giving them. But as you progress and begin to take on responsibilities, this question of knowing where to find the facts will become increasingly important. Don't wait until the distant future and then find yourself looking for *a* book containing the facts you need, but dip into the pages of such publications as those listed on page 179 to get a general idea of what each book is about. Then, when you want your facts you can go straight to *the* book which contains them.

Another class of facts which we may want to use from time to time comprises names and formulae. The names of genera, natural orders and parts of the plant, are examples of the first. The cubic capacity of water tanks, the relation between Centigrade and Fahrenheit thermometer scales, metric conversion tables, are examples of the second.

Learning the Basic Jobs

We can use the same definition for basic jobs as for basic facts: those jobs which frequently recur. You will find them in Chapter 14. Is there any special method by which you can learn to do them? Yes, *the method of maximum proficiency.* Let me explain.

Take one of the commonest of horticultural operations—single-spit digging. There are right and wrong ways of digging. What do we mean by "right" and "wrong"? Generally speaking, we say digging has been done rightly when the *results* of digging are satisfactory, i.e. the soil has been turned right over to the depth of a full spit, all weeds have been buried, and the surface left level. We judge by results.

Now I want to put it to you that getting the right results is only half the story. The average man will be content merely to get the results. The man who aims at maximum proficiency will also consider *how* he gets the results. This is an intensely interesting matter which applies to every basic job. When you have understood and mastered it you will have earned fully the title of "master craftsman".

Do you remember I gave you a slogan for learning facts? It was "organize your knowledge". Now I want to give you one for learning jobs: it is ORGANIZE YOUR MOVEMENTS. To dig a full spit deep, bury weeds and get a level surface you must of necessity push the spade vertically down, lever it up, turn it over and place the soil in the right place. But in doing this, your hands can be placed in quite a number of different positions on the shaft and handle of the spade for any given movement; your stance could be one of several; your wrists, arms, and body could take up various positions for the same movement. One person could do it one way, a second person another way and both get equally good results as far as the soil is concerned.

But only one way is the way of maximum proficiency. Which? That's for you to discover. Study your movements, reduce them to a minimum; notice where the heavy muscular strain occurs, reduce it to a minimum; notice the speed of your digging, adjust it to the optimum.

Have you ever admired the "effortless" flick of the wrists with which Hutton cuts the ball to the boundary for a four? Or envied the perfect action of Trueman as the ball goes swinging towards the batsman? That's the way to dig. Conserving your energy, co-ordinating your movements, timing them with precision. We call it style in cricket and the word is just as appropriate to digging done in the right way. It takes a good man to score a century in one day and feel ready to do it again the next. And it takes every bit as good a man to dig all day at the rate of a rod an hour without retiring. The easy rhythm of the expert digger, his style and precision, are not acquired in a day. Brains are required as well as brawn.

Think how much more interesting all routine jobs become when they are tackled in the way I have described—pricking out, potting, tying up, drawing drills, hoeing. Repetition work need not be boring, even when you are working alone, and in any case you are not likely to exhaust all the possibilities of achieving maximum proficiency during the first three years.

You will hardly need me to point out that organizing your movements has other advantages besides that of providing additional interest in your work. Your employer benefits and he won't be much of a man if he fails to notice it or testify to your skill. But more important to you is the fact that every day you will be exercising your mind and disciplining your body until organized thinking and organized action become a habit. There are no better foundations for success.

Knowing about other Jobs

There are so many jobs for you to learn in your career, that for quite a number of years there are bound to be some you will never have done yourself, though you may have read about them or seen someone else do them. Now, knowing about jobs is quite important. For instance, you may never have had the opportunity to bud roses or make a lawn, but if you have carefully read about the one and watched someone else do the other then, if the necessity arose, you could at least have a shot at doing these things yourself; or you would be able to give a reasonably good answer to a question on these subjects in an examination paper. Moreover, if you have previously read about how a job is done, you will almost certainly learn to do it more quickly then if you had read nothing about it.

Chapter Eight

USING FACTS

So far as horticultural practice is concerned there are two kinds of facts. The first describe what is going on around you (the sun is shining, this plant is flagging)—the facts you *observe*. The second consist of what you have learnt in your studies and from your experience (sunshine increases the rate of transpiration, plants flag if they are dry or if they cannot take up water—the facts you *accept* as being established.

Many times a day you may have to observe facts (which suggest ideas) and check those observations (and ideas) against accepted facts. You will have to do this in the most ordinary routine, such as watering plants; you will have to do it in special cases, such as the diagnosis of disease.

Of course, we check our observations by our knowledge in the everyday things of life. There is nothing new in this. But, in horticultural practice, this principle often has to be applied with a rigour (I almost wrote "ruthlessness") and precision foreign to everyday life. Our observations and deductions have to be thoroughly methodical and scientific.

For example, if you are to observe accurately, your mind must be free of preconceived ideas. If you are prejudiced in your approach to a problem; if you have been unduly influenced by someone else's opinions, e.g. your fellow-workers' or your employer's; if, when you are criticized, your first impulse is to defend your actions or views with some heat instead of considering the criticism dispassionately and with care; if you believe "common sense" is reliable—then your observations are not likely to be accurate. This is even truer of the idea which may occur to you as a result of your observations. You should train yourself to observe critically and impartially until it becomes a habit.

Most of all you need to be methodical in trying to interpret what the facts mean. First assemble all the relevant facts that can be observed. What do they point to? Here you have to use your knowledge and reasoning powers and perhaps as good a way as any of doing this is the method of elimination. Discard your theories (ideas) in the order of probability that they are *incorrect*. You may then be left with two or so possible explanations. Select *the most probable*, and see if you can think of a condition (fact) which, if it actually existed, would make it practically certain that your theory was correct. Or, if there is no such condition to be observed, then try to think of a test that would decide between the alternative explanations. The test might be one you could apply at once (e.g. watering a flagging plant to see if drought was the cause of flagging*) or you might have to think out a special test (e.g. raising a batch of plants in different soils to observe their effect). To put it in a nutshell: eliminate the improbable notions first then search for evidence of the probable.

Here is an example—a simple one—by way of illustration. In a batch of tomatoes planted in a bed, one is wilting. Is this due to disease which may spread, and how can the trouble be controlled and further occurrences prevented?

FACTS OBSERVED: Only one plant is wilting; it shows no other symptoms of disorder: neither the soil nor subsoil is dry.

FACTS KNOWN: Plants wilt when they transpire water faster than their roots absorb it. Noxious fumes may also cause wilting.

ELIMINATION: Enquiry and observation show that noxious fumes are not responsible in this instance.

INFERENCE: Then the plant is wilting because it is not getting sufficient water. Why?

PROBABLE EXPLANATIONS: The roots are diseased; the stem is diseased.

* This test is not to be recommended.

DISCRIMINATING TEST: Dig up the plant and examine its roots: if they are sound then the stem must be at fault. The root system is apparently sound. The stem? At ground level, where it is difficult to see, the outer tissues are partly eaten or rotted away to a depth of one-sixteenth of an inch. Here is the cause of the wilting: the water-conducting tissues are severed. By what means? Are there any signs of soil pests able to inflict such damage? Does it look like a fungus attack, a stem rot? Could the damage be caused by an implement? And so on. With absolute precision, overlooking no piece of evidence, however small, the issue is methodically narrowed down.

Notice in particular that the soundness of your conclusions and decisions will depend, not merely on the number of facts you know, but on whether you can marshal those facts in a useful way and relate them to your observations so that they fit together, like jig-saw pieces, to give a true picture.

One more word. One day you will be a supervisor. You will have to decide (1) what is to be done, (2) how it is to be done, (3) when it is to be done, and (4) who shall do it. The last of these means that you must know your men, their individual competence and reliability. The third is a question of doing the right thing at the right time; of knowing which job must be done next. The second depends on your knowledge of jobs; on your "practical experience". But the first is the real test of your ability as a supervisor—knowing *what* to do. And what you should do depends on the facts—or rather, on your skill in using them. *Facts are the tools for making decisions.* Aim at becoming a craftsman in their use.

Most of what I have said in these first eight chapters has been of an introductory character; to prepare you for your work and studies. We've now come to the point where you must roll up your sleeves and get down to study in real earnest. As I said at the beginning, read straight through the book to get an idea of what it's about. But you will have to come back to the next six chapters many times. They outline the *essentials* to a proper understanding of horticultural principles and practice; those things you must master thoroughly so that they are at your instant command.

Chapter Nine

ABOUT MATTER: CHEMISTRY

Do you know how a thermometer works, why a glasshouse is a "sun-trap," how soil acidity is measured and why a light soil is warmer than a heavy one? Underlying these and many similar questions are certain facts of science which you should know if you are to do your work intelligently and proficiently.

In Chapters 11 to 14 I have outlined those facts and jobs which *relate* to horticultural theory and practice. In this and the next chapter I want to deal with those facts and laws of science which *underlie* horticultural theory and practice. Some of you may be familiar with this basic science from instruction in physics and chemistry you received at school. To you, all I need say is, be sure you clearly understand how it applies to horticulture. Others of you, however, will have been taught little or no science, and, left to your own devices, will not know where to look for the facts, or indeed what to look for. This difficulty is made the greater because the information you require is widely scattered among the different sections of science, such as those that deal with heat, light and organic and inorganic chemistry. Thus unaided, you may find the necessary search makes big demands both on your time and pocket.

In the following pages, therefore, I have brought together the facts basic to horticultural theory and practice, noted those aspects which should receive special attention, and briefly indicated their application to horticulture.

I have also made a selection of suitable, inexpensive text books. This list of books, together with some comments on them, you will find on page 176.

ABOUT MATTER: CHEMISTRY

Chemistry inquires into the *nature and composition of matter.* It is the study of the ultimate particles of matter, how they may be combined to form new substances, how their combinations may be broken down; and of the various phenomena which occur when different types of matter react and are *changed in their composition.*

Atoms

All material things are made of one or more of 92 different types of **atoms.** Atoms are incredibly small. The mass of the smallest (hydrogen) expressed in grammes is 0.0000000000000000000000017—a figure utterly beyond our comprehension. Different types of atoms have different weights, the mass of the largest type (uranium) being nearly 240 times that of the smallest. Atoms are not the smallest particles: they are built up of very much smaller **electrons, protons** and **neutrons** and it is the numbers of these which determine the weight and chemical characteristics of the different types of atom.

Molecules

Only a few types of atom occur *free* or alone: the majority tend to combine with each other in orderly ways to form groups called **molecules.** Molecules differ greatly in size. The smallest is the hydrogen molecule, consisting of two hydrogen atoms only. The largest are giants: they are built up of groups of atoms (we might call them sub-molecules) repeated over and over again—in all, many thousands of atoms. Protein (p. 73) is made of these giant molecules. Most of the molecules which concern us in this book consist of a few atoms only.

Elements

An **element** is a substance consisting of atoms of one type only. Hence an element is a substance that cannot be split up into chemically different substances and therefore cannot be formed by combining other substances. Hydrogen, carbon, oxygen, iron and mercury are examples of elements. Since there are 92 different types of atom, there are also 92 different elements. The elements are conveniently divided according to their appearance, into (1) **metals,** bright, hard substances that are good conductors of heat and electricity (e.g. copper and mercury); and (2) **non-metals** (e.g. sulphur a solid, and oxygen a gas). A few elements are intermediate in character; they behave as metals in some respects and as non-metals in others (e.g. carbon, in its ordinary form is a good conductor of electricity).

Compounds

We have seen that atoms tend to combine with one another to form molecules. Since there are 92 different types of atom it follows that most molecules are built up of two or more different types of atom, i.e. most substances are **compounds.** For example, a molecule of water consists of two atoms of hydrogen combined with one of oxygen; and a molecule of table sugar is built up of 12 carbon, 22 hydrogen, and 11 oxygen atoms. Remember that although the molecules in a compound contain different types of atoms, the molecules themselves are all alike.

When elements combine to form a compound, (*a*) they always do so in definite proportions by weight, (*b*) heat is produced or absorbed; in other words, there is chemical action, (*c*) the properties of the compound are quite different from those of its constituents, (*d*) it is impossible to separate and recover the constituent elements by mechanical means.

Mixtures

In compounds, the individual atoms comprising them are associated far more intimately than is possible by mechanical mixing. For example, if we mix some flowers of sulphur with iron filings, then no matter how small the particles may be, they still contain millions of sulphur or millions of iron atoms. They are really small lumps of sulphur mixed with small lumps of iron, and no amount of stirring or mixing will ever enable atoms of sulphur to combine with atoms of iron. Hence, while the molecules of a compound are all of the same type, those of a **mixture** are of *two or more types*.

When a mixture is made, (*a*) the constituents may be in any proportions, (*b*) no chemical action occurs, (*c*) the properties of the mixture are what would be expected, knowing the properties of the constituents, (*d*) the constituents can be separated and recovered by simple mechanical means. Mixtures may be of various types, e.g. solid with solid, liquid and solid, liquid and liquid, liquid and gas.

Before we go on, let us summarize the facts about elements, compounds and mixtures.

	Atoms	*Molecules*
Element	All alike	All alike
Compound	Two or more different types	All alike
Mixture	Two or more different types	Two or more different types

Suspensions

If a little soot is put into water, the fine particles **disperse** themselves throughout the liquid, but remain solid and visible. Such a mixture of *solid* particles floating in liquid is termed a **suspension.** If the soot-water is allowed to stand, the particles gradually settle to the bottom. The soot can also be separated from the water by filtering. In a suspension of clay in water, the particles are very fine and take days to settle.

The arsenical sprays used for spraying fruit trees are suspensions of *lead arsenate* in water.

The rate at which particles in a suspension settle to the bottom depends upon their size; large ones sink quickly, small ones slowly. Now some sprays used in horticulture are suspensions, e.g. lead arsenate spray, and it is essential that the rate of settling (sedimentation) is reduced, otherwise the spray will not be uniform in concentration. A "spreader" therefore is added to the spray and this acts by surrounding the particles with a coat of watery jelly (colloid) which, being of a similar density to water, delays sedimentation. Gelatine is an example of such a spreader.

Emulsions

If milk is examined beneath a microscope, it can be seen to consist of numberless transparent droplets of fat of very minute size, floating in a clear, colourless liquid, the milk plasma. Such a mixture of *fluid* particles suspended in a fluid is called an **emulsion.** The fat particles can easily be separated as cream by leaving the milk to stand. The particles in an emulsion sometimes tend to run together (coagulate) and thus become separated from the solvent. They can often be kept dispersed, however, by adding an **emulsifier,** e.g. soft soap is an emulsifier for paraffin and water.

Colloidal Solutions

In suspensions and emulsions the particles of the dissolved substance are visible to the naked eye or with a microscope. If the particles are so small as to be ultra-microscopic, though still composed of many molecules, then the mixture is said to be a **colloidal solution.** Some of the fungicides used in horticulture are colloidal solutions containing, for example, ultra-microscopic particles of copper. The particles in colloidal solutions are so small as to pass through the finest filters. Substances which have a finely-grained structure like the dissolved substance in a colloidal solution are called **colloids.** Glue and starch as prepared for use, also clay and humus, are examples of colloids. Because of their finely-grained structure colloids have large surfaces like a sponge and will take up considerable amounts of water (cf. clay).

True Solutions

If common salt is put into water, the particles disappear or **dissolve.** The liquid containing the dissolved salt is called a **solution,** the water is known as the **solvent,** and the salt as the **solute.** In a true solution, the particles of the solute are *single* molecules and therefore ultra-microscopic. Dissolved substances can easily be recovered from a solution by evaporating it to dryness. Water is a solvent for many substances, e.g. sulphate of ammonia, copper sulphate. Soil-water also is a solution of salts (p. 127).

All natural forms of water contain air which gets dissolved in raindrops as they fall through the air. The presence of dissolved air in water is essential to plant life.

Saturated Solutions

If more and more salt is added to a given quantity of water, a point will be reached when no more salt will dissolve. The solution is then said to be **saturated.** The higher the temperature of the solvent, the greater the amount of solute required to produce saturation. If a saturated solution is cooled, a point is at last reached when the solution cannot hold all the solute, consequently some of it is thrown out or **precipitated** to the bottom (cf. humidity, p. 90).

Diffusion

If a crystal of permanganate of potash is put into some water, the purplish solution that is formed as the crystal dissolves can be seen to spread through the water until it is uniformly coloured.

This tendency of the molecules of a substance, when it occurs as a gas or in solution, to move from points of greater concentration to points of lesser concentration, until all the molecules are evenly distributed through the total available space, is called **diffusion.**

Diffusion will also take place through a **membrane** separating two solutions, providing the membrane is permeable to the dissolved substances.

Osmosis

Membranes differ in their nature, however. Some are permeable to water, but not to certain substances which are soluble in water. For example, let us suppose we have a vessel divided into two compartments by a piece of *parchment* that is permeable to water but impermeable to dissolved sugar. Into one we pour a weak solution of sugar in water, i.e. one containing, per unit of volume, relatively few sugar molecules, Into the other compartment we pour a strong solution of sugar in water, i.e. one relatively abundant in sugar molecules, but with fewer water molecules per unit volume. If it were not for the parchment, the sugar molecules would diffuse from the stronger to the weaker solution. As they are unable to do so, water molecules will diffuse from the weak sugar solution to the stronger, and will go on doing so until both solutions are equal in concentration, i.e. contain an equal number of sugar molecules per unit of volume. The diffusion of water through a membrane is known as **osmosis** and a membrane of the kind described above is a **semi-permeable** membrane.

Osmosis is the process by which water passes from the soil into the roots of the plants, *the root hairs acting as semi-permeable membranes* which readily allow water to diffuse through them, but prevent the outward diffusion of sugar (and other substances) dissolved in the sap. Thus the sap within the cavity of the root hair is maintained at a relatively high concentration and under appropriate conditions water can pass continuously from the soil to the plant.

In time of drought the solution in the soil is much stronger and it is then difficult for the roots to absorb water.

The semi-permeable root hairs do more than absorb water. They also absorb *mineral salts* dissolved in the soil water, selecting some salts in preference to others. Thus food materials, in appropriate amounts, are also taken in.

Symbols, Formulae and Equations

Chemical symbols and formulae are useful means of giving information in a brief fashion; information about the properties of substances and the ways they react with one another. *One atom* of an element is represented by the capital letter which forms the initial of the name of the element, e.g. H for *one atom* of hydrogen, C for *one atom* of carbon. When two or more elements have the same initial letter, a second small letter is used to distinguish them, e.g. C stands for one atom of carbon, Ca for one atom of calcium and Cl for one atom of chlorine. In a few cases the letters are taken from the latin name of the element, e.g. K for one atom of potassium (kalium) and Na for one atom of sodium (natrium).

To indicate a *molecule*, the symbol of the element is written and a small figure added just below the line to show how many atoms there are in the molecule, e.g. H_2 stands for *one molecule* of hydrogen containing two hydrogen atoms and Cl_2 stands for *one molecule* of chlorine containing two chlorine atoms.

In the same way, formulae are used to describe compounds, e.g. CO_2 stands for one molecule of carbon dioxide and tells us that this molecule consists of *one* atom of carbon and *two* of oxygen. Similarly, $CaCO_3$ indicates one molecule of calcium carbonate, consisting of one atom of calcium, one of carbon and three of oxygen.

When a chemical reaction takes place, the atoms of the molecules concerned are rearranged. This rearrangement is expressed by means of an equation. For example, if calcium carbonate ($CaCO_3$) is strongly heated, CO_2 (carbon dioxide) comes off as a gas and CaO (calcium oxide or quicklime) is left, thus:

$$CaCO_3 = CaO + CO_2$$

Again, if water (H_2O) is poured on quicklime (CaO) calcium hydroxide (slaked lime) is formed:

$$CaO + H_2O = Ca\ (OH)_2$$

Air

Air is a *mixture* of invisible, odourless and tasteless gases, together with a variable amount of water vapour. In the latitude of London the average percentage composition of air by volume has been found to be:

	Per cent
Nitrogen	77·32
Oxygen	20·80
Rare gases	0·93
Carbon dioxide	0·03
Water vapour	0·92
Total	100·00

(1) Nitrogen (N). Free (uncombined) nitrogen comprises approximately four-fifths of the air, but it plays no direct part in the life of plants, *which utilize combined nitrogen only.* Combined nitrogen occurs naturally in coal, Chile saltpetre ($NaNO_3$), and in the proteins of plants and animals. Plants take in nitrogen as salts dissolved in the soil water. *Nitrates* (salts of nitric acid) are the most readily taken up, therefore the quickest acting. The *ammonium* of fertilisers is slower acting since it must be oxidized to nitric acid first. The free nitrogen of the air is the main source of the synthetic nitro-

genous fertilisers in common use to-day, e.g. ammonium nitrate (NH_4NO_3), ammonium sulphate ($(NH_4)_2SO_4$), calcium nitrate ($Ca(NO_3)_2$), calcium cynamide ($CaCN_2$).

(2) OXYGEN (O). Free oxygen is an element essential to all higher forms of life. It is the commonest element on the surface of the earth. By weight it constitutes about one-half of the commonest kinds of rocks (limestones, silicates), one-fifth of air, and eight-ninths of water. Chemically it is very active, and readily forms compounds with other elements. These compounds are called **oxides** and the process of their formation is known as **oxidation.** In some cases, oxidation goes by other names, e.g. *rusting* when oxygen joins with iron, *respiration* (breathing) when it joins with organic materials in the breathing of plants and animals, and *combustion* when substances are burnt. The chemical process is the same in all three cases; only the rate at which it proceeds is different. Rusting is really very slow burning in which the amount of heat produced is negligible. In respiration in mammals enough heat is produced to keep their bodies warm. In burning the chemical change is quick and produces much heat: and when it is violent we call it an explosion.

Thus, for a substance to burn, oxygen must be present. During burning, the substance combines with the oxygen and the product of combustion is the oxide of the original substance, e.g. hydrogen burns to give hydrogen oxide, which is water. The more oxygen present the more rapidly burning proceeds. So, on a cold day we open wide the damper on the boiler that heats our glasshouses in order that the draught may bring new air, therefore more oxygen, to the fire in a given time. Burning is most rapid in pure oxygen.

Now let us see what happens when coal is properly burnt in a boiler fire. Coal consists mainly of various **hydrocarbons** (i.e. compounds of hydrogen and carbon) together with compounds containing sulphur and nitrogen. When the coal is burnt the hydrogen, carbon and sulphur are oxidized to water, carbon dioxide and sulphur dioxide (SO_2) respectively. Not all of the hydrogen and sulphur are changed into water and sulphur dioxide. A little of the hydrogen unites with sulphur to give the gas hydrogen sulphide (H_2S), or with nitrogen to give ammonia (NH_3). If, however, oxygen cannot be obtained at a sufficient rate then combustion (oxidation) is incomplete. Carbon may escape completely unoxidized in the form of soot, partly oxidized as carbon monoxide (CO) or combined with hydrogen as hydrocarbons.

Apart from the wastage of fuel when combustion is incomplete (not to mention the pollution of the air), the heating efficiency of the fire is further reduced by the deposition of soot on the boiler, soot being a bad conductor of heat. We may note in passing that some of the ammonia formed when coal is burnt is found in the soot as ammonium sulphate and it is this which gives soot its manurial value (see p. 125).

(3) RARE GASES. These are chemically very inactive and have no concern with plants. One of them, **neon,** is sometimes used in horticultural irradiating lamps.

(4) CARBON DIOXIDE (CO_2). This compound of carbon and oxygen is continually being produced by the respiration of plants and animals, and by burning, It is also continually being used by plants for the manufacture of food. Carbon dioxide is heavier than air, and in the upper layers of the soil, where it is produced by the decay of plants, concentration increases with depth. Carbon dioxide, like nitrogen, will not burn and will not support combustion. It is slightly soluble in water, to which it gives an acid taste (e.g. soda water). In a solution of carbon dioxide in water a small part of the carbon dioxide combines with the water to form a weak acid, **carbonic acid** (H_2CO_3).

Indirectly, carbonic acid is of the greatest importance in plant nutrition. In the ordinary way, rocky materials are insoluble in water, but most of them are attacked by water charged with carbonic acid. By its aid rocks are broken down into clay and the locked-up potash and phosphate made available to the plants. *Carbonic acid is the great natural solvent.*

(5) WATER VAPOUR. Compared with the total mass of the air, the amount of water vapour it contains is very small, about 0·9 per cent by volume. Nevertheless, the influence of this water vapour, both on weather and on the growth of plants, is profound (see pp. 88–92).

Water (H_2O)

Pure water is a compound of the elements hydrogen and oxygen. We considered the properties of oxygen on p. 61. Hydrogen is the lightest substance known. It burns quietly if pure, explosively if mixed with air, but will not support combustion. It is insoluble in water. Natural water is never quite pure. Minute dust particles occur even in the purest air of the countryside, while over large towns the air is often polluted with soot and sulphurous matter. Some of this solid matter gets dissolved in the rain (e.g. sulphur dioxide) or is carried down by it (e.g. soot). Some air also is dissolved in the rain as it falls, about 2½ per cent by volume.

On reaching the earth, part of the rain water runs off the surface into streams and rivers. The rest sinks into the ground where two things happen. First, various mineral salts are dissolved, consequently all spring and well waters contain a proportion of these salts. Second, since the upper layers of soil are rich in carbon dioxide produced by the decay of plants, more carbon dioxide becomes dissolved in the water. The effects of this are considerable. *Chalk* (carbonate of lime, $CaCO_3$) is only slightly soluble in pure water, but the presence of a little carbonic acid increases the solubility of chalk to a marked degree; as a result, any chalk present in the soil is constantly being removed and carried away in the drainage water. On the average this loss varies from one to four hundredweight of *calcium oxide* (quicklime) per acre each year, according to rainfall and other factors, but in industrial areas, the acids washed into the soil from the atmosphere may greatly increase the rate of loss. To maintain soil fertility, the grower must make good this loss by periodically liming his soil (see p. 70).

The presence of calcium compounds such as *calcium sulphate* ($CaSO_4$) and *calcium bicarbonate* ($Ca(HCO_3)_2$) in water makes it **hard,** i.e. it does not readily give a lather with soap. Soap is a mixture of various sodium compounds, such as *sodium stearate*, and when it is mixed with hard water the calcium dissolved in the water unites with the stearate to give *calcium stearate* and prevents the making of a lather. Calcium stearate is insoluble in water and rises to the surface as a curd. Not until enough soap has been added to unite with all the calcium present will a lather be produced. The harder the water the more soap is needed to make a lather, consequently the degree of hardness can be measured in this way. *Magnesium* compounds may also cause hardness and what is said about calcium compounds may also be applied to magnesium compounds.

Hardness can be removed and the water softened by various methods. If the compound causing hardness is calcium bicarbonate, boiling will remove it thus:

$$Ca\,(HCO_3)_2 = CaCO_3 + H_2O + CO_2$$

Since the calcium carbonate formed is insoluble it settles out as "fur". Hardness which can be removed by boiling is known as **temporary hardness.** If the compound causing hardness is other than calcium bicarbonate—calcium sulphate for instance—it cannot be removed by boiling. Hardness which cannot be removed by boiling is said to be permanent. **Permanent hardness** can be removed by using sufficient soap, or by chemical action in a water softener. In Britain the **degree of hardness** is expressed as grains of carbonate of lime (or their equivalent) per gallon of water (70,000 grains).* Below

* The water companies in their analyses, however, refer to the amount of calcium carbonate (and other substances) present in the water in terms of parts per 100,000.

ten degrees of hardness the water may be called soft. Rain water is completely soft, the water of fresh-water lakes has a hardness of less than 10, spring water has a hardness of 25–50, while that of London's "mains" water obtained from the Thames, is about 17·5.

Hard water is objectionable for the preparation of sprays containing soaps, since the curd produced is apt to clog the spray nozzle and the spreading properties of the spray are destroyed. Decorative glasshouse plants should not be syringed with hard water because it leaves an unsightly deposit on the leaves. Temporary hardness is responsible for furring up the insides of boilers and hot-water pipes. The fur is a bad conductor of heat and consequently more fuel has to be used to heat the water and pipes.

Acids

We have seen that many elements combine with oxygen to form oxides (p. 61). These fall into two classes according to whether the combining element is a metal or a non-metal: thus we get **metallic oxides** and **non-metallic oxides.** Most non-metallic oxides combine with water to yield **acids,** hence another name for them is **acidic oxides,** i.e. acid-forming oxides. *All acids contain hydrogen* (e.g. carbonic acid (H_2CO_3), hydrochloric acid (HCl), nitric acid (HNO_3)), and it is characteristic of acids that *part or all of this hydrogen can be replaced by a metal.* All acids have a sharp or "acid" taste (e.g. vinegar, lemon juice), and turn a purplish vegetable substance, called litmus, red.

Bases

Another name for metallic oxides is **basic oxides.** Not all basic oxides are soluble in water but any one that is, is said to form an **alkali** with water and the solution is termed **alkaline.** Alkaline substances turn litmus blue. In general, we may say a base is a metallic oxide, *the metal of which can be exchanged with the hydrogen of an acid.* An example is calcium oxide (CaO).

Salts

We saw that all acids contain hydrogen, and all bases replaceable or exchangeable metal. Now if we add an acid to a base, the two substances react chemically: the hydrogen of the acid is replaced, partly or wholly, by the metal of the base and a new compound is formed called a **salt.** Water is a by-product of this reaction. A salt does not taste acid and usually does not affect litmus paper. It is then said to be **neutral** and the acid is described as neutralizing the base. From this we can see that another way of defining bases is to say that they are *substances which react with acids to give salts and water.*

In general terms:

$$\text{Acid} + \text{Base} = \text{Salt} + \text{Water}$$

Examples of salt formation are:

$$\underset{\text{(carbonic acid)}}{H_2CO_3} + \underset{\text{(calcium oxide)}}{CaO} = \underset{\text{(calcium carbonate)}}{CaCO_3} + \underset{\text{(water)}}{H_2O}$$

It should be noted in passing that the gas called ammonia (NH_3), although it contains no metal, forms an alkaline solution with water, i.e. its solution behaves like a base.

The name of the salt of a particular acid is derived from the name of the acid. Thus:

Nitric acid forms salts called *nitrates*
Sulphuric acid forms salts called *sulphates*
Carbonic acid forms salts called *carbonates*
Phosphoric acid forms salts called *phosphates*
Silicic acid forms salts called *silicates*

The first word in the name of a salt indicates the base, the second indicates the acid, e.g. sodium nitrate ($NaNO_3$), ammonium sulphate ($(NH_4)_2SO_4$).

We have seen that rain water percolating downwards through the soil becomes a weak salt solution. Actually, all plant food-materials taken in by the root hairs are in the form of weak solutions of salts, in the form of ions (see p. 71), such as *calcium phosphate* and *calcium nitrate.* Many artificial fertilisers also are salts, e.g. ammonium sulphate, sodium nitrate, potassium sulphate.

Soil

We shall briefly consider the chemistry of the soil under the headings, sand, clay, humus and chalk, since these are the main ingredients of fertile soils.

Sand

Sand is a form of *silica* (SiO_2). **Silicon** is the second most abundant element in the earth's crust, amounting to about 26 per cent. It never occurs in the free state but always combined with oxygen as silica or **silicates.** *Quartz* and *flint* are familiar forms of silica; grains of ordinary sand and sandstone consist chiefly of quartz.

Clay

Clay is a compound of silica, *alumina* (aluminium oxide) and water. **Aluminium** is the third most abundant element in the earth's crust, 7 per cent by weight. It occurs naturally in the form of silicates, e.g. **felspar** and **mica** which after weathering become clay. In the weathering process, water becomes combined with the silicate. Clay therefore may be described chemically as a *hydrated silicate of aluminium.*

Clay has properties which make it indispensable to soil fertility. First, the bulk of it occurs in colloid form, and in this state it has unusual physical properties (p. 67). Second, while larger mineral particles such as silt and sand are chemically inert, the colloidal clay readily takes part in certain chemical reactions. The clay particle contains near its surface bases such as calcium, magnesium, potassium, sodium and ammonia, but in water-insoluble forms. These substances, however, can be made available to plants through the reaction called **base exchange.**

BASE EXCHANGE. When colloidal clay is brought into contact with a salt solution (e.g. soil water) there is an immediate exchange of bases; some of the base from the salt joins the clay, while the clay gives up an equivalent amount of bases which form new salts in solution. For example, if the clay contains a potassium base, then the bases may exchange in the following way:

$$\left.\begin{array}{l}\text{Clay and}\\ \text{insoluble}\\ \text{potassium}\end{array}\right\} + \left\{\begin{array}{l}\text{salt and}\\ \text{soluble}\\ \text{calcium}\end{array}\right\} = \left\{\begin{array}{l}\text{clay and}\\ \text{insoluble}\\ \text{calcium}\end{array}\right\} + \left\{\begin{array}{l}\text{salt and}\\ \text{soluble}\\ \text{potassium}\end{array}\right.$$

This behaviour is of great importance to the gardener. By applying a dressing of lime he can set free the insoluble potassium which occurs naturally in a clay soil, and make it available to his plants. It is as if the clay acts as a bank where plant-food currency can be exchanged—you pay in lime and take out potash. The reverse happens, too. Thus, if sulphate of ammonia is applied as a fertiliser, the ammonium base may replace insoluble calcium, which, becoming soluble is *leached* (washed) out in the drainage water. Consequently, though the ammonium is safely deposited in the bank, continued applications of sulphate of ammonia may lead to a decrease in fertility due to the loss of calcium and a corresponding increase in soil acidity (see p. 71). Again, if sodium nitrate is applied to the soil, the sodium may replace the calcium base of the clay to the detriment of the soil, sodium clay being much wetter and poorer in tilth than a calcium clay. We can summarize the above remarks as follows. By base exchange:—

1. The natural store of insoluble potash in clay can be made available to plants by applying lime to the soil.

2. Sulphate of ammonia and sulphate of potash, which are soluble in water, are retained by the clay, where otherwise they would be lost in the drainage water. They can be liberated again and made available to the plant under appropriate conditions.

We may note in passing that dissolved *phosphoric acid* is also retained by colloid clay—though not in the same way as potassium and ammonium.

Humus

Humus is the name given to decayed vegetable (and animal) matter which has decomposed sufficiently to have lost its original structure and become a brown or blackish mass, e.g. well-rotted horse manure and leaf mould. Although very different chemically from clay, humus behaves in a similar way as regards base exchange. Indeed, the colloidal part of fertile soil is composed of clay and humus intimately mixed, the two together being referred to as the colloidal complex. So all that has been said about base exchange in clay also applies to humus, only more so, since humus has an exchange capacity roughly six times that of clay. As humus decays it yields carbon dioxide, which, dissolved in the soil water, attacks the mineral particles and makes available the potash and phosphate they contain.

Chalk

Chalk is a compound of calcium. Calcium occurs in nature as *carbonate* (chalk, limestone, marble), *sulphate* (gypsum), *silicate* (in clay) and *phosphate*. **Marble** is a crystalline and fairly pure form of calcium carbonate; **limestone** and **chalk** are impure and less crystalline; **marl** is a mixture of chalk with considerable amounts of clay. Since calcium compounds are important in horticulture we must consider them in detail.

CALCIUM OXIDE (CaO), called **quicklime,** is manufactured by heating limestone ($CaCO_3$) in kilns, thus driving carbon dioxide off and leaving calcium oxide behind:

$$CaCO_3 \longrightarrow CaO + CO_2$$

Exposed to the air, quicklime absorbs water vapour and carbon dioxide and slowly crumbles into a powder of calcium hydroxide and calcium carbonate.

CALCIUM HYDROXIDE ($Ca(OH)_2$). When water is poured on quicklime it is changed into a powder, **calcium hydroxide** or **slaked lime** (hydrated lime), with considerable evolution of heat and increase of volume:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

Slaked lime is only slightly soluble in water, about one part in six hundred; the solution is known as lime water. If slaked lime is stirred up with only enough water to give a thin paste, it forms a suspension called milk of lime.

CALCIUM CARBONATE ($CaCO_3$). The two chief types used in horticulture are **ground limestone** and **chalk.** Calcium carbonate is practically insoluble in pure water. In water containing carbon dioxide it dissolves to some extent, forming calcium bicarbonate ($Ca(HCO_3)_2$).

Good quality burnt lime, hydrated lime, and carbonate of lime contain respectively about 95, 70, and 50 per cent by weight of calcium oxide.

Lime, in whatever form it is added to the soil, is rapidly converted to calcium carbonate. Some of it may then, by base exchange, become loosely attached to the clay and humus molecules. This lime is called "free," "active," or **exchangeable** lime.

This exchangeable lime is the all-important factor in soil fertility and controls the nature of the soil water, the amount of calcium available to plants and micro-organisms, the availability of fertilisers and tilth of the soil. Loss of exchangeable lime results in increasing soil acidity. Hence it is important always to have a reserve of calcium carbonate present in the soil, from which loss of exchangeable lime can be made good. The soil is said to be *saturated* with exchangeable lime whenever there is a surplus of calcium carbonate.

Soil Acidity

Soil water may be neutral, or acid or alkaline in varying degree. This is because it contains varying proportions of *hydrogen* (H) ions and *hydroxyl* (OH) ions. **Ions** are electrically-charged atoms or groups of atoms. A solution that is neutral contains equal numbers of hydrogen and hydroxyl ions; an acid solution contains more hydrogen than hydroxyl ions, and the greater this excess the greater the acidity; an alkaline solution contains more hydroxyl than hydrogen ions and the greater the excess the greater the alkalinity.

A special logarithmic scale is used to measure these differences, called a *p*H scale. It consists of 14 divisions known as *p*H units. Neutral is 7; values from 7 to 0 constitute the *acid* range and values from 7 to 14 the *alkaline* range. The *p*H value of a soil indicates, not its total acidity or alkalinity, but the *intensity* (degree) of acidity or alkalinity. Thus a clay soil and a sandy soil having the same *p*H values require widely different amounts of lime for neutralization. Other factors also affect the lime requirements of soils, e.g. the organic matter content. A rough idea of the extent of these differences between soils will be given by the following table. The figures refer to the number of pounds of burnt lime required per acre, to change the soil reactions by 1·0 *p*H.

TABLE II

Type of soil	*Organic Matter Content*	
	Low (1%)	*High* (*peaty*)
Sandy	500	1500–3000
Loamy	2000	4000
Clayey	3000	4500

The *p*H values of cultivated soils range from 4 to 8, the great majority falling between 5·0 and 7·5. The majority of plants will tolerate a *p*H range of 1·0 and do best in soils between *p*H 5·5 and 6·5, i.e. in slightly acid soils. Most cuttings root best in a slightly acid medium.

Nitrifying organisms (see p. 122) decline in activity when the *p*H of the soil is below 5·5, hence acid soils may be deficient in available nitrogen. Phosphates are most available between *p*H 5·5 and 7·5. Above and below this range they unite with various soil substances to form insoluble or poorly available compounds. In very acid soils the amount of available calcium and magnesium is too small for good plant growth. The acidity of the soil also affects the growth of soil fungi and bacteria, e.g. club-root of brassicas is most common in soils with a *p*H between 5·5 and 6·3. The nitrogen fixing bacteria in some legumes do not thrive when the *p*H is less than 6·5.

Plants

Plants consist of a number of compounds, of which four types are specially important.

CARBOHYDRATES

These organic compounds are built up from carbon, hydrogen, and oxygen, the hydrogen and oxygen being in the same *proportion* as they are in water, namely two atoms of hydrogen to one of oxygen. Thus, a molecule of **cane sugar** can be represented as $C_{12}H_{22}O_{11}$ and a molecule of **glucose** as $C_6H_{12}O_6$. **Starch** and **cellulose** (the substance of which all cell-walls are made) are examples of another type of carbohydrate in which each molecule is built up of a number of sets of $C_6H_{10}O_5$. Sugar and starch are found in all green plants and only green plants can make them (see photosynthesis, p. 114).

Oils and Fats

The oils and fats are also made up of carbon, hydrogen, and oxygen, but unlike the carbohydrates the hydrogen and oxygen are not in the proportions of water. In fact, the oils and fats have quite different properties from carbohydrates and they are not so important from our point of view.

Proteins

The proteins of plants and animals are organic compounds consisting of nitrogen, carbon, hydrogen and oxygen, together with a little sulphur and sometimes phosphorus as well. There are many kinds of protein, containing varying numbers of the atoms of these elements, but all proteins are built up from simpler substances called **amino acids** (of which there are a number of kinds) arranged end to end in long chains. Thus, the protein molecule is not only very complicated, but a giant. Protein is the most important constituent of protoplasm.

Enzymes

These are complex organic compounds containing nitrogen. They have the remarkable property of being able to produce chemical reactions in other bodies without undergoing permanent change themselves. A substance which can do this is called a **catalyst** and is said to catalyse the body it affects.

Most enzymes catalyse one substance only. **Diastase** is an enzyme which, in plants, brings about the breakdown of starch into a sugar. Chlorophyll is a further example of a substance which may be regarded as a catalyst.

Chapter Ten

ABOUT MATTER: PHYSICS

PHYSICS may be defined, for our purpose, as the study of the *properties and behaviour of matter in the mass:* the study of bodies as bodies. It deals with all the changes matter may undergo *without alteration to its composition* (cf. chemistry).

MATTER

Matter is the stuff things are made of and may be defined as anything that has **weight.** A **body** is the name given to a portion of matter.

PROPERTIES OF MATTER

(1) MATTER OCCUPIES SPACE and usually affects one or more of our senses.

(2) MATTER CAN EXIST IN DIFFERENT FORMS: (*a*) *solid*, having definite shape and volume; (*b*) *liquid*, having definite volume, but taking the shape of the containing vessel; (*c*) *gaseous*, taking both shape and volume of the containing vessel. Gases, if free, expand almost indefinitely.

(3) MATTER CANNOT BE DESTROYED OR CREATED. This is known as the *law of conservation of matter.*

(4) MATTER IS DIVISIBLE TO A LIMITED EXTENT, i.e. into molecules and atoms.

(5) MATTER IS POROUS AND COMPRESSIBLE TO VARIOUS EXTENTS. This and the previous statement follow from the atomic nature of matter (see p. 53).

(6) MATTER IS ELASTIC. Any substance can be altered in shape and volume by applying force. When this force

is released the substance tends to recover its original shape and volume; i.e. matter opposes change of shape and/or volume.

(7) MATTER POSSESSES INERTIA. Force must be applied to make it move or to change its motion.

(8) MATTER SHOWS PARTICULATE ATTRACTION. All bodies, from the smallest atoms to the largest stars, are attracted to one another by the force of **gravitation.** For instance, a stone "falls" to earth. The strength of this attraction decreases with the square of the distance separating the bodies, and increases with their masses. Thus, while the stone (of small mass) is obviously attracted to the earth (of large mass) we do not notice the attraction between two flower pots standing side by side: the vertical gravitational attraction of the earth is so strong by comparison that it completely masks the slight horizontal attraction between the pots.

When particles are very close together, as in the case of the atoms of a body, the force of attraction is exceedingly strong and the collection of atoms behaves as one rigid body; e.g. a piece of iron.

Cohesion

The attraction between particles of the *same* kind is called **cohesion;** solids would crumble to powder and drops of liquid would not run together if it were not for cohesion. Cohesion is greater in solids than liquids and greater in liquids than gases. In fact, gases show no cohesion at all.

Adhesion

The attraction between molecules at the surfaces of two substances (similar or dissimilar) in close contact, is conveniently distinguished as **adhesion.** Thus, a dew-drop on the waxy leaf of a cabbage retains its globular shape because cohesion between the water particles is greater than adhesion between the surfaces of the water and leaf.

Inability to wet leaves would be a serious drawback in the application of insecticides and fungicides, therefore it is common practice to add a **spreader** to water-soluble sprays to give better wetting, spreading and penetrating properties than those of water alone. These spreaders act by lowering the surface tension (see below) of the water, thereby giving better adhesion between spray and leaf. **Soft soap, saponin,** and **casein** are examples of water-soluble spreaders. Certain oils have a high spreading efficiency and are used as carriers of insecticides.

Surface Tension

A drop of water hanging from a sheet of glass, clings to it because of the adhesion between the adjoining molecules of water and glass. Quite apart from this, however, the drop behaves as if it were surrounded by an elastic skin or membrane. This is because the molecules lying side by side in the surface of the water cling to one another (cohere) so that *the surface contracts into the smallest possible area for a given volume*, i.e. it becomes *spherical* in so far as its own weight permits.

Capillarity

If the amount of liquid in a drop of water is steadily increased, the drop elongates more and more, becomes dumb-bell shaped, and finally the narrow neck breaks and the drop falls under the influence of gravity. The smaller the drop, the less the influence of gravity compared with that of surface tension. This may be clearly seen in another connection. If a number of fine glass tubes of different bore are dipped into water, the water visibly rises in them to varying heights (Fig. 2); *the finer the bore the higher the water rises.* Actually the curved water surface extends, as an invisible film, all the way up the tube, the film becoming thinner towards the top. The curve of the water surface is called a **meniscus.** The reason for this curvature is that the *contracting* force at the surface of the water (surface tension) exerts an upward pull against the downward pull (gravity) of the column of water, and the water is drawn up the tube until the two forces counter-balance. This rise of water in fine tubes is said to be due to **capillary attraction.** It will occur in any very fine channel or crevice, e.g. soil water will move upward in the crevices between the fine particles of soil and is firmly held there. The finer the crevices the more firmly is the water held. Hence, soil water not only rises higher by capillary attraction in a clayey (fine-grained) soil than in a sandy (coarse-grained) one, but it is held more tenaciously by the clayey soil than by the sandy. Clay soils are therefore more difficult to drain than sandy.

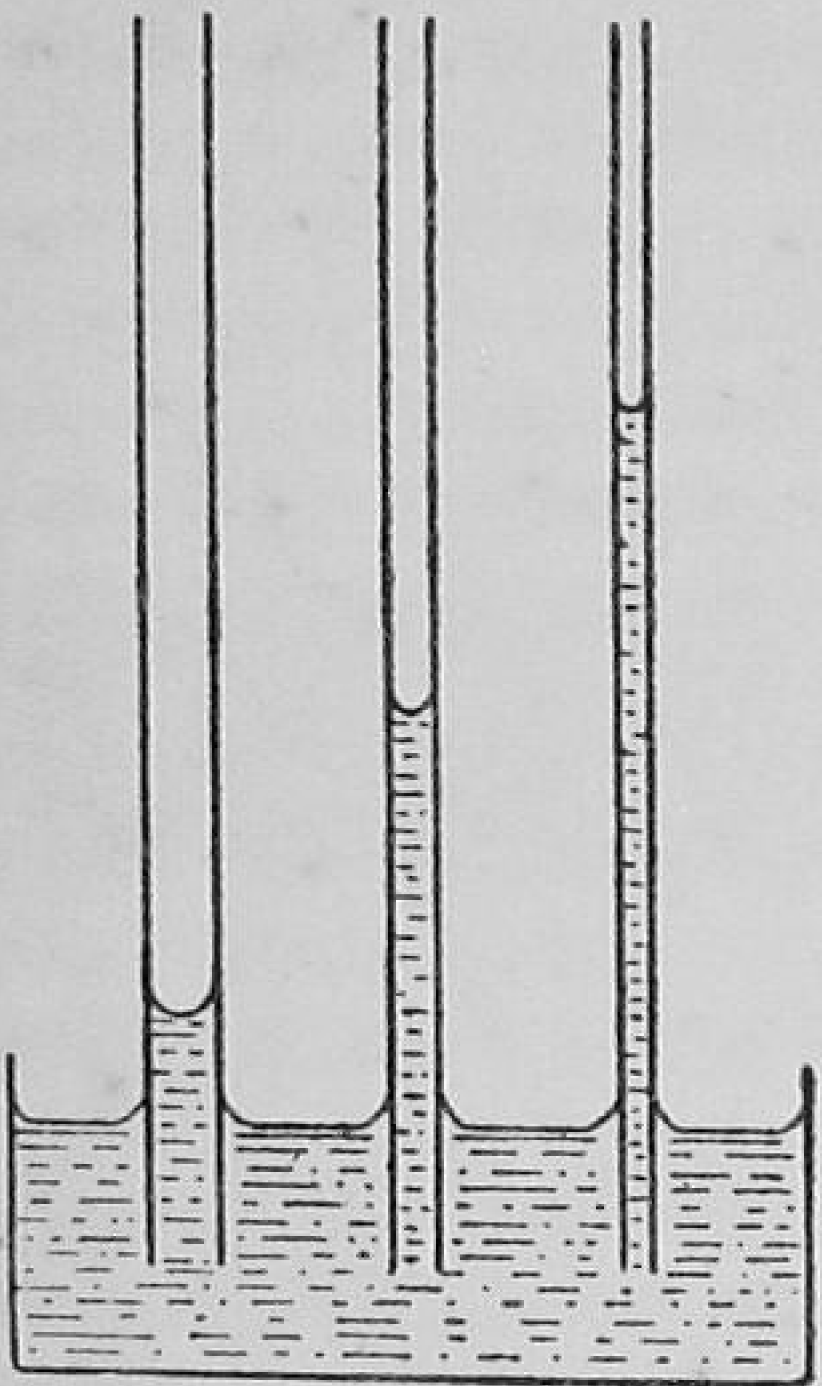


Fig. 2. THE RISE OF WATER IN CAPILLARY TUBES

The water wets the glass, consequently the meniscus is concave in shape.

It should be emphasized here, that water is drawn up by capillarity from the underground **water-table** (i.e. the permanent level of the water in the ground) *only two or three feet at the most*. This is because the fine crevices between the soil particles are not uniform in diameter like the bore of a glass tube, but irregular in shape, consisting of more or less spherical **pore-spaces** of all sizes connected by narrow necks. In consequence of this arrangement, water in the soil resists being moved. Thus, as water is absorbed by roots or lost by evaporation from the upper layers of the soil, there is no large capillary movement to replace it from the deeper levels. Lateral movement is similarly restricted. Roots therefore must ramify extensively and search for water; it won't come to them.

MEASUREMENT OF MATTER

Measurement is the basis of all *exact* knowledge. The fundamental units of measurement are those of *weight*, *length* and *time*. You should know the British and Metric units of measurement.

BEHAVIOUR OF MATTER

Mass is the **quantity of matter** in an object and does not change. *Weight* is the **force of attraction** between an object and the earth: this force (gravity) may vary slightly for the same mass from place to place and should not be confused with mass.

RELATIVE DENSITIES. Different substances of the same mass or weight, may occupy different volumes; e.g. a pound of iron occupies less space than a pound of water. This is because the particles of iron are packed closer and are heavier than those of water: iron, we say, is *denser* than water.

SPECIFIC GRAVITY. The relative density of a substance compared with that of water is called its **specific gravity,** and denotes how many times the substance is denser than water. Thus, the specific gravity of water is 1·0, wrought iron 7·8, aluminium 2·7, methylated spirits ·83, air ·0013.

AIR PRESSURE. The particles of all substances, solid, liquid, or gas, are attracted towards the earth by its gravitational force. Thus, the air, which surrounds the earth to a depth of some 200 miles, presses down with an average weight of 14·73 lb. on every square inch of surface at sea level. Air pressure is measured by the **barometer.** There are two kinds of barometer, **mercury** and **aneroid.** Both work on the same principle.

In the *mercury barometer* a glass tube, a yard long and closed at one end, is filled with mercury and then inverted, open end downward, in a bowl of mercury, taking care that none of the liquid in the tube escapes in the process (Fig. 3). The mercury in the tube is therefore free to run down into the bowl Actually it will be found that only a few inches run out, leaving an empty space at the top of the tube and about 29 to 30 inches of mercury between this space and the mercury in the bowl. The space contains no air, and is a *vacuum*. The mercury in the tube cannot run out since the downward pressure of the air on the mercury in the bowl counterbalances the weight of the mercury (14 to 15 lb. per square inch in the tube). Thus the *height* of the mercury in the tube is a measure of the pressure of the air.

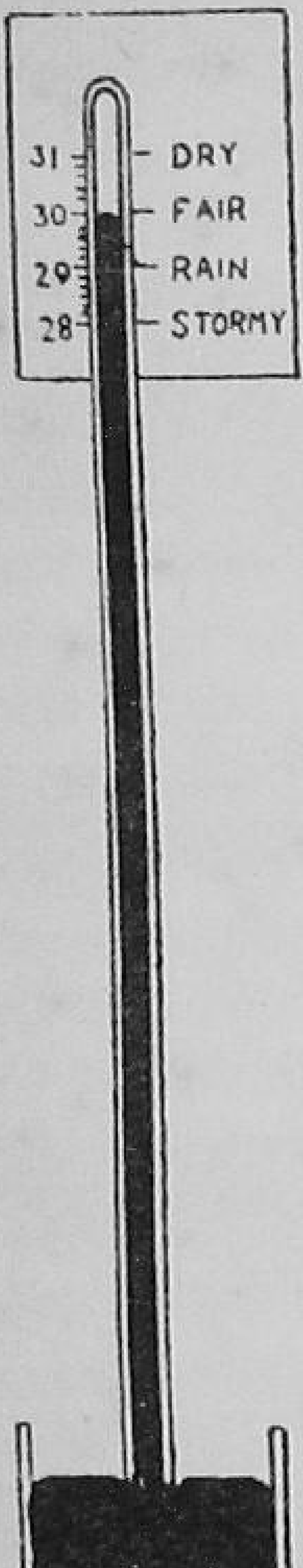


Fig. 3. MERCURY BAROMETER

The mercury does *not* wet the glass, consequently the meniscus is convex in shape.

The *aneroid barometer* consists of a flat, air-tight metal box which has been exhausted of air (Fig. 4). Thus there is an excess of air pressure on the thin, corrugated metal diaphragm forming the top of the box and a strong spring has to be used to support the diaphragm and balance the atmospheric pressure. Any changes in this pressure cause small movements of the diaphragm and these are magnified by a system of levers joined to a pointer which rotates round a dial.

Barometers are used chiefly to predict changes of the weather. In general when the air pressure is steadily decreasing (i.e. the barometer is "falling") the weather is likely to deteriorate; when it is steadily increasing (i.e. the barometer is "rising") the weather is likely to improve.

The working of the common water pump also depends on air pressure. On the downstroke, the piston valve (Fig. 5) opens under the pressure of the air underneath it, the shaft valve remaining closed. On the upstroke the weight of the piston valve keeps it closed, and air pressure in the barrel is thereby reduced. The atmospheric pressure on the surface of the water in the well is now greater than the air pressure within the barrel, consequently water rises up the shaft and passes through the shaft valve. After a stroke or two sufficient water will have risen to fill the barrel with water. On the next downstroke the water passes up through the piston valve, and on the following upstroke the piston valve closes and the water is lifted by the piston and flows through the spout.

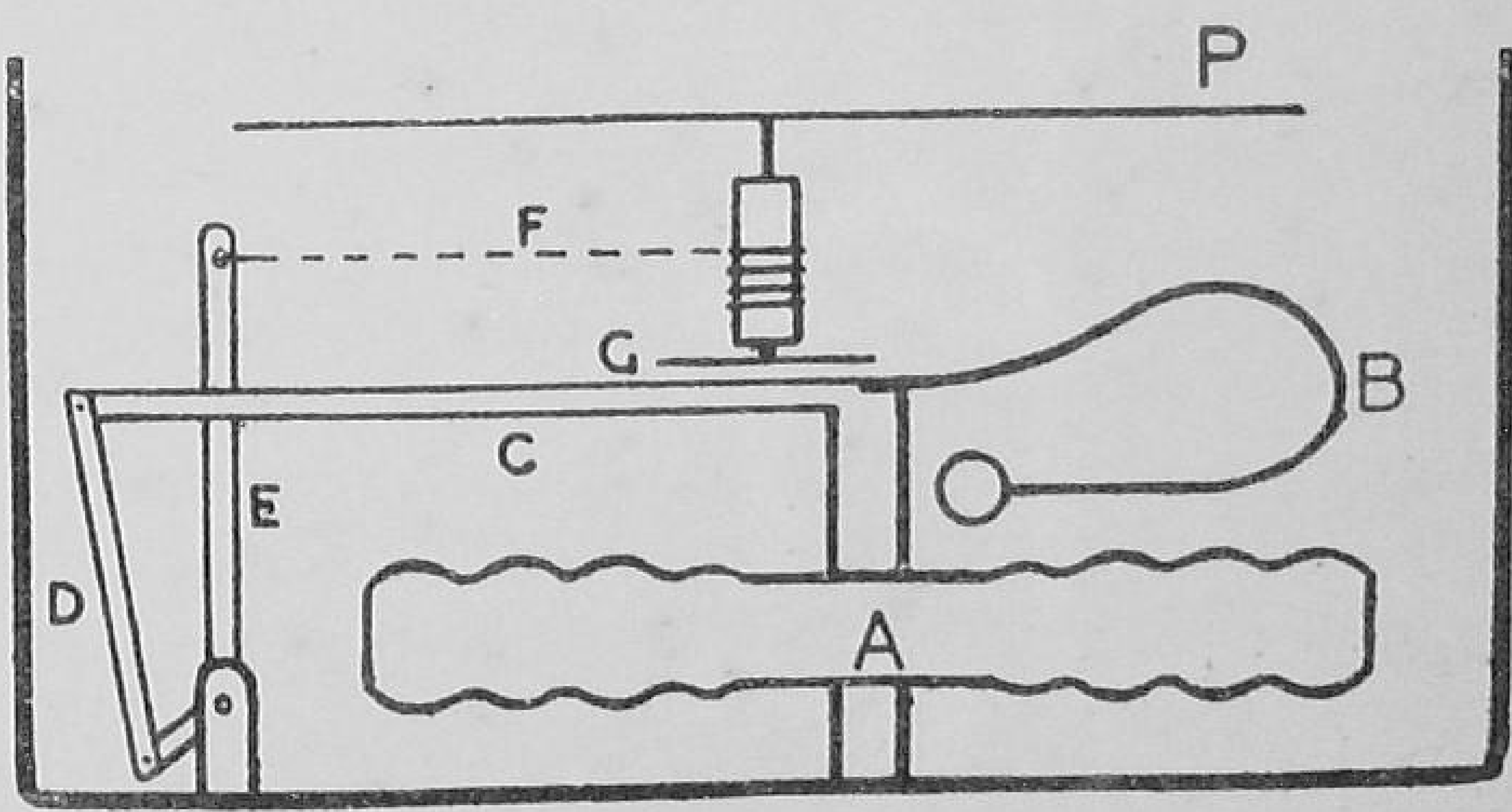


Fig. 4. ANEROID BAROMETER

A. Corrugated metal box exhausted of air. B. Strong spring supporting diaphragm of box. C. Rod attached solidly to spring and diaphragm. D. and E. Levers multiplying motion of diaphragm. P. Pointer. F. Fine chain connecting levers to spindle of pointer. G. Clock spring to keep chain taut.

ENERGY

Matter that can do work is said to have energy. Energy may exist in different forms and may be changed from one form to another. Thus, the **light** energy of the sun is stored

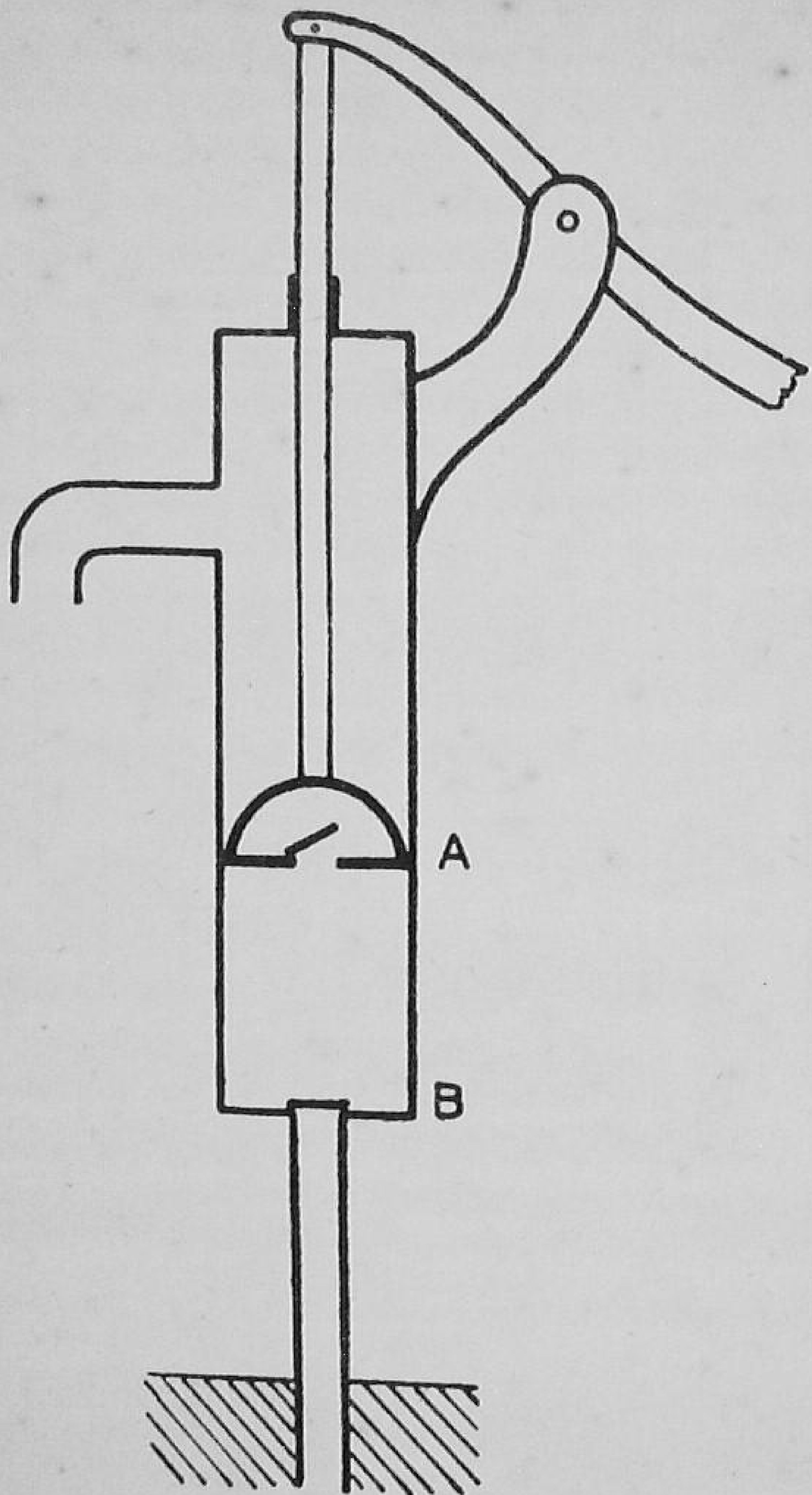


Fig. 5. THE COMMON PUMP

A. Piston valve.
B. Shaft valve.

up chemically by plants, and by coal which is derived from plants. When coal is burnt this chemical energy is released as **heat,** which can then be changed into the **kinetic** energy (energy of motion) of the steam-engine. By coupling a dynamo

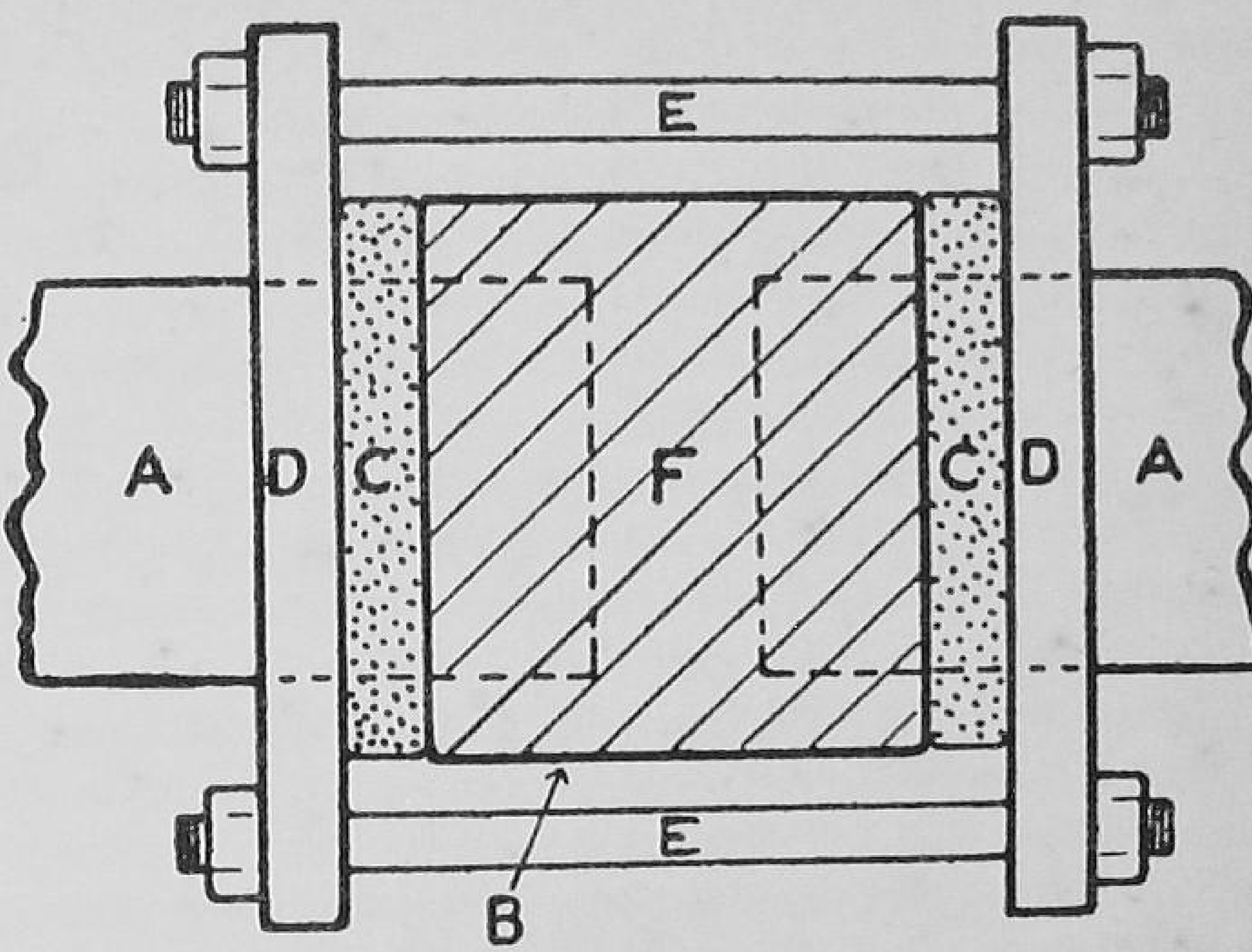


Fig. 6. EXPANSION JOINT

A. Hot-water pipes. B. Iron ring (cross hatched) fitting over ends of pipes. C. Rubber bands circling hot-water pipes. D. Iron collars. E. Bolts. F. Space between ends of pipe for expansion. When bolts are tightened up, the collars, band and ring are pulled together and make a water-tight joint.

to the steam engine, kinetic energy is changed to **electrical** energy and finally, in the electric lamp, electrical energy is changed back again into heat and light. *Energy can never be destroyed or created;* the total amount remains unchanged.

HEAT

In this book we are concerned with two forms of energy only, *heat* and *light* (see p. 104). The atoms and molecules of which all substances consist, are always in motion. The greater this motion the greater the heat of the substance. Heat, like other forms of energy, is invisible, but some of the changes it produces in matter can be studied. These effects of heat are given below.

Effects of Heat

(1) CHANGE OF DIMENSIONS. Nearly all solids, liquids and gases expand on heating and contract on cooling. For example, a length of cast-iron hot-water pipe which measures 100 feet long at 32° F., increases $1\frac{3}{8}$ inches in length when heated to 212° F. If this expansion is not allowed for it might fracture the pipes, so expansion joints (Fig. 6) are often used to connect hot-water pipes. In tropical regions, where it is extremely hot by day and cold by night, the alternate expansion and contraction of rock surfaces eventually results in their disintegration.

The behaviour of water is unusual and of special importance. When water is cooled down from 100° C. it contracts until its temperature is 4° C. (39·2° F.), but below this it *expands* again and continues to do so until it freezes at 0° C. (Fig. 7). Water increases in volume by nearly $\frac{1}{16}$th (6·4 per cent) when it freezes. This expansion is of great consequence to the gardener. In winter time, the frequent freezing of water in rock and soil crevices disintegrates the material, (*a*) gradually turning rocks into soil, and (*b*) producing a good tilth. Pipes are burst by the expansion of water on freezing.

(2) CHANGE OF TEMPERATURE. Temperature is the *degree of "hotness"* of a body and is not to be confused with *amount* of heat (see Measurement of Heat).

THERMOMETER. To measure temperature a thermometer is used. A typical thermometer consists of a thick-walled glass tube with a fine bore, blown out into a bulb at one end and sealed off at the other. The bulb and part of the stem contain either mercury or alcohol, while the rest of the stem is empty except for mercury or alcohol vapour. When the thermometer is placed in contact with a hot body the mercury (or alcohol) expands and rises in the stem; in contact with a cold body the mercury contracts and falls in the stem.

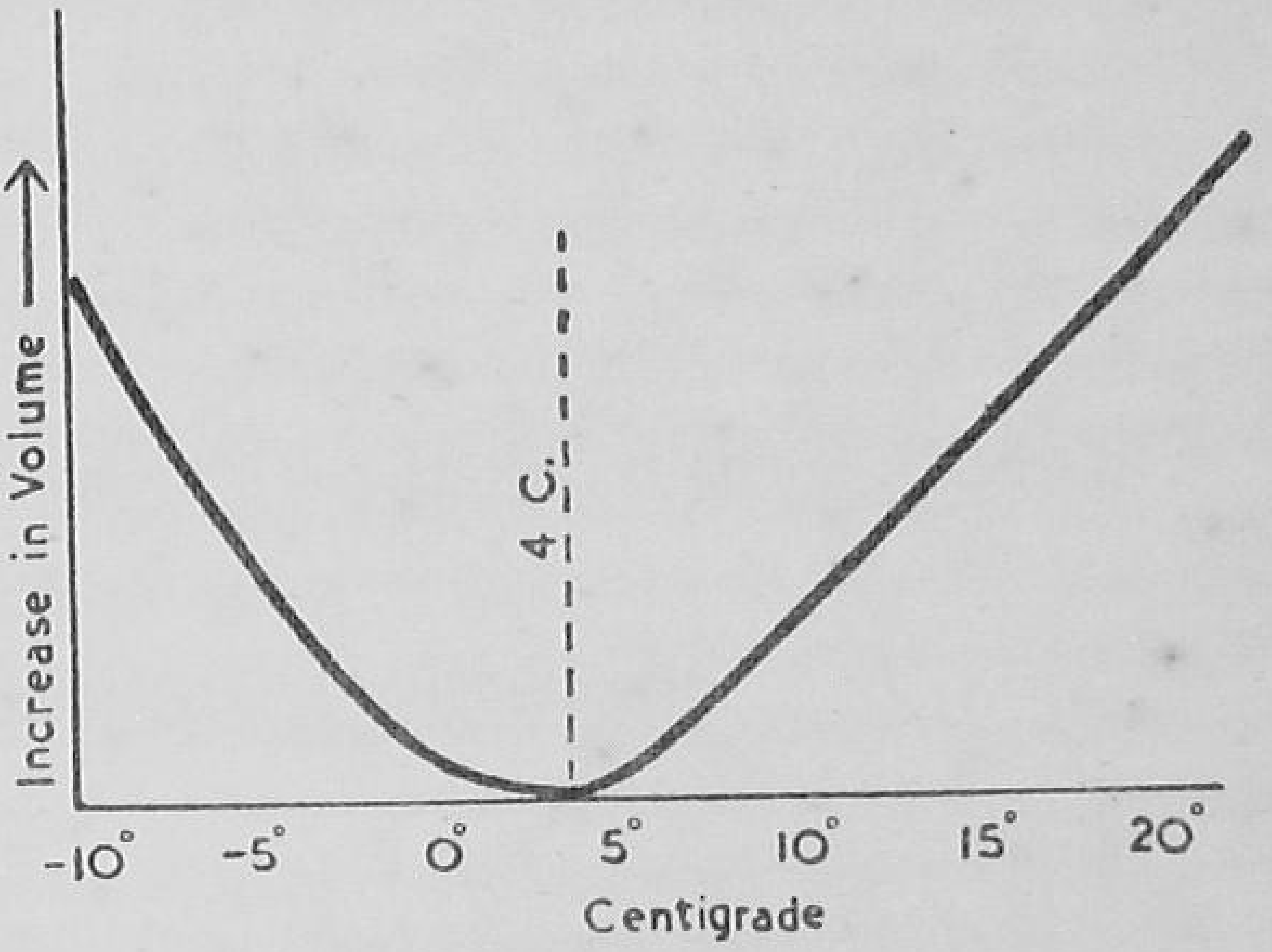


Fig. 7. Showing the expansion of water, between 4° C. and 0° C. (freezing point)
By taking special precautions, water may be cooled to —10° C. without freezing, expansion continuing as the temperature falls.

In order that thermometers should always agree in the temperatures they register the levels of the mercury must be marked at two definite standard temperatures, namely the temperatures of (*a*) pure melting ice, and (*b*) steam from pure water boiling at standard atmospheric pressure, 29·9 inches. The levels of the mercury at these two temperatures are known as **fixed points** and the distance between them is divided up into equal parts or **degrees.** Two scales of temperature are in common use. The **Centigrade** thermometer is marked 0° at freezing point and 100° at boiling point, and the **Fahrenheit** thermometer 32° at freezing point and 212° at boiling point.

In the maximum thermometer the expanding mercury pushes a small steel or glass "index" in front of it, but on contracting it leaves the index behind. Hence the end of the index *nearer* the bulb of the thermometer marks the highest temperature reached.

In the *minimum* thermometer, alcohol is used instead of mercury. As the alcohol expands, it flows past the index and leaves it behind, but when it contracts the surface of the alcohol drags back the index. Thus the end of the index *farther* from the bulb marks the lowest temperature reached. Mercury is not suitable for a minimum thermometer because its high surface tension will not allow it to flow past the index or to drag it back.

Both maximum and minimum thermometers can be reset with a magnet (steel index) or by gently tapping or shaking the instrument (glass index).

The combined *maximum and minimum thermometer* (Fig. 8) consists of a U-shaped glass tube, with sealed bulbs at each end. Bulb A is filled with alcohol which extends down the tube to B. From B to C there is a thread of mercury and from C to D alcohol again. The alcohol in D does not fill the bulb, a space being left for expansion. The thermometer is worked by the expansion and contraction of the alcohol in A. When the temperature rises, the alcohol in A expands, flows past the steel index in the left-hand tube and pushes the mercury round. This in turn pushes the index in the right-hand tube to the highest temperature occurring, the lower end of the index indicating the *maximum* temperature. When the temperature falls, the alcohol in A contracts, the mercury follows it back, pushing the index in the left-hand tube to the lowest temperature, the lower end of this index indicating the *minimum* temperature. Light springs (Fig. 8, E) are attached to the indexes to stop them slipping under their own weight, but these springs are not strong enough to prevent the mercury from pushing the indexes along the tubes. The thermometer is set by applying a small magnet to the outside of the tube and drawing the indexes down on to the mercury. The alcohol in the right-hand tube

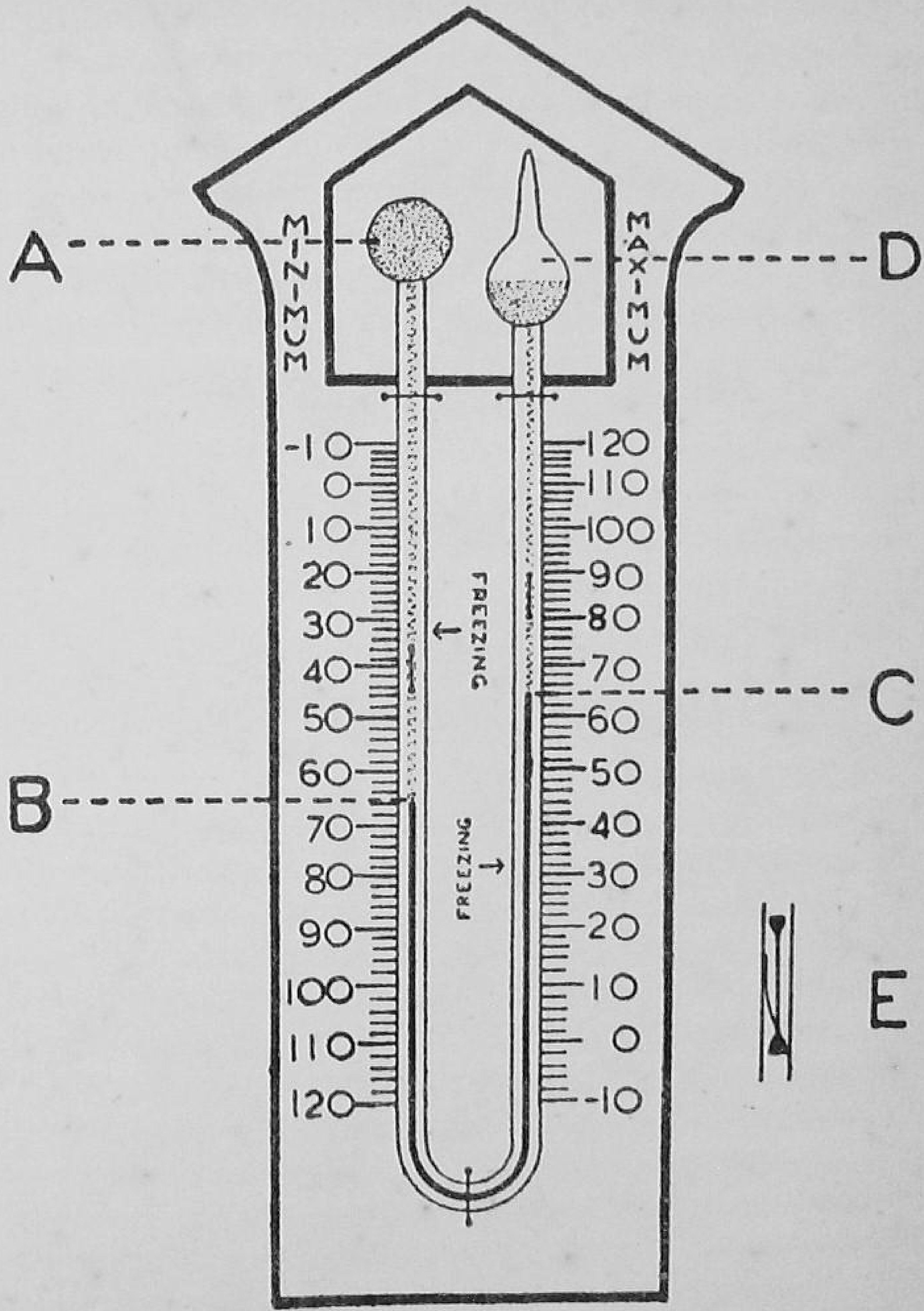


Fig. 8. MAXIMUM AND MINIMUM THERMOMETER

is there to balance the weight and vapour pressure of the other alcohol; it takes no part in the actual working of the thermometer.

(3) CHANGE OF STATE. Matter may exist as solid, liquid, or gas, the actual state depending on the temperature and pressure of the substance; e.g. above 100° C. water is gaseous, between 100° C. and 0° C. it is liquid, below 0° C. it is solid. The upper and lower temperatures at which matter sharply changes its state are known respectively as (*a*) the boiling point of the liquid, and (*b*) melting point of the solid (or freezing point of the liquid).

The following examples bear on horticulture:

Liquid to solid. The freezing of water at 0° C.

Liquid to vapour.

(*a*) By boiling; e.g. the boiling of water at 100° C. to produce steam for soil sterilization.

(*b*) By evaporation.

EVAPORATION. The molecules in substances are always moving (comparatively slowly in solids, rapidly in liquids), and collisions between the molecules are frequent. As a result, at any given moment some molecules are moving faster than others. The attraction between molecules ensures that the great majority of them cannot move out of the substance, but the fastest molecules may have sufficient velocity to shoot from the surface into the air. In liquids this process is called **evaporation** and it explains why pools of water disappear at ordinary air temperatures. Evaporation goes on at all temperatures, the rate depending partly on the temperature of the water. (When we heat water to boiling point we are merely accelerating the process.) The consequences of evaporation are of the greatest importance to the gardener (see vapour to liquid). It is also the end process by which water is **transpired** (given off) from the leaves of plants. Glasshouses are "damped down" in order that the water may evaporate, make the air moister, and thus check transpiration. It should be noted here that, since only the fastest molecules escape from an evaporating liquid, the slower ones must remain. Now the temperature of a body depends on the rate at which its molecules are moving, therefore evaporation produces cooling. (Rapid evaporation is the principle used in refrigeration.) Thus "damping down" a cool greenhouse on a warm day helps to cool the air.

SATURATION. There is a limit to the number of molecules of water that perfectly dry air will hold and this limit is set by the temperature of the air. When air at any time holds as much water vapour as it can, it is said to be **saturated.** It takes less water to saturate cold air than warm, hence the degree of saturation is relative to the temperature of the air.

Under natural conditions the air is never perfectly dry but always contains some moisture. Consequently the rate of evaporation at a given moment depends not only on the temperature of the air, but also on the amount of water vapour present. Thus, in one case, the rate of evaporation from soil was found to be three and a half times as great with a relative humidity of 75 per cent as when it was 90 per cent.

The relative amount of water vapour in the air is measured by means of a wet and dry bulb **hygrometer** consisting of two identical thermometers. The bulb of one is exposed and dry; the other is covered with muslin, the free end of which dips into a vessel of water, and is kept moist by capillarity. The wet bulb thermometer being cooled by the evaporation of water from the muslin, registers a lower temperature than the dry bulb thermometer. The warmer the air and the less saturated it is, the more rapid is evaporation and the greater the difference between the two readings of the thermometers. By noting this difference and referring to special charts the relative amount of vapour in the air is easily ascertained. A saturated atmosphere feels sultry and oppressive in summertime (cf. tropical glasshouse) and "miserably cold" in winter-time. An atmosphere of low saturation feels dry and buoyant.

Vapour to Liquid. We have seen that less water vapour is required to saturate cold air than warm. Therefore, if the amount of vapour in the air on a warm day is fairly high, then as the temperature falls in the evening a point will be reached where the air is completely saturated. The slightest cooling below this temperature results in the air being over-saturated and some of the water vapour will **condense,** i.e. change from vapour to liquid. This critical temperature is called the **dew point.** Under natural conditions, condensation may take place in several ways.

DEW. Dew is the result of condensation, not in the air itself, but on the surface of solid bodies exposed to the air, e.g. the dewing of a glass full of cold water in a warm room. In this country, the soil always contains some moisture which is continually evaporating upwards into the air. The leaves of grass and other plants also give off large amounts of water vapour. Loss of heat by radiation (p. 102) at night cools the blades of grass and the *surface* of the ground, and the water vapour condenses upon them as dew. Thus, it is not altogether true to say that dew "falls"; indeed, heavy dews might be more accurately described as rising.

GROUND MIST. If the air above the grass is cooled, it will be unable to hold both the water vapour already in it and that rising from the warmer soil beneath the surface. Condensation will then take place upon the minute particles of "dust" (e.g. salt from sea spray; sulphur dioxide) always present in the air and a ground fog will result as well as dew.

HOAR FROST. Evaporation proceeds more slowly when the soil *beneath* the surface is cold as well as the surface itself. Consequently there is less water vapour in the air immediately above the ground and the dew point will be at a much lower temperature. If it is lower than 32° F. then hoar frost will be formed instead of dew.

The most favourable conditions for the formation of dew and hoar frost are: (*a*) when there is little or no wind so that the layer of air near the ground is stationary, and (*b*) when the sky is clear.

CLOUDS. Clouds are formed when the air is cooled *en masse*, sometimes through the meeting of warm and cold air currents, but mainly when there are rising currents of air (see convection currents, p. 98). As the air rises it cools and condensation occurs when dew point is reached.

RAIN. Rain, like clouds, is formed by the ascent of damp air. If condensation goes far enough, the tiny drops of water run together to form bigger ones, which fall as rain.

SNOW. If the dew point is low enough, the water vapour in a cloud condenses as small crystals of ice which may unite to form snow flakes.

Hail. Hail and sleet may be described as frozen rain, though they are not simply drops of frozen water.

The air, therefore, contains a huge store of water vapour which is continually being added to by the evaporation of water from seas, rivers, lakes, etc., according to the varying temperatures of the air. The degree of saturation has a profound effect on plant life since it is the main factor regulating the rate of transpiration of water vapour from the leaves of plants.

Vapour to Solid. Water vapour condenses to a liquid when cooled, but the vapour of certain substances such as *sulphur* and *naphthalene* condenses to a solid, a process known as **sublimation.** Now sulphur is an excellent material for protecting plants from fungus attack, but in order to use it with maximum effect all the surfaces of the leaves and stems must be covered with a fine unbroken coating of sulphur. This can be done by heating the sulphur till it vaporizes and fills the glasshouse. When the vapour condenses the solid particles are so very numerous and minute that they uniformly cover every part of the plant. Fungus spores are killed when they come in contact with this sulphur coating and such pests as begonia mite are also eliminated. Naphthalene is used, in a similar way for combating red spider on cyclamen. Special fumigators must be employed both for sulphur and naphthalene.

Measuring heat

Heat Units. A thermometer does not measure the amount of heat, only the "hotness" (temperature). *Amount* of heat is measured in terms of its power of raising the temperature of water. The unit for general purposes in Britain is the

British Thermal Unit (B.Th.U.) and is the quantity of heat necessary to raise the temperature of 1 lb. of water through 1° F. Average B.Th.U. values for fuel commonly used in horticulture are, anthracite 14,700, semi-coke 13,300, coke 13,150 per pound of fuel. For measuring the heat-producing capacity of coal gas, the gas companies employ a larger unit of heat, the **Therm,** equal to 100,000 B.Th.U. One cubic foot of gas has a value of about 500 B.Th.U. (1 Therm = 200 cu. ft.).

Heat Capacity. Different substances have different capacities for heat: weight for weight, some will absorb (and give out) more heat than others per degree change in temperature. Water has a high, and soil a low, capacity for heat; i.e. it takes much less heat to raise the temperature of soil to a given extent than is the case with water. Conversely, a pound of water will give out more heat than a pound of soil if both are at the same temperature to begin with. From the above we can see that soil with a low water content will be warmed by the sun quicker than a soil with a high water content.

Specific Heat. To indicate the heat capacities of various substances they are compared with an equal mass of water. The ratio of the heat capacity of a substance to the heat capacity of the same mass of water is termed the **specific heat** of that substance. The approximate specific heats of equal volumes of wet, but well-drained soils, are of special interest: water 1·0, clayey soil 0·6, loamy soil 0·5, sandy soil 0·3. Thus, compared with the clay soil, the sandy one requires only half as much heat to raise its temperature by a given amount. Light soils therefore warm up in the spring more quickly than clay or peat soils, and seed germination and plant growth begin earlier. Conversely, on account of their higher specific heat, clay and peat soils cool slower after the heat of summer than light soils, and plant growth continues somewhat longer.

Transmission of Heat

Heat is transmitted in three ways: by radiation, by convection, by conduction.

(1) **Radiation.**—(*a*) FROM THE SUN. The sun sends out **electro-magnetic waves** which travel in straight lines in all directions at 186,000 miles a second. It is characteristic of these waves that no material substance is necessary for their transmission; they can travel in empty space.

Electro-magnetic waves may differ enormously in wave-length. The shortest known are about 10^{-13} cm. (0·0000000000001 cm.), the longest about 10^{10} cm. (10,000,000,000 cm.), and between these extremes there is every gradation (Fig. 9). Waves of different length have different effects. Most wavelengths cannot be detected by our senses, but two groups produce the sensations of light and heat.

Light rays range in wavelength from about 0·00004 cm. (violet light) to 0·00007 cm. (red light). Waves longer than those of red light do not affect our eyes, though our bodies can detect them. For example, if we hold our hand near an iron poker which has been heated in the fire, we can feel the **radiant heat** (heat rays) it gives out long before our eyes detect any change of colour (iron begins to get red-hot at 525° C.). These invisible heat rays range in wavelength from about 0·00007 cm. to 0.04 cm.

It will be seen from the above remarks that short waves are given off by bodies at high temperatures and long waves by bodies at low temperatures (e.g. less than 500° C.).

It should be noted that radiant heat is not heat in

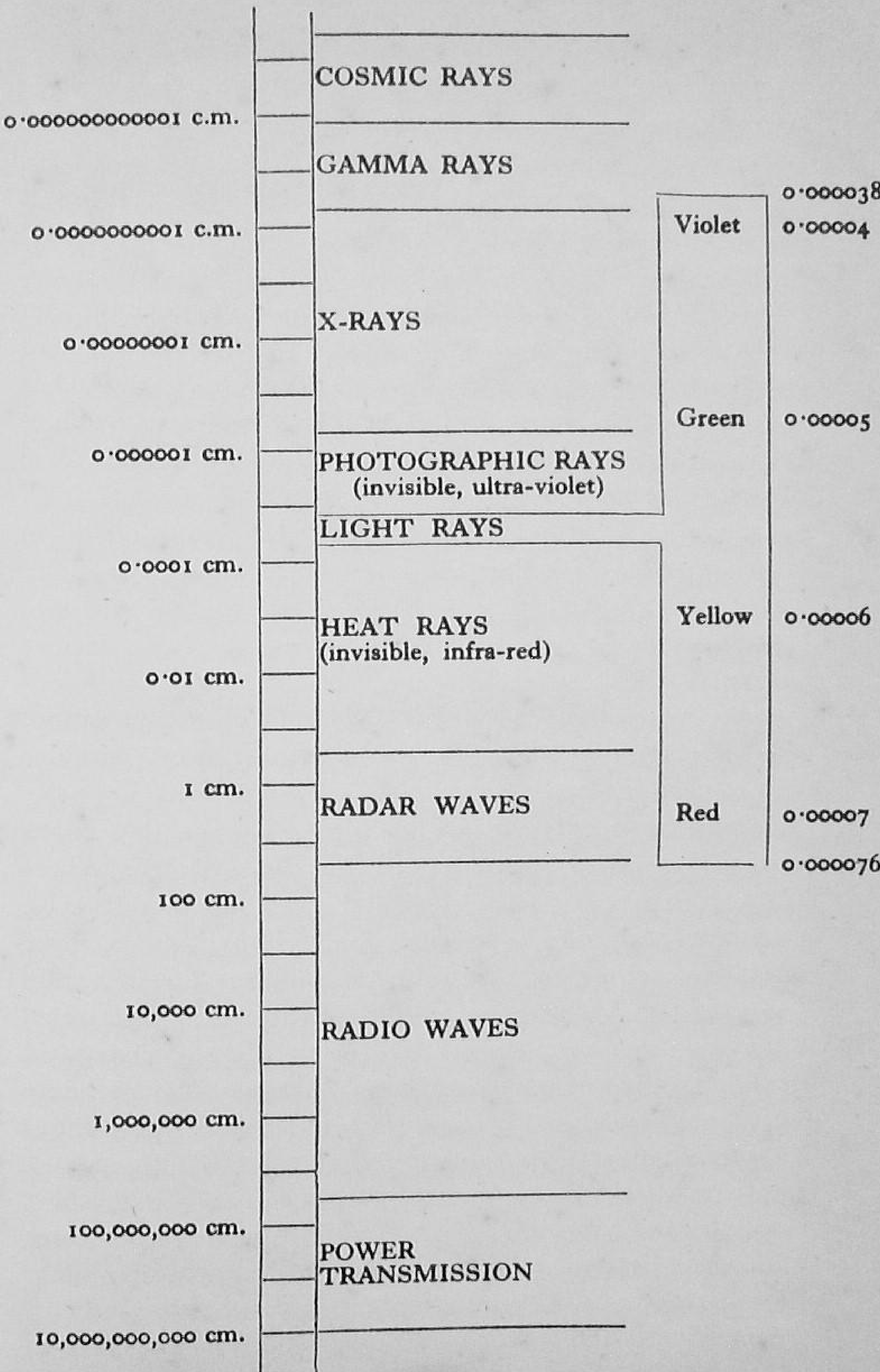


Fig. 9. ELECTRO-MAGNETIC SPECTRUM

the ordinary sense of the word. For example, a hot body sends out energy in the form of radiant heat which can be changed back into heat again when it is absorbed by another body.

(*b*) FROM SURFACES. All bodies, whatever their temperature, send out heat rays. The *quality* (wave-length) of this radiation depends on the temperature of the body: the higher the temperature the shorter the waves sent out. The *quantity* of radiation from unit area of the surface, depends on the nature of the surface as well as upon the temperature. In general, dull rough surfaces are good radiators, brightly polished surfaces are bad. Hence, soil is a good radiator, water less good: and hot water pipes painted with a mixture of lamp black and linseed oil will radiate more heat than when painted with a mixture of aluminium flakes and oil (i.e. aluminium paint). *Good radiators are also good absorbers.*

(*c*) TRANSMISSION OF RADIANT HEAT. Most solids transmit very little radiant heat. Glass transmits a considerable part of the short-wave radiation (mostly visible light) from an intensely hot body like the sun (6,000° C.) but intercepts all long-wave radiation (heat rays) emitted by bodies at temperatures less than 100° C. Until recently it was thought this explained why a glasshouse was a "sun-trap". The short wave radiation from the sun passed through the glass and was absorbed by the soil, walls, etc., which became heated. The heated soil then re-radiated some of the absorbed energy but as its temperature was much below 100° C., this radiation consisted only of long-wave heat rays which, it was said, could not penetrate the glass. The result was the glasshouse became warm.

It now appears that the main reasons for the glasshouse being a "sun-trap" are as follows. First, the long-wave radiation from the glasshouse, soil etc. is absorbed by the inner surface of the glass in the roof which, being thin, readily conducts the heat to the outer surface, from which it escapes into space as long-wave radiation. Therefore the differential transmission by glass of short and long wavelengths is only a very minor factor in raising the temperature under glass.

Secondly, short-wave radiation from the sun heats the surface of the soil, which heats the air in contact with it, and this heat is spread through the atmosphere by diffusion (wind) and convection (see under CONVECTION). Now in the open, the heated air would be rapidly carried away by wind currents and the soil quickly cooled. But in the glasshouse convection and wind are greatly reduced, consequently less heat is taken from the soil, causing a rise in soil and air temperatures. As will be seen, it might well be more appropriate to call the glasshouse (and frames and cloches) an air-trap rather than a sun-trap since it is the reduction of free air movement that maintains soil and air temperatures.

(*d*) ABSORPTION AND REFLECTION OF RADIANT HEAT. When radiant heat falls on a body, some is *reflected* and some *absorbed*. If one of these effects is large, the other will be small: i.e. *a good reflector is a bad absorber.* For example, soil is a good absorber, but a poor reflector. Again, the whitewash used for shading glasshouse roofs is a moderately good reflector of high-temperature radiation (but a poor absorber), therefore whitening the roof of a glasshouse helps to keep the house cool in sunny weather. It should be noted here that when rays of *light* fall on a surface which does not reflect them, they are absorbed by the surface and turned into heat, therefore bodies may be warmed by light as well as by heat (cf. glasshouse and radiant heat). Let us now gather together the facts about radiant heat, so that we have a clear picture in our minds, taking special care to distinguish between short- and long-wave radiation.

TABLE III

Material	High-Temperature Radiation (Short Wave)			Low-Temperature Radiation (Long Wave)
	Absorber	Reflector	Transmitter	Radiator
Dull black surface, Dark-coloured soil, Light-coloured soil	good	bad	bad	good
Water	mod. good	poor	mod. good	good
Glass	poor	mod. good	mod. good	good
Whitewash ..	poor	mod. good	bad	mod. good
Dry Air	bad	bad	good	bad
Polished metal surface	bad	good	bad	bad

(2) **Convection.**—Convection is the method of heat transmission which consists in the *movement of particles that carry heat from one place to another*. It is only possible, therefore, in liquids and gases. In water, the liquid near the source of the heat is warmed, expands, becomes lighter and rises, while the colder and heavier water takes its place (Fig. 10). In this way the whole mass of water is eventually heated. Such a stream of moving particles is called a **convection current.**

This is the method by which glasshouses are heated in the "gravity" system of hot-water circulation (Fig. 11). The water is heated by a boiler and the heat carried round the pipes by moving particles of water which, after giving their heat to the pipes, return to the boiler for re-heating. The air around the pipes becomes heated, convection currents are set up and the heat carried by the moving particles of air to every part of the glass-

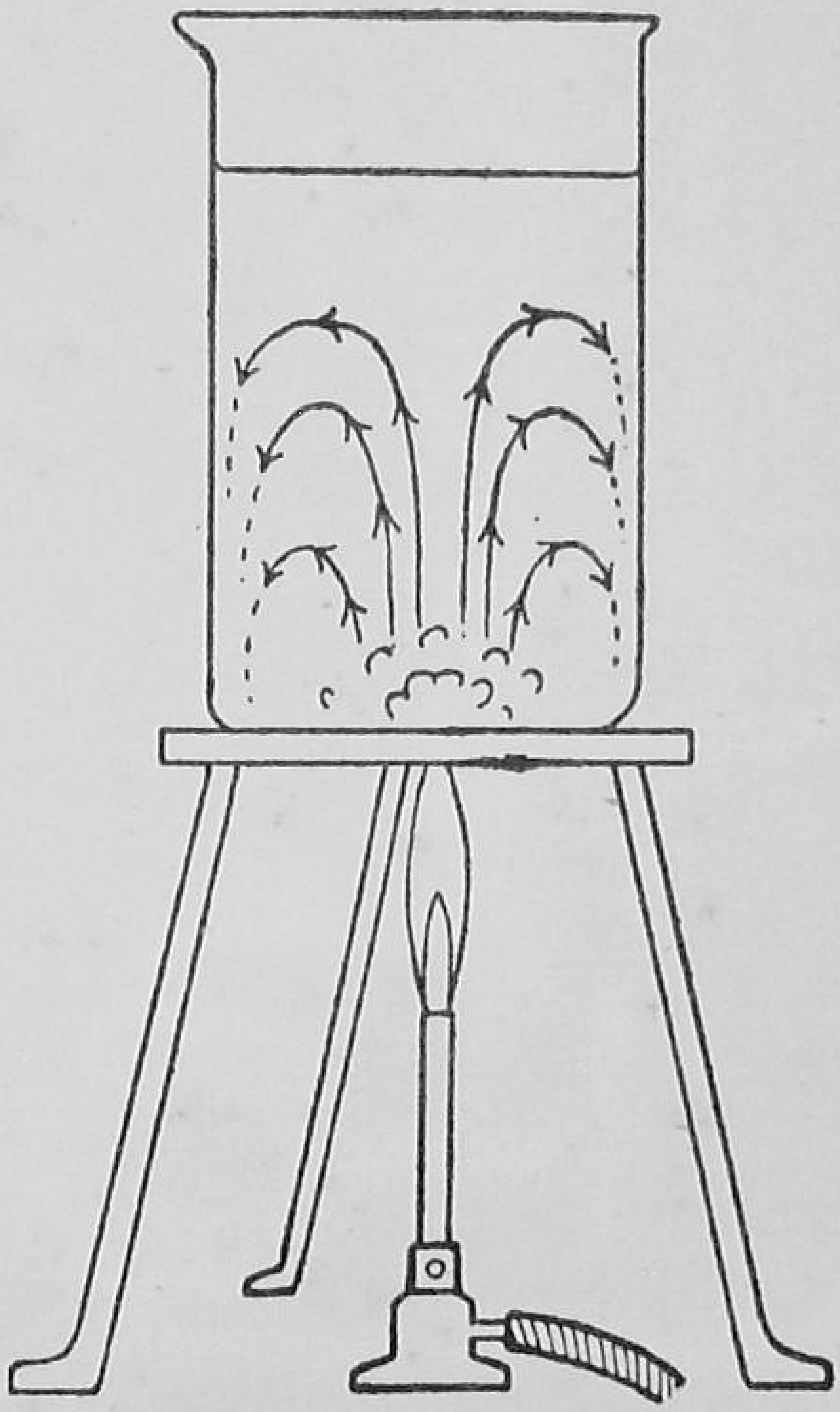


Fig. 10. CONVECTION CURRENTS IN WATER

house. About four-fifths of the heat imparted to the air by the hot-water pipes is imparted by convection, and only one-fifth by radiation.

Ventilation also depends upon convection currents. Hot air rises to the top of the glasshouse where it

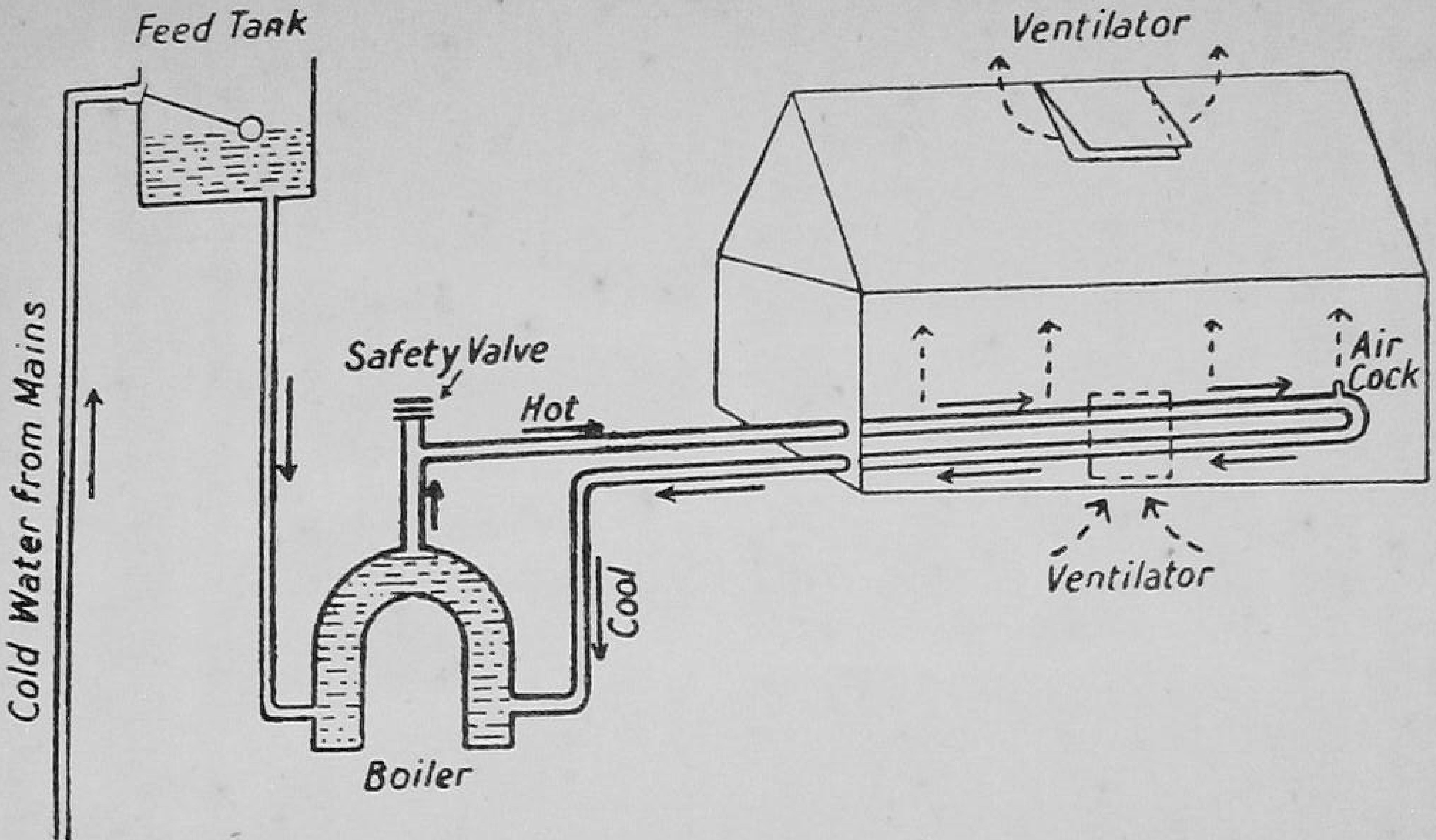


Fig. 11. HOT-WATER HEATING OF A GLASSHOUSE

The water circulates through the pipes by convection and heats the air in the glasshouse. The heated air also circulates by convection, warm air escaping by the top ventilators, and cold air entering by the bottom ventilators.

escapes through the ventilators, while cold air flows in to take its place through the bottom and side ventilators.

Convection currents play an important part in weather. During the day the radiant heat of the sun warms the air very little directly. The ground, however, is warmed considerably and gives some of its heat to the adjacent air, which expands and rises. Cold air rushes in to take its place thus giving rise to convection currents. This is how winds are caused. Examples of local convection currents are land and sea breezes. The trade winds result from large-scale convection currents in the air over the equatorial regions.

(3) **Conduction.**—Conduction is the process by which heat is transferred in solids from one particle to the next, *without any visible movement of the particles.* Actually the molecules of any substance are in a constant state of vibration. When heat is applied at one point the molecules there vibrate more strongly and "jostle" their neighbours, which in turn jostle theirs, the process continuing through the substance. This increased motion makes itself felt as heat. Thus, when one end of an iron poker is put in the fire, the other end gets hot, and the heat is said to "flow" along the iron. All metals are good conductors, some being better than others. Non-metallic substances are bad conductors, e.g. wood, asbestos, glass and snow. Most liquids are bad conductors and gases are the worst.

Iron, which is a cheap metal, is also a fairly good conductor of heat, hence it is used extensively for the construction of horticultural boilers and hot-water systems. Asbestos, which is a bad conductor, is used to insulate ("lag") those portions of hot-water systems which pass through the open air and from which heat would be lost. Snow also is a bad conductor; therefore snow on the ground protects plants during severe frosts.

How the Rules of Heat affect the Horticulturist

(1) WEATHER. We have seen that radiant heat from the sun passes through dry air without materially heating it, but air always contains some water vapour, and this stops a good deal of radiant heat. Clouds, which are largely made up of droplets of water, stop most of it. This has a marked effect on the temperature of the earth's surface.

In the daytime, the earth receives far more radiation from the sun than it gives off to the air, so it heats up. At night, when practically no heat falls on the earth, it rapidly loses its heat to the air. As we have seen, clouds and water vapour act as a blanket, shutting out the sun's heat by day and keeping in the heat radiated from the earth at night. As a result, the ground and air close to it do not get so hot in the daytime or so cold at night time and the temperature is comparatively equable. But if the sky is clear, the night calm, and humidity low, the earth loses its heat rapidly. These are the conditions under which a sharp frost may be expected in late spring or early autumn.

In general, the temperature of both air and soil decreases with elevation above sea level. The bottoms of valleys and hollows may be exceptional, however. On a night when frost may be expected, the loss of heat from the ground cools the layer of air above it. This cold air, being denser, flows downhill and accumulates at low levels. At higher levels the replacement of the cold air by warm, checks radiation from the earth, to some extent, but in the hollows and valley bottoms radiation proceeds uninterrupted. Thus, frost may be formed in a hollow but none on the higher ground around it. This is what is meant by a **frost pocket.** Frost pockets can be the cause of much damage to horticultural crops, e.g. fruit trees in blossom. By using oil heaters, the temperature of the air near the ground can be raised sufficiently to prevent the fruit blossoms from being frosted.

(2) SOILS. The most difficult soils to cultivate successfully are the heavy clay and light sandy ones. In the case of the clay soil, the chief methods of improvement comprise draining, liming, exposure to frost and the addition of humus. Each of these helps to decrease the water content: the first directly, the other three by increasing the size of the soil pore-spaces, thus facilitating the removal of water. Since soil has a lower specific heat than water, drainage makes the soil warmer and "earlier". Further, the addition of humus to the surface layer of the soil darkens it, consequently still more of the sun's heat is absorbed. In the case of the sandy soil, in summer time there is a deficiency of water and the soil becomes too hot and dry. By adding humus, which has a high water-absorbing capacity, the water content, and therefore the specific heat of the soil, are increased. Evaporation, too, is accelerated, thus further cooling the light soil.

Wind keeps soil cold in springtime, when the land is moist from winter rains and seed sowing is due to begin. The provision of windbreaks may very materially decrease the rate of evaporation of water from the soil, thereby raising its temperature a degree or two. Since drainage may also raise the temperature of a heavy soil by 2° F., it is clear that the cumulative effect of the various methods of cultivation mentioned above, may easily raise the mean temperature of cold soils by five or six degrees, to the great benefit of the crops in springtime.

LIGHT

COLOUR. When light-waves fall on the sensitive area (retina) at the back of our eyes, they produce a sensation of colour according to the particular wavelength of the light. Waves about 0·00004 cm. long give the sensation of violet light, those about 0·00007 cm. the sensation of red light. Other colours have intermediate wavelengths in the order violet, blue, green, yellow, orange and red. White light is a mixture of all the colours. Opaque objects are visible to our eyes only because they reflect light, their colour depending on the wavelength of the reflected light. Thus, a green leaf appears green because green light is reflected, and the other wavelengths absorbed. An object which reflects all the colours equally appears white: one which absorbs practically all the light falling on it appears black.

INTENSITY. The illuminating power of light is compared with that of a **standard candle,** in terms of **candle power.** The intensity of illumination of a surface is measured in **foot-candles,** one foot-candle being the illumination produced on a vertical screen *at a distance of one foot from a standard candle.*

The following figures refer to the illumination (on a horizontal plane) in foot-candles for the whole sky, including the sun, and are averages: June 3,500, December 500; wet days in summer time 500; mid-November to mid-January 500; dull winter days 100–200; very dull winter days 50–100. The highest figures for direct sunlight in Britain are: June 6,500, December 4,500. These figures are for outdoors. They must be reduced 30 to 50 per cent for indoors in glasshouses.

Most of the plants we grow in our glasshouses will not grow vigorously unless they receive *at least* ten hours of illumination a day, of an average intensity of 1,000 foot-candles. No matter how brightly the sun may shine for an hour or so, it cannot make up for a day that is too short. What matters to the plant is foot-candle-*hours*. Thus, certain glasshouse plants (e.g. Schizanthus) practically cease growth in December and January, and even in November and February they do not grow well.

In the case of indoor plants, intensity of illumination is still further reduced by soot deposited on glasshouse roofs, especially in residential and industrial districts. Horticultural flat-drawn sheet glass when new and clean transmits about 90 per cent of the total light. In winter time in London, after three months exposure the total light transmitted is reduced to 75 per cent, and after one year the figure is 60 per cent. The rate of dirtying is twice as fast in winter as in summer. Thorough washing and cleaning restores the original transmission of 90 per cent, therefore periodical cleaning, especially in winter-time, is strongly to be recommended. The above figures refer to overall light transmission: the transmission of radiant heat would be rather less affected by soot deposit.

The *aspect* of a garden or nursery has considerable effect on the warmth of the soil. In the northern hemisphere the sun is never overhead, hence more rays fall on southern slopes than flat ground, and on flat ground than northern slopes. This is shown in Fig. 12 where WX, WY and WZ represent equal areas of ground, and AD, AC and AB the amount of light and heat rays falling on these areas. In the illustration (an exaggerated one) over 100 per cent more light falls on the flat ground as compared with the northern slope, and 30 per cent more on the southern slope than on the flat ground.

Reflection. When light falls on a polished surface (e.g. a mirror) the rays are not absorbed but travel off again at an angle equal to that at which they struck the reflecting surface.

Most surfaces, however, are rough, as far as light is concerned. For example, the white surface of the woodwork in a newly painted glasshouse has millions of little irregularities, and rays of light striking these microscopic hillocks and valleys are reflected and scattered (diffused) in innumerable directions.

Now winter days are often too short, or on the verge of being too short, for healthy plant growth, and so it becomes

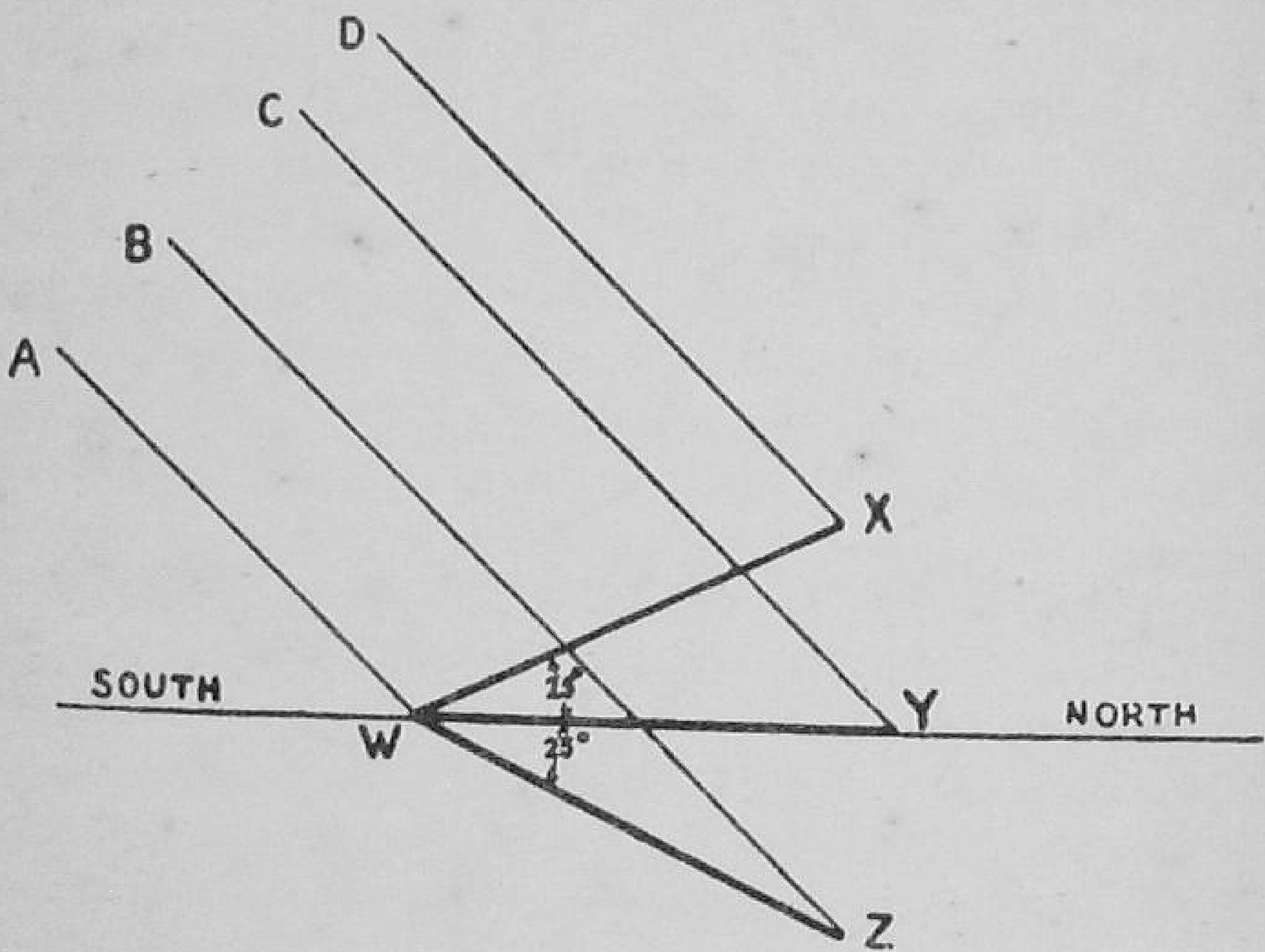


Fig. 12. THE IMPORTANCE OF ASPECT (see text)

of great importance to the glasshouse grower to ensure not only all the light possible is getting into his glasshouse, but that most of it is being reflected from the woodwork, walls, etc. A good white paint reflects up to 80 per cent of light. By keeping his glass clean, and by painting his woodwork and walls white he will increase the average intensity of illumination and may also be able to add 30–60 minutes to the length of day, above the minimum intensity useful to the plant. The same applies to frames, which is one reason why

"Dutch lights" made of one large sheet of glass, are replacing the old many-paned lights.

ELECTRICITY

The "handy-man" will learn something about electricity, so that he knows how to maintain fuse-boxes, bells, lamps, motors, etc., in good working order, and how to diagnose faults and breakdowns.

Chapter Eleven

ABOUT PLANTS: GROWTH AND REPRODUCTION

IF you are to grow plants well, then clearly you should know the chief facts about their structure, the way they work and how they reproduce themselves. There is an embarrassing number of botany books on these subjects, most of them too detailed for the young grower. Your first concern, therefore, will be to select a suitable book or books and then to concentrate on those parts of them that teach the basic facts. So my aim in this chapter is to outline what you should learn about the plant and to draw attention to any special points to be observed. One thing I want to emphasize again: always relate theory to practice. For example, as you learn about the work of the roots, think of osmosis in terms of garden practice—not as something of abstract and academic interest, smelling strongly of the classroom or lecture theatre.

You will most surely grasp the facts about plant growth and reproduction if you think of the plant as if it were an industrial organization. There are four main stages in every industry. The raw materials must be:

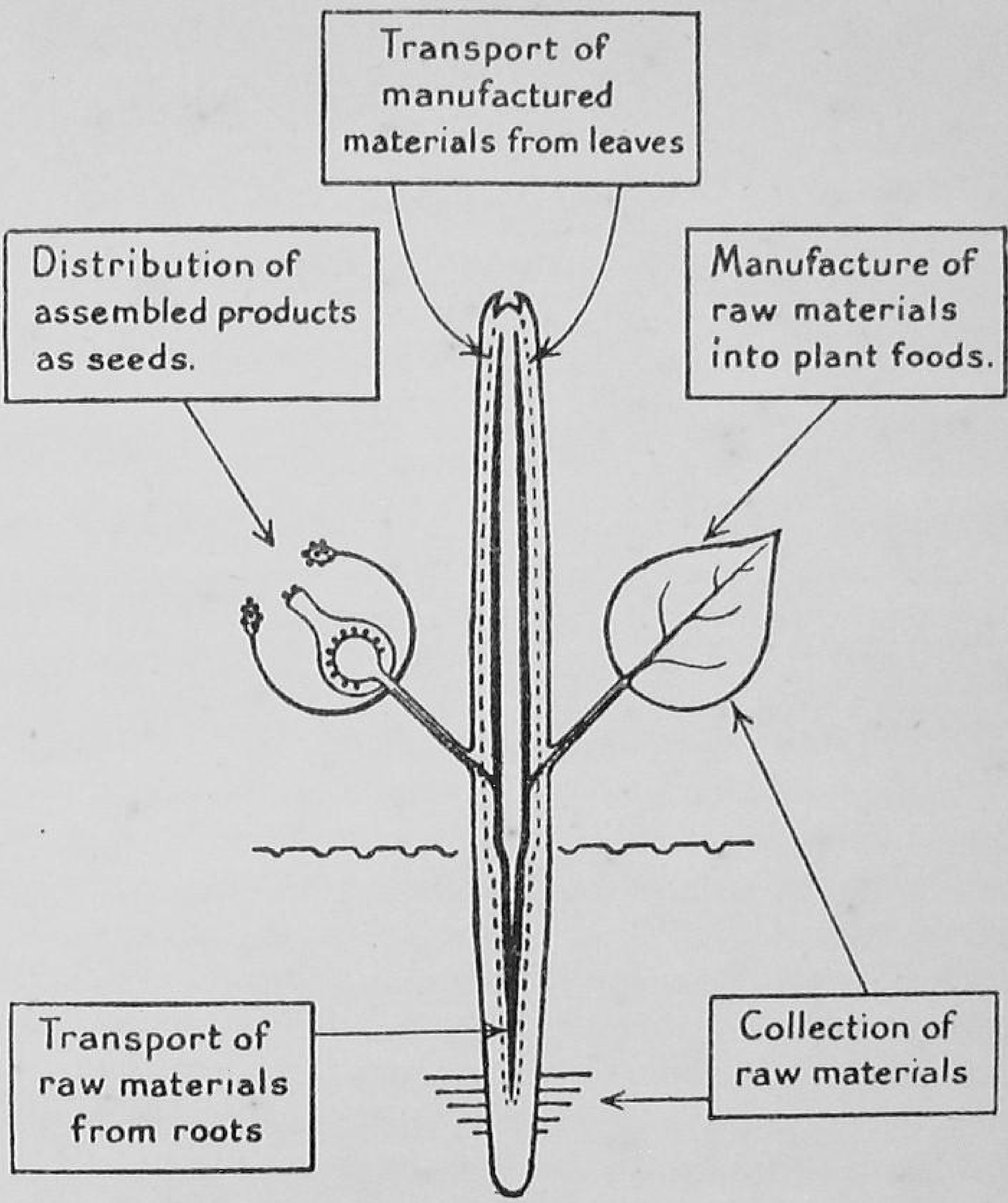
(*a*) *Collected* from their sources;

(*b*) *Transported* to the factory;

(*c*) *Manufactured* into the component parts;

(*d*) *Assembled* ready for distribution.

This accurately describes the work of the plant and the four stages give us a simple picture that is easy to remember (Fig. 13).



THE PLANT AS AN INDUSTRY
FOR MAKING OTHER PLANTS
Fig. 13

A special system is concerned in each stage of production (Table IV):

TABLE IV.

Stage	Systems	Work Done
Collection	(*a*) Root (*b*) Leaf	Removal from soil of raw materials Removal from air of raw materials
Transport	Stem	(*a*) Transport of raw materials to leaves (*b*) Transport of manufactured materials to other parts of plant
Manufacture	Leaf	Manufacture of plant foods (carbohydrates and proteins)
Assembly and Distribution	Flower	Assembly of seed components and distribution of seeds

If the organization as a whole is to work with the greatest efficiency, the supply of raw materials must be precisely adjusted—in quantity and proportion. Similarly, factory conditions must be right: abundant energy to work the machines, which must be in good order, a steady supply of raw materials, and the prompt clearance of the various products to store or for use. The art of horticulture consists in seeing that there are no bottle-necks to restrict output.

A word or two about the products manufactured by the leaves. We may regard them as being used for two purposes. First to extend the organization, i.e. to enable the plant to grow. This means that the manufactured products must be transported from the leaf factory to the living cells of inflorescence, stem and root. So there is a double stream of traffic along the arterial way we call the stem; raw materials passing upward from the root and manufactured materials passing, upwards and downwards, to all parts of the growing plant. Secondly, the products of the leaves are assembled in the flowers to make seeds for distribution. These, dispersed to suitable localities, enable new plant organizations to be started. The seed contains all the necessary materials and is fitted out with all the necessary equipment for starting the new organization.

Regarded in this way, we can hardly fail to realize that the plant is a remarkable piece of organization. Its perfection will seem even more remarkable when we further realize that not a single seed produced by a flowering plant is exactly identical with any other seed. Each has a slightly different constitution in respect of its material and equipment. This is not an accident, but a vital device. The seeds are distributed to sites (environments) differing slightly in many ways. If all seeds were alike only one environment would be ideal. Since all seeds differ very slightly, some will be better suited for one environment, some for others. In this way provision is made for local differences in environment, and there is the possibility of an efficient organization being established in each. Thus, *future* as well as present efficiency is assured. Incidentally, this device, which the botanist calls *variation*, is the one which has also enabled the plant breeder to produce the many useful and attractive plants found in our gardens.

This, then, is the background to your study of plant growth and reproduction. Always think of the parts of the plant (structure) in terms of the work they have to do (function). And be sure to relate the whole to garden practice.

To help you to do this, I have made diagrams (Figs. 14–17) representing the four systems which comprise a plant (root, stem, leaf and flower) and indicated their main functions. The diagrams should enable you to see the work of the plant as a whole. They are not intended to take the place of the more detailed accounts in the books on botany; nor to suggest the order in which you should tackle the subject. You will probably do best to start with seed germination and, in general, follow the growth of the plant to maturity.

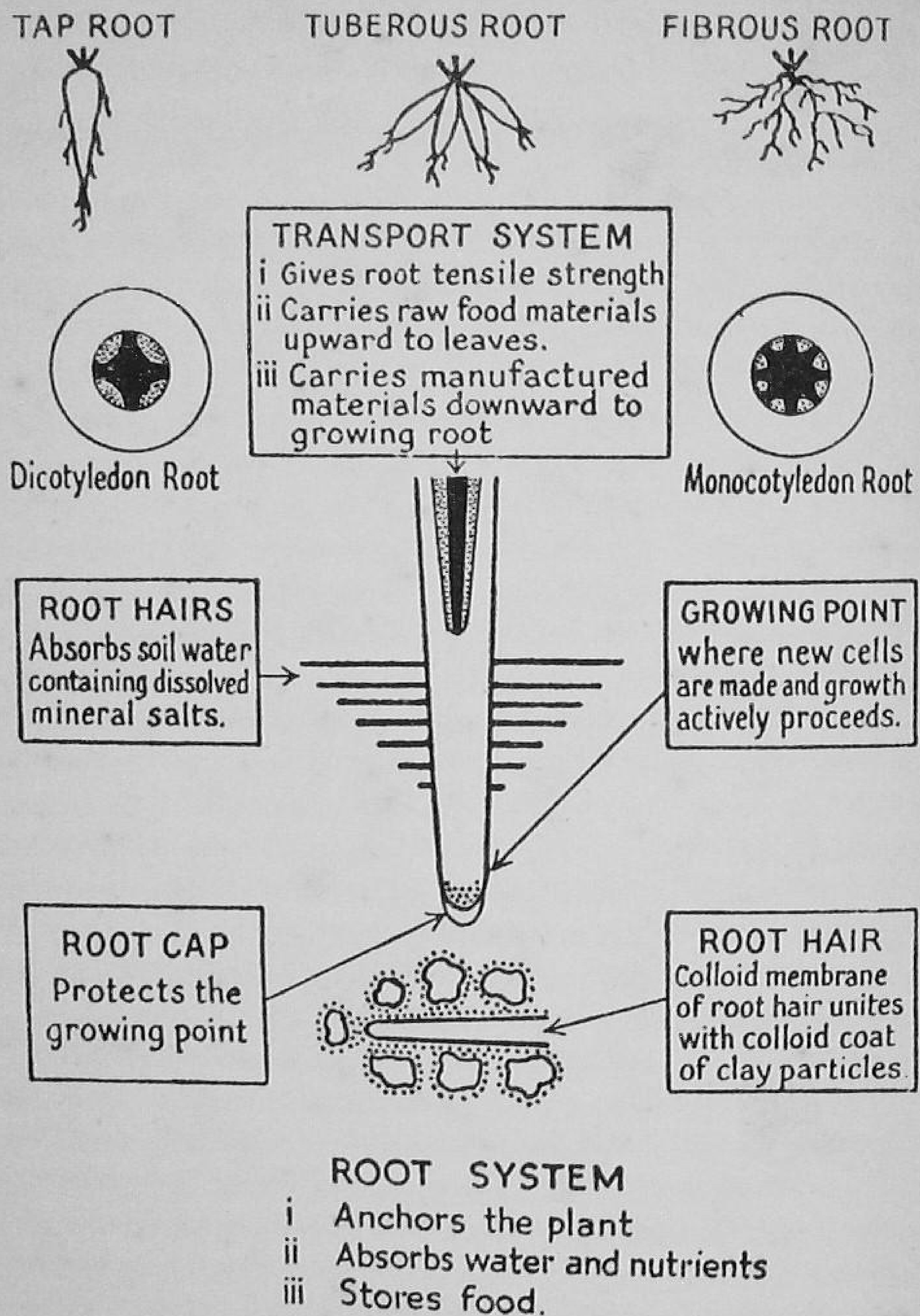

TAP ROOT
TUBEROUS ROOT
FIBROUS ROOT
TRANSPORT SYSTEM
i Gives root tensile strength
ii Carries raw food materials upward to leaves.
iii Carries manufactured materials downward to growing root
Dicotyledon Root
Monocotyledon Root
ROOT HAIRS
Absorbs soil water containing dissolved mineral salts.
GROWING POINT
where new cells are made and growth actively proceeds.
ROOT CAP
Protects the growing point
ROOT HAIR
Colloid membrane of root hair unites with colloid coat of clay particles
ROOT SYSTEM
i Anchors the plant
ii Absorbs water and nutrients
iii Stores food.

Fig. 14

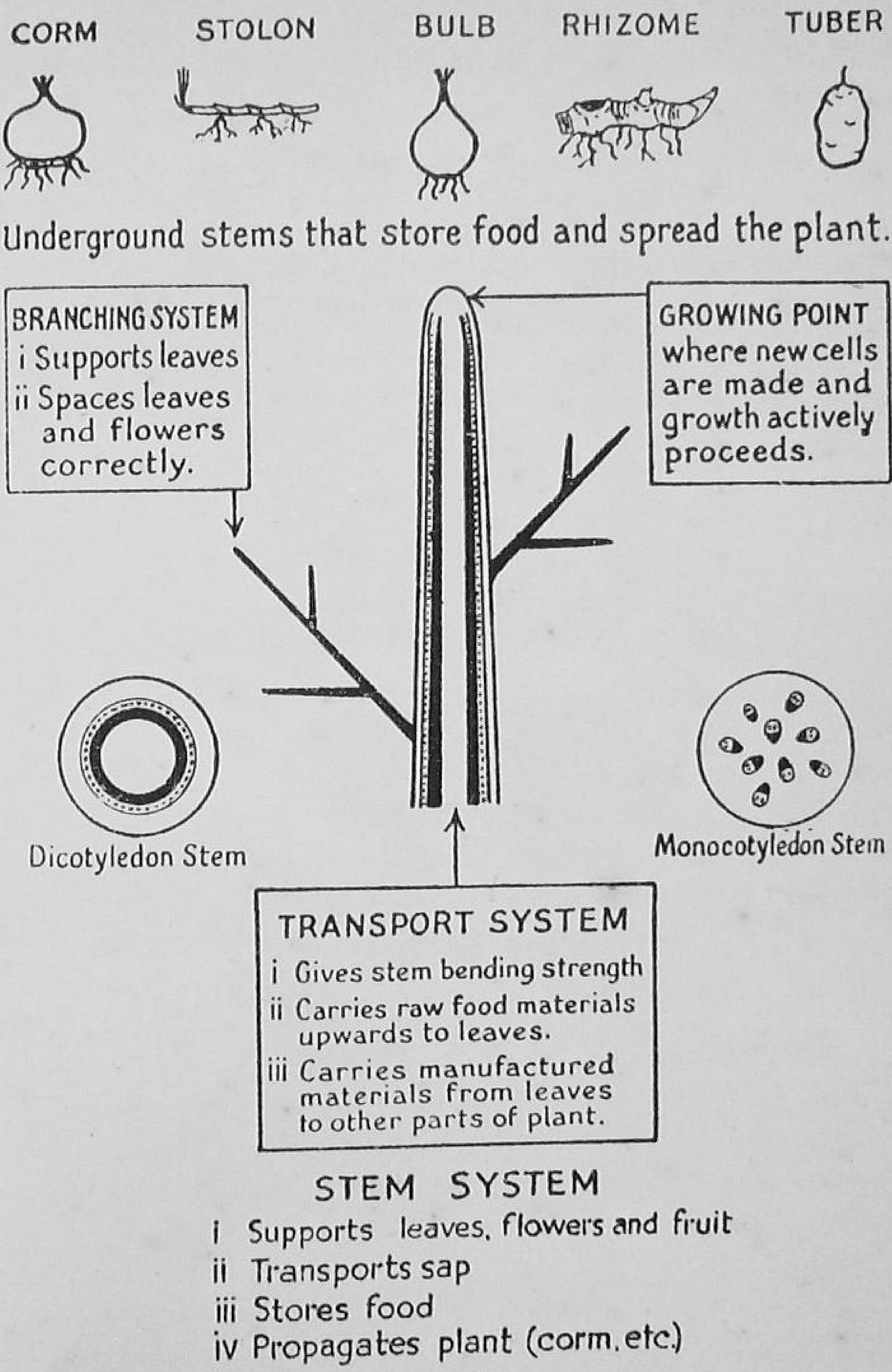
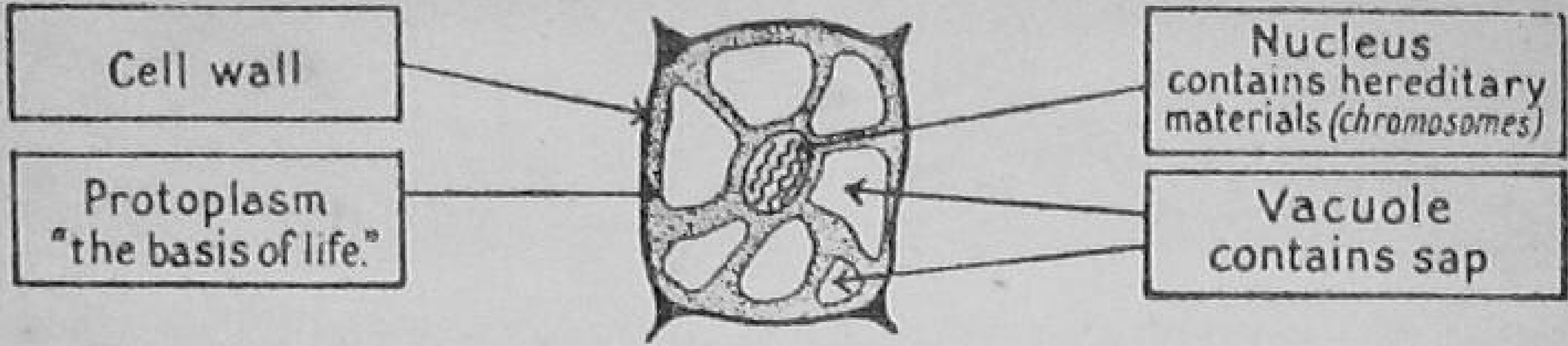
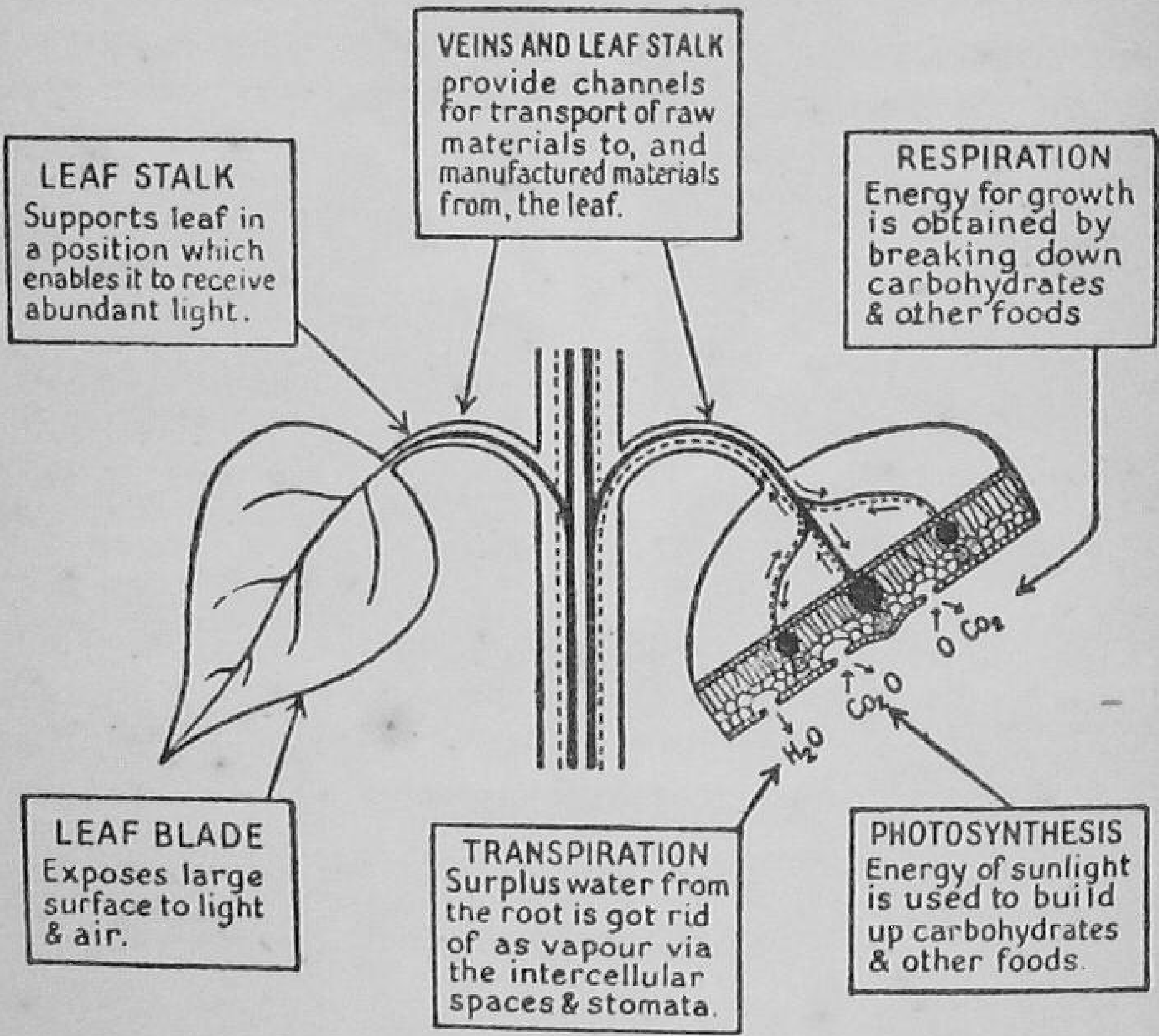

CORM
STOLON
BULB
RHIZOME
TUBER
Underground stems that store food and spread the plant.
BRANCHING SYSTEM
i Supports leaves
ii Spaces leaves and flowers correctly.
GROWING POINT where new cells are made and growth actively proceeds.
Dicotyledon Stem
Monocotyledon Stem
TRANSPORT SYSTEM
i Gives stem bending strength
ii Carries raw food materials upwards to leaves.
iii Carries manufactured materials from leaves to other parts of plant.
STEM SYSTEM
i Supports leaves, flowers and fruit
ii Transports sap
iii Stores food
iv Propagates plant (corm, etc.)

Fig. 15



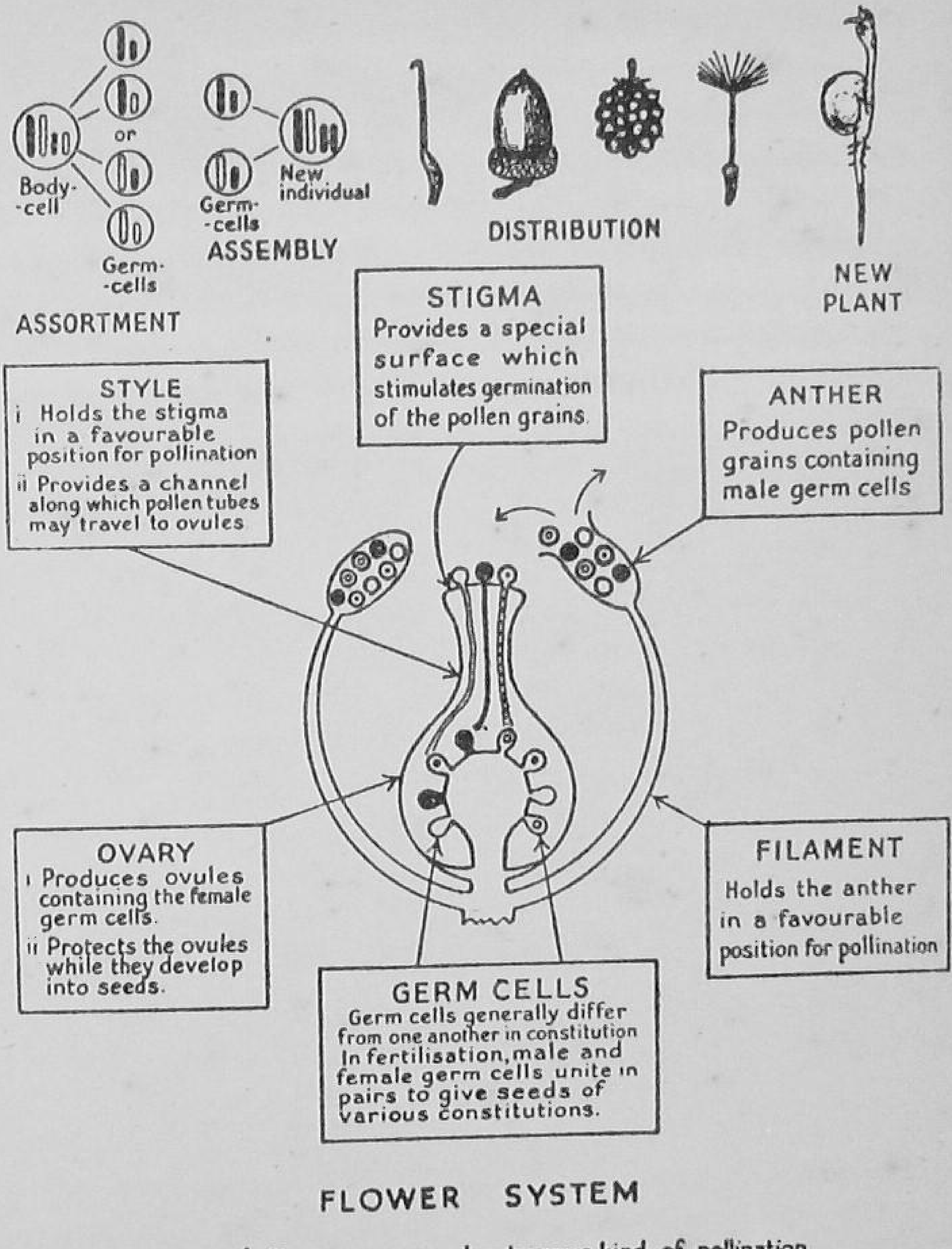
A SIMPLE CELL



LEAF SYSTEM

I Makes plant food (photosynthesis)
II Breaks down plant food (respiration)
III Gets rid of surplus water (transpiration)

Fig. 16



FLOWER SYSTEM

i Encourages an advantageous kind of pollination
ii Assorts hereditary materials (germ cell formation)
iii Assembles hereditary and seed materials (fertilisation)
iiii Distributes seeds

Fig. 17

Below is a list of some specially important things to be learnt about plants:

(1) Conditions essential for seed germination.
(2) Uses of water to plants.
(3) Importance of light to green plants.
(4) Effect of external conditions on transpiration.
(5) Work of the green leaf (distinguishing between respiration transpiration and photosynthesis).
(6) Chemical elements essential for plant nutrition.
(7) Commoner mechanisms for self- and cross-pollination.
(8) Value of selection and cross breeding.

Chapter Twelve

ABOUT PLANTS: NUTRITION

MY aim in this chapter is the same as in the last one: to reduce the subject to its simplest terms so that you may see it clearly as a whole and thus recollect it with ease. We pictured the plant as a four-fold system—roots, stems, leaves and flowers. We shall do the same with plant nutrition, under the headings: (1) Soil Structure, (2) Soil Life, (3) Fertilizers and Manures, and (4) Cultivation. But first let's get the background right.

What materials do plants need for growth? Three types of material: a gas, various salts, and water. The gas, carbon dioxide, comes from the air, and enters the plant mainly through the leaves. The salts must be dissolved in the water, and both salts and water are taken in by the roots. Carbon dioxide, salts and water—that is all.* *Soil is not necessary.* Excellent commercial crops of tomato, carnation and other plants are grown in America and in this country without soil. Soil is merely convenient as a medium for growing plants. True, it is the natural medium, but it is also a very complex one, therefore you must get the outlines of the picture right before filling in the details.

Before passing on, we must be clear in our minds about the terms "nutrient" and "food". The raw materials mentioned above (carbon dioxide, etc.) are necessary for the plant's nourishment, but they are not, properly speaking plant foods. We humans find our food ready made, e.g. milk, fruits, meat.

* Atmospheric oxygen is, of course, necessary for respiration, but we may conveniently separate this from materials more directly concerned in nutrition.

But the plant has to make its foods, and this it does in the leaf where the raw materials are brought together and synthesized into the true plant foods, carbohydrates, proteins, etc. So we shall use the word "nutrient" to indicate a raw material (e.g. calcium nitrate) and reserve the word "food" for the material manufactured by the leaf (e.g. sugar).

What Soil is made of: Soil Structure

Fertile soil consists of four kinds of substances: mineral matter, organic matter, air and water.

Mineral Matter

Sand. The soil minerals are derived from the weathering of the original rocks which are broken into smaller and smaller pieces by the action of heat, cold, wind and water. The larger particles we call sand, finer ones silt, and the smallest clay. The proportions of the different-sized particles determine the character of the soil: whether it is light, medium or heavy; what its texture and mechanical qualities are; and, to some extent, how much air and water it contains. The figures in Table V show broadly how soil structure varies. Many gradations occur between these extremes (and beyond them) with a corresponding variety of differences in the way the soil "works".

Clay. We can picture the structure of clay in a fertile soil as follows: the smallest particles (less than 0·0005 mm. in diameter) with their coats of jelly-like colloidal material, are collected together in the form of crumbs. The **crumbs** (0·5 to 3·0 mm. in diameter) are separated from one another by relatively large pore-spaces, the **particles** by very small pore-spaces. Sand grains may be enmeshed between the crumbs.

TABLE V

Mechanical Analyses of Some Typical Soils

(Percentages)

Fraction	Diameter Limits	Loamy Sand	Sandy Loam	Loam (*a*)	Loam (*b*)	Silty Clay Loam
Coarse Sand	2·00–0·20 mm.	67·3	31·8	30·1	2·1	2·3
Fine Sand	0·20–0·02 mm.	19·7	31·3	26·9	53·3	19·6
Silt	0·02–0·002 mm.	3·6	12·5	17·1	20·6	38·5
Clay	below 0·002 mm.	5·5	17·6	22·3	18·9	33·9
$CaCO_3$		0·0	2·6	0·0	0·9	0·0
Organic Matter,* etc.		3·9	4·2	3·6	4·2	5·7

Organic Matter

The organic matter of the soil is composed of the remains of plants and animals, including micro-organisms; and dressings of dung and similar manures applied by the grower. The percentage of organic matter in fertile soils (excluding fen-land soils) ranges from 2 to 7 per cent. Organic matter which has decomposed to the point where its original structure can no longer be recognized is called **humus.** We must be careful how we use the terms "humus" and "organic matter". Humus has physical and chemical properties quite different from those of less decomposed matter. The fraction of humus that is colloidal plays a specially important part in soil fertility (p. 69).

Air

The amount of air (pore-spaces) in a fertile soil ranges

* The figures for organic matter need qualification as follows. The Loamy Sand sample was from grass-land; under arable cultivation the percentage of organic matter would be 2 per cent or under. The figure for the Silty Clay Loam is rather low for this type of soil. The figures for the other loams are fairly typical for such soils under good arable cultivation: they might be as high as 10 per cent in old gardens that have been heavily dunged.

from one-third to half its bulk. Soil air is usually saturated with water vapour, and contains a variable amount of carbon dioxide, on the average seven or eight times (about 0·2 per cent) as much as in atmospheric air.

WATER

The approximate weight of water held by well-drained soils is, sandy soils 10–15 per cent, loams 15–20 per cent, clay soils 25–35 per cent. The amount of water which a well-drained soil can hold depends on the size of its particles. The smaller the particles the greater their total surface area, therefore the greater the amount of water that can be distributed over the surfaces of the particles as films. In the case of sand grains—even the smallest—the water merely wets the surface of the grains; it does not penetrate them. But in the case of the microscopic clay particles, the water molecules mingle with the clay and become part of it. The force with which this water is held increases from the outside to the centre of the crumb; it is freest (i.e. able to move under gravity and capillarity) between crumbs, loosely held (adsorbed) on the outer layers of the colloidal material, and chemically combined, therefore strongly retained, nearer the centre of the crumb. Clay owes its physical properties of plasticity, impermeability to water, and shrinkage and tenacity on drying to the composite structure of colloidal material and water described above.

What goes on in the Soil: Soil Life

Fertile soil is not dead, but teems with life, chiefly microscopic. Leaving aside the flowering plants and insects, those organisms most concerned in soil fertility, and what they do, are given below. Their numbers depend a great deal on the temperature of the soil and on its content of air, water, calcium and humus. In a fertile soil there may be something like twenty-thousand million micro-organisms, chiefly bacteria, in every teaspoonful of soil (thirty billion bacteria weigh about one ounce). That is some $2\frac{1}{2}$ tons in the top six inches of one acre of soil.

Worms

Worms aerate the soil; and their burrows, often several feet deep, enable water to percolate to the lower levels. Their chief importance, however, lies in the way they eat soil, digest the vegetable debris it contains and bring the undigested soil to the surface in the form of casts. In the process the soil is ground up very finely and thoroughly mixed. The casts bury some of the vegetable matter on the surface of the soil. Thus, in forty or fifty years the whole of the soil to the depth of a spit is intimately mixed and brought to the surface. It has been estimated that the number of worms in fertile soil is 3–4,000,000 per acre.

Eelworms

Eelworms (Nematodes) belong to the same order as the earthworms. They occur in large numbers in the soil and those kinds which are parasitic on plants cause great damage to crops. Eelworms are very tiny in size, in length not more than $\frac{1}{25}$ inch and only $\frac{1}{1000}$ inch thick. They are therefore normally invisible to the eye.

Protozoa

These are amoeba-like micro-organisms which prey on the nitrifying bacteria. Soil sterilization destroys the protozoa and nitrifying bacteria, but not the ammonifying ones. The nitrifying bacteria eventually re-infect the sterilized soil but for some weeks there is more ammonium than nitrate nitrogen.

Fungi and Bacteria

(*a*) The organic matter of the soil is consumed as foodstuff by many fungi and bacteria, which oxidize carbon compounds to carbon dioxide and water. As a result, the air in fertile soil is always rich in carbon dioxide (see p. 120).

(*b*) Fungi and bacteria are also responsible for the initial stages in the decomposition of nitrogenous organic matter, e.g. protein ⟶ amino acids and amides ⟶ ammonium salts.

Nitrosomonas

This bacterium oxidizes ammonium salts to nitrites.

Nitrobacter

This bacterium oxidizes nitrite to nitrate.

Clostridium and Azotobacter

These soil bacteria are able to use the free nitrogen of the air for the building up of proteins. When they die the proteins are decomposed into ammonium salts. Thus, the nitrogen *fixed* from the air is made available to plants.

Bacillus radicicola

This organism, which lives only in the nodules found on the roots of leguminous plants, also has the power of fixing atmospheric nitrogen. Consequently, by digging in a crop of clover or lucerne (green manuring) the soil may be considerably enriched in nitrogen.

Feeding the Soil: Manures and Fertilizers

All wild plants are underfed; and most cultivated ones.

They starve, part or all of their lives, chiefly through lack of nitrogen, phosphorus, potassium and water. Either there is not enough of these substances present, or they occur in unavailable forms. Plants may also suffer from deficiencies of boron, magnesium, manganese, iron, copper and similar "trace" elements.

Most growers would be extremely surprised to see how luxuriant their plants grew when perfectly fed under ideal conditions. Why don't we grow them better? For several reasons, but mainly because it doesn't pay. Do we grow them as well as it would pay? Quite often, no; and usually because of ignorance. Growers don't feed the soil—build up its fertility—because they aren't aware of the fact that most plants are under-nourished. They accept plant malnutrition as the normal thing.

Now, though the soil is complex, building up fertility is not a complicated matter. Three things have to be done. Organic matter, fertilizers and lime must be applied in the right amounts at the right time. Each of these materials has a distinct part to play: and each is complementary to the others.

Organic Matter

The chief value of organic matter, especially in the form of humus (see p. 119), lies in its effects on the structure and water content of the soil.

(*a*) Structure. In a relatively undecomposed condition organic matter opens up and aerates heavy soils, thus enabling roots to penetrate easily and deeply. As humus, especially if it is actively decomposing, it consolidates light soils, and helps to build up a good stable crumb structure in all soils. In short, organic matter "conditions" the soil and makes it work more easily.

(*b*) Water content. Humus *regulates* the water supply (notice the word, "regulates"). It permits excess water to drain away from heavy soils and makes them warmer. It retains moisture in light soils and makes them cooler. Humus not only has a large capacity for water, but it *releases* it at a steady rate. Consequently, rapid alternations in the water content of the soil are avoided and a more continuous supply assured. Humus is the only substance that can materially prevent water "starvation" (p. 127).

Farmyard manure, composted vegetable matter, leaves and peat are bulky kinds of organic matter which may be dug into the soil in autumn or early winter.

Fertilizers

The chief value of fertilizers lies in their suitability for making good the natural deficiencies of plant nutrients, especially deficiencies of nitrogen, phosphorus and potassium. Some of the bulky organic materials mentioned above contain appreciable amounts of these nutrients, so they serve a double purpose when applied to the land. A list of the most important fertilizers appears in Table VI. The Table is to give you an idea of the amounts and kinds of nutrients supplied by fertilizers and manures and to indicate certain of their characteristics.

You will notice that some of the fertilizers are *single*, supplying only one nutrient; others are *compound*, supplying two nutrients. A number of these fertilizers may be safely mixed together to make *complete* fertilizers supplying nitrogen, phosphate and potash. When dealing with compound fertilizers you should note the *ratio* of N: P: K: as well as the actual percentage of each. For example, a general mixture for feeding vegetables out of doors should contain approximately equal amounts of N, P and K whereas a mixture for feeding root-bound plants in pots should be nearer 3N: 1P: 1K.

* N=nitrogen, P=phosphoric acid, K=potash.

TABLE VI

Material	Percentage			Remarks	Usual time to Apply
	N	P as P_2O_5	K as K_2O		
Horse and Cow Manure*	0·5	0·25	0·5		Autumn
Dried Blood	12–14	—	—		Spring
Hoof and Horn	12–14	—	—		Spring
Soot	1–6	—	—	N. as sulphate of ammonia	Spring
Sulphate of Ammonia	20·6	—	—	N. as ammonia	Spring
Nitrate of Soda	15·5	—	—	Tends to make heavy soils more sticky and wet. N. as nitrate	Spring
Nitro-chalk	15·5	—	—	Contains 44% ammonium nitrate and 51% calcium carbonate. N. half as nitrate, half as ammonia	Spring
Superphosphate	—	18	—	Contains 50% calcium sulphate (insoluble) and 50% calcium phosphate (soluble). P_2O_5 in water soluble form	Spring
Basic Slag	—	6–22	—	Contains lime equal in value to an equal amount of $CaCO_3$. P_2O_5 in water insoluble form	Autumn

* Approximate figures only.

TABLE VI—*continued*

Material	Percentage			Remarks	Usual time to Apply
	N	P as P_2O_5	K as K_2O		
Bone Meal	3·5–4·5	20–25	—	P_2O_5 in water insoluble form	Spring
Sulphate of Potash	—	—	48·5	Contains 90–95% potassium sulphate	Spring
Muriate of Potash	—	—	50–60	Contains 80–85% potassium chloride and about 15% common salt	Spring
Potash Salts	—	—	20–30	Is a mixture of potassium chloride and salt	Autumn
Wood Ash	—	—	5–15	Contains potassium carbonate and much calcium	Spring

LIME

The importance of lime in building up fertility has already been mentioned, in part, on pages 63 and 70. We may summarize the facts about lime as follows:

Lime—

(1) is an essential plant nutrient;

(2) promotes the decay of organic matter by bacteria, hence the supply of nitrogenous and other plant nutrients also;

(3) improves the structure and drainage of heavy soils, by causing the clay particles to **flocculate** (i.e. form crumbs);

(4) makes the mineral nutrients of the soil more available, e.g. phosphorus; the calcium in the lime reacts with the relatively insoluble iron and aluminium phosphates to form the more soluble calcium phosphates;

(5) locks up and preserves nutrients, e.g. potassium and ammonium; by base exchange the calcium in the colloidal complex gives place to the potash and ammonium (see p. 69);

(6) controls certain diseases, e.g. club root.

Water

Crop yields are more often restricted through lack of water than through shortage of nutrients. These must be dissolved in the soil water before they can be absorbed by the plant. *Hence a dry plant is a starved plant.*

An indication of the water requirements of plants is given by the amount of water transpired by a crop during its growth. A moderate estimate for a kitchen or market garden would be 10 tons a rod (1,600 tons per acre), equal to 16 inches of rain. Now the annual rainfall in England averages 25 inches in the East to 35 inches in the West, hence when allowance is made for the rain which is evaporated from the land in summer time, or falls during the non-growing season, it is clear that crops may easily run short of water from time to time. In general, the growth of plants in England is likely to be checked in summer time if no rain falls within fourteen days. Hence the need for conserving the soil moisture by building up a good crumb structure (p. 129), adding suitable organic materials, and keeping the land free of weeds.

Handling the Soil: Cultivation

Soil structure (and fertility) depends a great deal on the way the soil is handled. From the grower's point of view many natural soils are poorly drained, close textured, contain many plant pests and are infested with weeds and weed seeds. By proper handling of the soil these undesirable conditions may be rectified in the space of a year or two.

Drainage

No soil can be fertile that is badly drained. To understand this we must examine briefly how water is contained in the soil and how it moves. In really wet soil, the pore-spaces are full of water which moves fairly freely from pore to pore under the influence of gravity, i.e. it can be drained off with ease. In a well-drained soil, the water exists as thin films lining the pore-spaces and the necks connecting them. These water films are relatively unaffected by gravity, and movement of water from pore to pore is comparatively little (p. 78). Now, soil that contains water which should drain off by gravity, holds too much water and too little air for the root hairs to perform their work efficiently; they function best in pore-spaces containing air and lined with water films. Consequently, a water-table 1 foot below the surface acts as a barrier to root growth and restricts the plants' water supply to the moisture contained in the top 12 inches of soil. By contrast, in a well-drained soil with the water-table at, say 5 feet, the roots have a much greater supply of moisture available to them. Thus, paradoxical as it may seem, drainage often *increases* the plants' water supply.

Apart from the question of water supply, undrained soils are infertile because the soil micro-organisms will not flourish in waterlogged, cold soils; they require air and warmth.

Digging

Digging does five things. It

(1) facilitates drainage;

(2) aerates the soil;

(3) buries the weeds;

(4) exposes pests (e.g. wireworm) to the attacks of birds;

(5) helps to develop a proper crumb structure.

We saw that, apart from the coarser mineral particles, a soil in good tilth is made up of small compound crumbs of clay containing very fine pore-spaces. Now, under natural conditions these crumbs are formed only when the clay is alternately wetted and dried, hence the importance of digging, which exposes the soil to the action of rain, frost and wind in the winter time. Cultivations may also affect crumb structure, e.g. if the soil is too moist or too dry the structure will be worsened. *Using the right tools at the right time* assists in producing a good crumb structure.

Raking

Raking is a device for getting a finer tilth, such as is required for a seed bed, than digging produces.

Hoeing

Hoeing does three things:

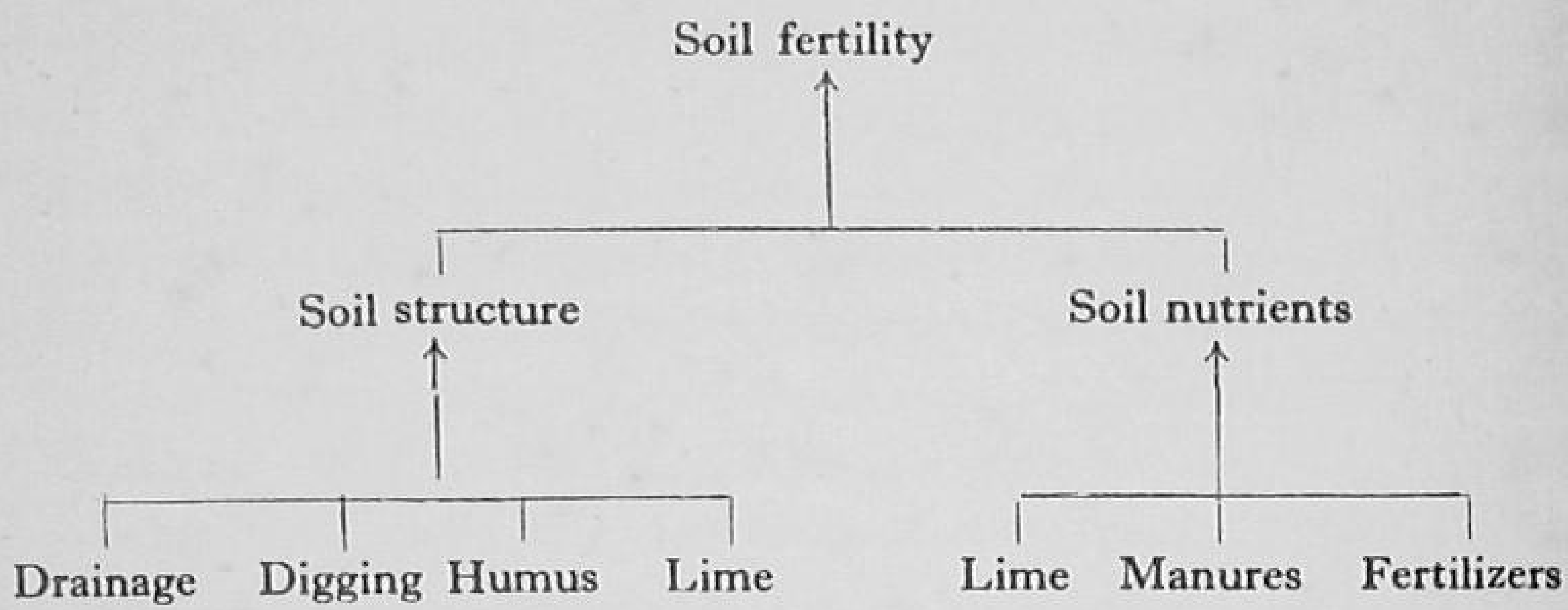
(1) It destroys weeds, which make big demands on the water and nutrient contents of the soil (p. 135). This is by far the most important effect of hoeing.

(2) It breaks up a dry crusted surface so that rain penetrates instead of running off.

(3) It prevents evaporation from the deep cracks and fissures which drought produces in heavy soils.

Contrary to earlier belief, hoeing seems to do little to conserve soil moisture by making a "dry mulch" and so checking capillary action. The great majority of soils are self-mulching. Once the top inch of soil has dried by evaporation, it is an effective barrier, whether loose or compact, to further loss of water.

The whole of the remarks in this chapter on plant nutrition can be condensed into the following diagram;



How to Build up Soil Fertility

Below is a list of some specially important things to be learnt about soils:

(1) Effects of drainage on soils and crops.
(2) Value of hoeing, digging and trenching.
(3) Effect of the sub-soil.
(4) Treatment of light and heavy soils.
(5) Uses of organic matter.
(6) Uses of lime.
(7) Comparative uses of manures and fertilizers.
(8) What constitutes soil fertility.
(9) Nitrogen cycle.
(10) Compost heap.

Chapter Thirteen

ABOUT PLANTS: HEALTH AND DISEASE

In the early pages of the book, we talked about aiming for success, *your* success in horticulture. We made a plan. You would learn the basic facts and jobs; those things of *immediate* practical importance to you as an apprentice—a subordinate. Other matters could be left to the future, especially those concerned with the supervision of crops and work—the employer's problems rather than the employee's. That was our plan: to examine selected details of the horticultural landscape rather than the landscape itself.

Now, if the number of details we examine is large, we shall probably get a fair idea of the landscape, so long as we are on our guard against not seeing the wood for the trees. But if the number of selected details is small, then there is a very real danger that we shall not even be aware that there *is* a wood. Such is the case with plant hygiene. Most young horticulturists learn a little about aphides, wireworms, potato blight, damping-off and a few other common pests and diseases, but have no conception whatever of the breadth and importance of hygiene generally.

Since many employers also are ignorant of the subject, the novice stands little chance of picking up anything from them by way of precept or practice. The result is that although plant hygiene is well-established as a science it is often neglected in practice, to the detriment of the growers' plants and prestige.

This is a situation I hope you will refuse to accept. If half the business of growing plants consists in feeding them well and giving them the right cultural treatment, then the other half consists in waging a ceaseless war against a disconcerting number of foes, whose tactics range from massed frontal attacks to the most insidious infiltration—usually the latter. Every year the casualties on the garden front amount to thousands of plants. This direct loss is bad enough, but it is small compared with the loss of time, labour and materials incurred in trying to beat off the mounting offensive of the enemy and in nursing hospital cases.

Because of these bad tactics, plant hygiene is assumed to be something in the nature of desperate and expensive counter-attacks. The truth is that plant hygiene, properly understood and applied, is inexpensive and remarkably effective. The proper strategy can be described in three words—*keep the initiative*. The proper tactic is—*seek out the enemy*. Don't wait for him to attack; anticipate his moves, destroy him in his bases. Only small forces are required to do this, but once let the enemy gain a foothold, then his overwhelming numbers give him an enormous advantage.

What does this mean from your point of view? Two things. First, you must be acquainted with the general measures of plant hygiene, and secondly, you must be able to recognize the *first* signs of attack. I have been surprised again and again at the inability of young growers to recognize the early symptoms of attack, say by thrips or red spider, or of the mite that causes reversion in currants. As a subordinate, your value to your employer will be enhanced if you can spot trouble before it has time to develop. As a prospective supervisor or employer, it is vital that you should become aware of hygienic measures as well as nutritional and cultural. Many times you will have to use all your knowledge and powers of reasoning in an effort to deduce the causes of ill-health or to diagnose disease. And in order to do this in the future you must prepare *now* and all through your career.

So now to make a start. First, let's become acquainted with the general landscape, then we shall see better how the individual items fit in. One important point: as growers we are only interested in plant enemies in so far as we can *control* and defeat them. Hence, our consideration of plant hygiene will always be in terms of control: control of all the conditions and organisms affecting the health of plants.

Read this chapter straight through without trying to remember particular examples. It's the headings that matter: the chief features of the landscape. You might then like to jot down these headings and sub-headings on one sheet of paper, so that the whole panorama is before you. And in months to come you could put a mark against those methods of control you have seen practised with some success. Or should have been practised and weren't!

Cultural Control

(1) **By good cultivation.** Many troubles can be avoided if plants are kept in a good general state of health. Below are examples of conditions which are often the cause of obscure troubles. It is easy to recognize a severe attack of green fly: it is far from easy to diagnose the cause of "debility" arising from nutrient deficiency, improper soil conditions and similar things. Yet the ill-health of many "C3" plants is due to such causes.

(*a*) Unsuitable Climate

Fruit trees cannot be grown properly in windy and exposed positions.

Fruits, vegetables, flowers, etc., are damaged in "frost pockets".

Glasshouse plants grow poorly in smoky industrial areas and fog defoliates glasshouse plants (e.g. begonia) in winter-time.

Salt spray in coastal regions may scorch the leaves of plants and check their growth.

Damping-off of seedlings and leaf-mould of tomatoes flourish in warm, humid (glasshouse) conditions.

Brown-heart of apples develops in a badly-ventilated store.

Scorching of flowers occurs in strong sunlight or high temperature.

CONTROL.—Select a site which is sunny, sheltered from cold and strong winds, free from smoke, etc., and with an adequate rainfall. Know and maintain the proper glasshouse conditions.

(*b*) BAD SOIL CONDITIONS

Seed germination and seedling growth are poor if the tilth is bad.

Root action is poor in badly-drained soil.

Growth is stunted on light soils in time of drought.

Club root of brassicas, and slugs and snails are encouraged on wet soils.

Growth is inferior on acid soils.

Growth is checked in badly-sterilized soil.

CONTROL.—See that the soil is well drained, adequately supplied with humus, in good tilth and corrected for acidity.

(*c*) INCORRECT MANURING

Growth is weak if nitrogen is deficient; and soft and susceptible to disease if it is in excess.

Seedling root action is bad, resistance to disease lowered and seed and fruit quality inferior if phosphorus is deficient.

Growth is mediocre and disease (and pest) resistance lowered if potassium is deficient; leaf scorch develops in apples, potatoes and other plants.

Chlorophyll production is inhibited (lime chlorosis) if lime is in excess.

Fruits may drop if nitrogen is deficient.

CONTROL.—Ensure adequate and balanced supplies of nitrogen, phosphorus and potassium. Avoid excessively limey soils.

(*d*) FAULTY PRACTICES

Potato tubers may be infected with blight if not earthed up.

Fungal diseases attack pruning wounds not painted with a sealing compound.

Blossom-end rot of tomatoes may develop if plants are allowed to become temporarily dry at the roots.

Apples are scorched by lime-sulphur sprays that are too concentrated.

CONTROL.—Attend scrupulously to all cultural requirements.

(2) **By Clean Cultivation.** In many gardens, nurseries, etc., there is plenty of room for improvement in the practice of clean cultivation. You would feel insulted if you were accused of being dirty in your home; of living in insanitary conditions. Vermin, rubbish, and filth are as disgraceful in your garden or nursery as in your home. And as dangerous. Never allow yourself to think of the following conditions as inevitable or even permissible. They are the trade mark of the inefficient gardener.

(*a*) WEED COMPETITION

Weeds compete with crop and garden plants for water, nutrients, light and air. *This competition is often very severe in its effects.* For example, the water and nutrient content of many soils is barely enough for the healthy growth of crops, even when there are no weeds present, hence a moderate number of weeds is quite sufficient to bring about an appreciable reduction in growth and yield.

Weeds are particularly harmful if they infest the ground thickly at a time when cultivated plants are in the *seedling* stage. Not only do they use up water and nutrients, but by forming a canopy over the seedlings they cut off much of the light (radiant energy) necessary for healthy and vigorous seedling growth.

CONTROL.—Destroy all weeds, while they are still *young*, by frequent hoeings.

(*b*) ALTERNATIVE HOSTS

Many pests and diseases of cultivated plants are also carried by wild plants, which act as sources of infection or re-infection.

Club root of brassicas also attacks charlock and shepherd's purse.

Black rust of wheat occurs on the wild barley.

Spotted wilt and other viruses are found on many weeds, especially in the potato family (Solanaceae).

Hollyhock rust attacks various wild plants in the hollyhock family (Malvaceae).

Crown gall of roses and apples occurs on wild forms of the same family (Rosaceae).

Wireworm finds cover and food in long grass.

Capsid bugs infest many wild plants.

CONTROL.—Elimination of weeds, especially those related to the crops of plants being grown.

(*c*) Breeding Grounds

Numerous pests and diseases find refuge and overwinter in rubbish, uncultivated ground and other hiding places.

Eggs, pupae, and adult insects are harboured by rubbish heaps, accumulations of leaves, long grass, dirty ditches, mossy bark on trees, etc.

Dirty glasshouses harbour red spider and wood lice.

Dirty water tanks shelter harmful fungi and bacteria.

Mummy apples carry over brown rot disease of fruit trees from one year to another.

Apple sawfly and the codling moth larvae may be sheltered for a while in fallen apples.

Many pests pupate in the soil (e.g. cabbage root fly, onion and carrot fly) and overwinter there if undisturbed.

Control.—Burn (or compost) all rubbish, destroy long grass or keep it mown. Keep ditches clean, sterilize glasshouses periodically, destroy mosses and lichens on fruit trees by winter spraying; gather infested and diseased fruits and destroy. Frequently cultivate soil to expose pupae, etc., to attacks of birds.

(3) **By Rotation of Crops.** Part of the life-cycle of many insect pests and fungus diseases is spent in the soil. If the same crop is grown on the same plot year after year, the pests and diseases attacking that crop may accumulate in the soil, sometimes in such numbers as utterly to destroy the crop.

The spores of club root of brassicas may survive in soil for several years, even though no brassicas are grown during this time. Tomato soils become "sick" after they have been cropped with tomatoes several years in succession, probably owing to the accumulation of harmful organisms in the soil.

CONTROL.—Avoid cropping the same soil with the same crop in successive years. A rotation of three or more years is often advisable. Soil sterilization will cure tomato soil sickness.

(4) **By Time of Sowing and Planting.** It is not often that a crop *must* be sown on a certain date; it is usually possible to advance or retard the date and still get the required crop. This margin of time can sometimes be used to make all the difference between success and failure; between a heavy crop and a light one. For example:

Seedlings transplanted in the morning on a hot day will wilt and suffer badly; transplanted late in the day they have time to recover during the cool of the night.

Planting out "by the calendar" without regard to the weather (wind, frost, drought, etc.) may result in severe losses: this risk may be lessened by closely studying the weather and selecting the best moment for planting.

Carrots sown in May are often attacked by carrot fly: sown in March they escape.

Onions sown out of doors in March–April may be attacked by onion fly: if onion setts are used (raised the previous year) or if seeds are sown early under glass and the seedlings transplanted, attacks are usually avoided.

Sweet corn sown out of doors in April is subject to attack by frit fly: planted out from three-inch pots or from frames as established plants, this danger is avoided.

CONTROL.—Sow or plant at a time which:

(*a*) ensures the best possible growth of the crop;

(*b*) does not leave the plant, at its most susceptible period, open to attack by a special pest or disease.

Propagation Control

(1) **By use of plump, large, seeds.** Undersized seeds have a small reserve of food and when they germinate are not able to withstand unfavourable conditions (e.g. cold, wet). Hence germination is reduced and seedling growth weakened.

CONTROL.—Use only large, plump seeds with a good reserve of food.

(2) **By use of clean seed and stock.** No amount of cultural skill is likely to make good the handicap of starting with diseased seed, bulbs, cuttings, etc.

> Celery leaf spot. This fungus is spread by infected seed. One remedy is to kill the fungus by soaking the seed in dilute formaldehyde.
>
> Viruses are sometimes transmitted in the debris found among badly cleaned seed.
>
> Raspberries and potatoes propagated from mosaiced (virused) stock will not recover however good the subsequent cultural treatment. Crops will be reduced and the disease spread.
>
> Narcissus fly. Bulbs containing the grub of this fly may be treated with hot water (110° F.) for one hour and the grubs destroyed.
>
> CONTROL.—Save or use seed, cuttings, etc., only from disease-free parents and stock; or take appropriate measures to kill any pest or disease present in stocks to be used for propagation.

(3) **By choice of variety.** A variety that does well in one locality may give disappointing results in another.

CONTROL.—Select varieties that have given good results in your own locality or under similar conditions of soil and climate.

(4) **By use of resistant varieties.** Varieties differ in their susceptibility to given pests, diseases and unfavourable environmental conditions. For example:

Cox's Orange Pippin apple is susceptible to scab: Edward VII is resistant.

King Edward potato is susceptible to wart disease: Majestic is resistant.

Most cucumber varieties are susceptible to leaf spot: Butcher's Disease Resister is immune.

Paul's Scarlet Climber rose (and many others) is susceptible to mildew: Emily Gray is immune.

CONTROL.—Where necessary, use resistant varieties.

Legislative Control

Pests and diseases sometimes increase to such an extent as to become a national danger. The Ministry of Agriculture may then issue an order under an Act of Parliament requiring the grower to obey certain regulations designed to control the pest or disease. Thus, outbreaks of wart disease of potato, colorado beetle, and onion smut must be reported to the Ministry of Agriculture, and there are penalties for failing to do this.

Biological Control

The natural enemies of a pest or disease can sometimes be used to keep it in check.

White fly can be a troublesome pest on indoor tomatoes. A small "wasp", *Encarsia formosa*, which lays its eggs in the larvae of the white fly, is sometimes employed to control this pest.

Chemical Control

After all the precautions mentioned in the previous pages have been taken, recourse to more drastic measures may be necessary before certain pests and diseases can be controlled. Chemicals in the form of solid, liquid or vapour are used; also heat.

Those used against plant pests are known as **insecticides:** those against fungus diseases as **fungicides.** A few chemicals have both good fungicidal and insecticidal properties; most are efficient in one capacity only. The business of making insecticides and fungicides has become highly specialized and a number of excellent substances are manufactured and sold under trade names.

Insecticides and fungicides may be conveniently divided into two classes, *protective* and *remedial*, according to their chief function. In the case of the protective class, the aim is to apply the treatment before infection or infestation has begun, i.e. to *prevent* an attack. The remedial chemicals are used directly against the pest or disease and kill by contact, i.e. the aim is to eradicate an attack. Some chemicals are both protective and remedial, but usually they are employed for one purpose or the other. Examples of the two classes are given below:

PROTECTIVE

Naphthalene and calomel dust against soil pests.

Bordeaux mixture against potato blight.

Sulphur sprays against mildew and tomato-leaf mould.

Nicotine spray against leaf-miners.

Partial soil sterilization may be included here, since its value is to *prevent* the attacks of soil-borne pests and diseases:

(*a*) By heat (steam and electricity).

(*b*) By chemicals (formaldehyde, cresylic acid, etc.).

REMEDIAL

(*a*) *Dusts* to kill (1) active insect life, e.g. derris, pyrethrum, nicotine dusts; (2) the spores and mycelia of fungi, e.g. the mercurial compounds used in dressing seeds to kill fungus spores.

(*b*) *Sprays* to kill (1) eggs, grubs, larvae and adults in insects, e.g. tar oil and petroleum sprays, derris, nicotine, D.D.T., T.E.P.P.; (2) spores and mycelia in fungi, e.g. bordeaux mixture.

(*c*) *Fumigants and Smokes* to kill active insect life, e.g. nicotine, azobenzene; also sulphur and naphthalene, volatilized as dust, to kill the spores and mycelia of fungi.

You should now have a fairly good idea of the various factors which bear on plant hygiene; of the landscape as a whole. There are, however, several items in the landscape of such importance as to warrant rather more detailed study.

First, you should know a little about a typical insect, its structure, how it grows and how it reproduces itself. Similarly, you should be acquainted with the main types of fungi and with viruses. Secondly, there are several pests and diseases which are so common and dangerous that you ought to learn about them early in your career. Here they are:

Pests	*Ministry of Agriculture Leaflet No.*	*Diseases*	*Ministry of Agriculture Leaflet No.*
Aphides	269	Apple and Pear Scab	245
Cabbage Root Fly	18	Brown Rot of Apples	155
Codling Moth	42	Club Root	276
Flea Beetles	109	Damping-off	—
Onion Fly	163	Onion Mildew	85
Red Spider	224	Potato Blight	271
Apple Sawfly	13	Potato and Tomato Virus Diseases	139
Slugs and Snails	115	Tomato Leaf Mould	263
Wireworms	199		

TABLE VII

SYMPTOMS OF ILL-HEALTH

Symptom	Possible Cause	Example
GENERAL—		
Lack of vigour	Drought	Seed pans, pot plants, outdoor plants and crops
	Nutrient deficiency	Nitrogen starvation
	Virus attack	Raspberry mosaic
	Pest attack	Eel-worm of chrysanthemum, onion, narcissus, phlox, etc.
	Fungal attack	In many plants
	Bacterial attack	In many plants
Wilting	Damping-off fungus	In seedlings
	Drought	In pot plants, outdoors, etc.
	Over-watering	In pot plants
	Root disorders	Root rots, wire-worm, etc.
	Stem disorders	Stem rots
	Excessive transpiration	In bright sunlight
	Fungal attack	Verticillium wilt of tomato
STEMS—		
Cracking	Frost	Bark splitting in trees
Warts	Pest attack	Apple woolly aphis
Canker	Fungal attack	Apple canker
Basal rotting	Fungal attack	Black leg of aster, stem rot of tomato
	Bacterial attack	Black leg of potato
Elongated	Insufficient light	"Drawn" seedlings
LEAVES—		
Colour: (*a*) General: pale or yellowish	Insufficient light	Overshadowed plants
	Excess of lime in soil	Lime chlorosis
	Fungal attack	Silver leaf of plums
(*b*) Local: spots and markings	Damage by sucking insect	Aphis, capsid bugs, red spider, thrips, etc.
	Nutrient deficiency (potash)	Leaf scorch of apples

TABLE VII—*continued*

Symptom	Possible Cause	Example
LEAVES (*contd.*)—		
Colour:		
(*b*) Local: spots and markings	Damage by leaf-miners	Chrysanthemum and celery leaf-miners
	Damage by cultural operations	Sun scorch, spray and fumigant scorch, abrasions
	Fungal attack	Mildews, rusts, moulds
	Virus attack (mosaic)	Spotted wilt (of many plants), potato mosaic, etc.
Mutilation:		
Eaten	Caterpillar attack	Cabbage caterpillar
Cut	Insect attack	Leaf-cutting bee (roses)
Holes	Fungus attack	Shot-hole of fruit trees
Malformation:		
Rolled	Pest attack	Apple and plum aphides
	Virus attack	Leaf roll of potato
Reduced in size	Virus attack	Reversion in currant
Blistered	Fungus attack	Leaf curl of peach
Leaf Drop	Drought	Basal leaves in pot plants
	Nutrient deficiency	Nitrogen starvation
	Fog and sulphurous fumes	Defoliation of winter-flowering begonias
FLOWERS—		
Bud and flower drop	Insufficient light	Glasshouse plants in winter
	Nutrient deficiency	Nitrogen starvation
	Failure of fertilization	In fruit trees, etc.
	Temporary drought	In tomato
Marks and distortion	Pest attack	Thrips in cyclamen, apple weevil
FRUIT—		
Fruit drop	Improper fertilization	June drop of tree fruits
	Drought	Summer drop of tree fruits
	Nutrient deficiency	Nitrogen starvation (including overcrowding of fruits)

TABLE VII—*continued*

Symptom	Possible Cause	Example
FRUIT (*contd.*)—		
Fruit drop	Pest attack	Apple sawfly and codling moths, pear midge
	Fungus attack	Brown rot of plum and apple
Blemish	Fungus attack	Potato blight of tomato, apple and pear scab
	Improper atmospheric conditions	Brown heart of apples
	Virus attack	Bitter-pit of apples
Split	Excess moisture	In tomatoes
	Frost	In apple
Rotted	Fungus attack	Brown rot of plum and apple, buck-eye rot of tomato
	Temporary drought	Blossom-end rot of tomato
ROOTS—		
Rotted	Fungus attack	Root rot of tomato
	Bacterial attack	Soft rot of carrot
Malformed	Pest attack	Cabbage fly, eelworm of potato and tomato
	Fungus attack	Club root of brassicas
	Bacterial attack	Crown gall of apples, roses, etc.

Don't attempt right away to memorize the life history of each of these pests and diseases. First learn what they look like from the illustrations in the Ministry of Agriculture's leaflets, but especially from life. Then memorize how each of these pests or diseases may be controlled.

The list I have given is a very short one and it is quite possible that in your own locality some other pest or disease is more serious than those I have mentioned. In this case get the appropriate leaflet and learn the essential facts at the time you are dealing with the disorder in practice.

This is a good rule to follow all through your career, for obvious reasons; you are much more likely to remember the facts about, say, apple sawfly after you have been in action against it.

In Table VII I have given some of the symptoms of ill-health, together with possible causes. This table is not intended for reference purposes in diagnosing ill-health; it is too brief. It is meant to give you a picture of what the symptoms of ill-health are like and the sort of causes you would have to review in diagnosing a complaint. In other words, the purpose of the table is to make you *aware* of the general situation. In actual practice, the method of elimination would probably be the best one for identifying a disorder.

Chapter Fourteen

ABOUT JOBS

THE best way to learn jobs is to do them—under proper supervision. You should be experienced in every one of the jobs mentioned in this chapter by the time you have completed the first three years of your career. I can't teach you to dig or spray or pot up plants; that is the business of your foreman or supervisor. My aim is to point out which are the basic jobs and to draw your attention to the more important details connected with them.

OUTDOORS—Digging

On page 45 of this book I suggested that if you were keen you would learn to organize your movements. Digging gives you as good a chance as any to practise this. No one appears to have studied digging movements scientifically. Here are some suggestions from my own experiments. Many experienced gardeners may disagree with me. You, at least, can try out these ideas and form your own opinion. The movements described below apply to a right-handed person digging from right to left.

POSITION OF FEET. About 12 inches apart, the left foot 12–14 inches behind the spot where the spade is to be driven into the soil.

POSITION OF HANDS. Start with the spade held upright. Muscular strain on wrist and arms is least when the left hand holds the *front* of the spade shaft, the back of the hand *toward* the trench, not away from it as so many people do. Similarly, it is easier to work when the right hand holds the handle of the spade so that the back of the hand is *toward* the trench (Fig. 18a).

DRIVING THE SPADE INTO THE SOIL

(1) With the right hand lift the spade vertically about 18 inches (Fig. 18a), bending the arms at the elbows, so that the handle is head high.

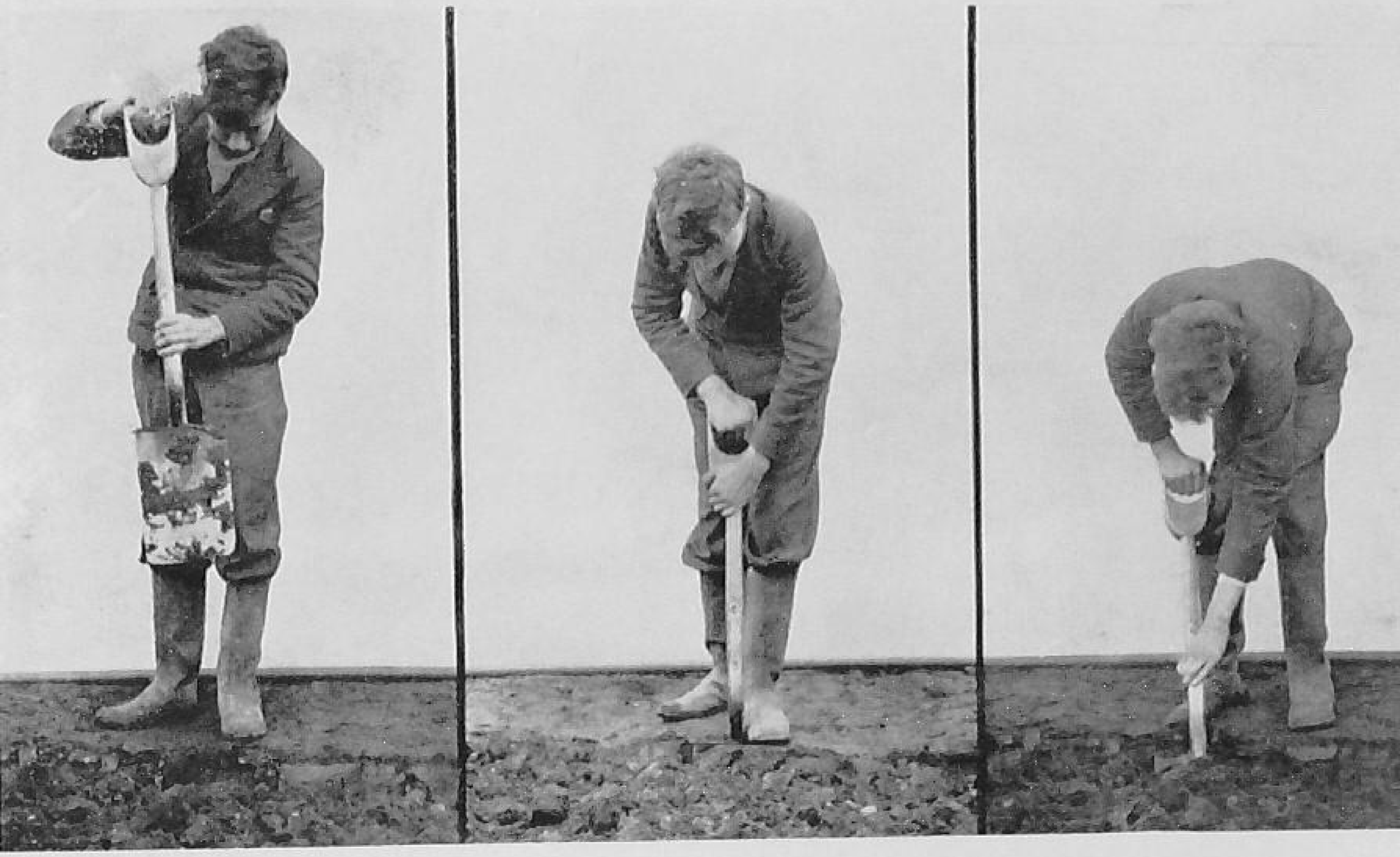
(2) Bring the spade down smartly so that the blade enters the soil several inches.

(3) With the left foot, drive the blade full depth into the soil (Fig. 18b), and at the same time lift the right foot off the ground, move it to the left and bring it down directly behind the spade. Use full *body weight* to drive the spade down.

(4) After the left foot has done its work, bring it to the ground directly behind where the spade will be for the next spit. The left hand does practically nothing during these movements, except to steady the spade.

LEVERING UP THE SOIL. With the right hand first pull, then press, the shaft sharply backwards and downwards (using body weight), pivoting the back of the spade on the edge of the trench. Simultaneously, slide the left hand low down on to the iron of the shaft (Fig. 18c). Continue the pivoting movement without pause, as the left hand becomes the fulcrum in place of the edge of the trench. Lift the spade *just clear of the ground* by straightening your body. Immediately twist the spade to the right with the right hand, the shaft rotating loosely in the left (Fig. 18d), and *slide* the spadeful of soil inverted into its proper position (Fig. 18e). These levering movements are made in *one continuous swing*.

RECOVERING. Straighten the body, slide the left hand higher up the shaft, which is brought to the vertical position, and you are ready to dig the next spit.



a b c

d e

Fig. 18a–e. SUGGESTED METHOD OF DIGGING

Fig. 19. SHOVELLING

MOVEMENT OF FEET. Each foot moves *once* to the left during these operations, so in digging you march steadily across the ground.

MUSCULAR EXERTION. The only effort made by the left hand is when the spadeful of soil is lifted from the trench. Even then it supports rather than grips the spade. At all other times the left hand merely touches the spade to steady it. The right hand lifts the spade, drives it down, and turns it over. All your movements should be loose and easy and your muscles relaxed whenever it is possible. As you straighten up, *pay special attention to relaxing the muscles of your back.* Half the art of learning to dig is in learning to relax.

In digging from left to right, reverse all the hand and foot positions, and dig *left-handed.* The advantage of digging right-handed across the plot one way and left-handed the other is that different sets of muscles alternately take the greater strain, consequently the work is less tiring as a whole. The above remarks are an outline only and refer to single spit digging alone. Modifications will have to be made under certain conditions. For example, on heavy or hard ground, more than one push may be required to drive the spade full depth; on weedy ground a cut will have to be made at right angles to the trench to cut off the next slice of soil.

Get experience in single-spit digging and bastard trenching as soon as you can. The main points to watch are:

(1) Don't take too big a spadeful of soil.

(2) Turn each spadeful of soil right over so that all weeds are buried.

(3) Keep your trenches of uniform width and depth or you will not be able to

(4) keep the ground level.

(5) Don't try to dig too fast; easy rhythm is more important than strenuous speed.

I have dealt with digging at length to encourage you to think about the way you do a job. *No garden operation is so simple that it can be approached with a closed mind.*

Shovelling

When you move a heap of soil, do all shovelling at ground level, not at the top or sides of the heap. Hold the shaft and handle of the shovel with the palms of the hands facing more or less *upward*—the reverse of the positions described for digging. If you are right-handed, rest the back of the right hand against the front of the right thigh, and the left forearm across the left thigh (Fig. 19). Place the blade of the shovel nearly flat on the ground, and push it into the base of the heap, partly by a forward swinging movement of the body from the knees, partly by a forward swinging movement of the arms from the shoulders. This double movement is simultaneous. Next, withdraw the shovelful of soil from the heap and by a similar double swing as described above, throw the soil to wherever it is wanted. There should be no jerkiness in these strong rhythmical movements. If the material being moved is light in weight, or if it has to be lifted up rather sharply, e.g. into a barrow, then you will find it less tiring to position the left hand as for digging, i.e. on the upper side of the shaft and with the palm facing downwards.

Wheeling

Place the barrow with the wheel facing the direction in which the load is to go. Load the material so that, when you are wheeling the barrow, *the main weight falls on the wheel*, not on the handles. There are two ways of turning a corner: (1) by lifting the handle on the opposite side to the turn and leaning the barrow over; (2) by moving to that side of the path which is opposite to the direction of the turn and so turning with the barrow quite level. The first turn is the one a cyclist makes, the second somewhat similar to that of an errand boy's tricycle. The first is the turn most commonly employed; the second is safer when wheeling heavy loads.

Hoeing

(*a*) Push (Dutch) Hoe. You cannot hoe properly standing straight up; your body must bend forward at the waist. The angle between blade and soil should be about 20°. The hands fall naturally on the handle of the hoe, the left hand lowest, about half-way down the handle, the palm facing upwards and to the right. The palm of the right hand should face downwards and to the left. Make your strokes as long as practicable and join them up; there should be no unhoed patches. In general, use a shallow cut for fibrous-rooted weeds (e.g. most annuals) and a deeper cut for tap-rooted weeds (e.g. goosefoot). Perennial tap-rooted weeds (e.g. dandelion and dock) should be dug up.

(*b*) Draw Hoe. This is better suited than the push hoe for ground infested with big weeds. The hoeing angle should not be more than 30°. In both push and draw hoes the blades should be kept clean and *sharp*.

Raking

Hold the rake as in hoeing. The pushing movement is more important than the pulling. Lightly draw the surface lumps towards you and then, in the pushing stroke, sharply strike the heap in order to break up the lumps. Here are three "don'ts":

1. Don't rake too deeply; it results in an uneven surface.
2. Don't rake the surface too fine; the first rain will make it pasty and it will dry out hard and cracked, which is bad for seedlings.
3. Don't move your feet more than is necessary; a trampled surface is not ideal.

In both hoeing and raking learn to work left- as well as right-handed.

Drawing Seed Drills

When drawing the drill, avoid pressing the hoe against the line, which should be tightly stretched, or you will get a bow-shaped drill instead of a straight one. Keep the drill a uniform depth; about ½ inch for small seeds (e.g. lettuce), 1 inch for medium size (e.g. beet), and 2 inches for large ones (e.g. beans). Bad germination is often the result of sowing too deeply.

Seed Sowing

Sow the seeds as soon as the drill is drawn. If you wait for long in sunny weather, the soil in the drill will dry out and this may result in germination being delayed. In dry weather, the ground on which the seeds are to be sown should be thoroughly watered the day before. Hold the seeds in the cupped left hand and sow a few at a time with a rotary movement of the thumb and first two fingers of the right hand. Another way is to hold the seeds in the right hand and by suitable movements allow the seeds to trickle out between the thumb and fingers.

Thinning

Grasp the seedlings as close to the soil as possible and pull *away* from those to be left with a steady pull, not a jerk.

Transplanting

(*a*) Overcrowded and starved plants don't transplant successfully; make your arrangements so that the plants are just ready at the proper time.

(*b*) Harden them off a few days before transplanting.
(*c*) Water them thoroughly overnight before planting out.
(*d*) When lifting the plants from the seed bed, boxes etc., damage the roots as little as possible.
(*e*) Handle the plants carefully, holding young seedlings by their leaves; especially avoid squeezing the stem and growing point.
(*f*) Plant at once before the plants can wilt.
(*g*) See that the soil is moist and in good tilth.
(*h*) Spread out the roots.
(*i*) Press the soil firmly round the *roots.*
(*j*) Water-in the plants at once if necessary.
(*k*) On a hot, drying day, plant in the evening if possible; alternatively, shade the plants. A light syringe may help. A dull, humid day is the best for planting.
(*l*) A day or two before transplanting, rake in a dressing of superphosphate (18 per cent P_2O_5), at the rate of 2 ozs. per square yard, to ensure the rapid development of new roots.

Staking and Caning

In the case of single-stemmed plants in exposed positions, put the stake, or cane, on the windward (prevailing wind) side of the plant; the plant will be least damaged when blown away from the stake (this does not apply to the inclined stakes often used for fruit trees). Where the decorative aspect is the most important consideration, see that the plant conceals the stake. Don't damage the crown or the roots of the plant when driving the stake in. In some cases it is better to stake first and plant afterwards.

Tying

Never tie so tightly or in such a position that the stem cannot grow thicker or taller without being damaged. Tie before the shoot has become crooked; you may break it trying to straighten it and anyway a "straightened" shoot always looks ugly. Tie where the greatest support is needed, e.g. just beneath the trusses in tomato. Tie so that the knot comes on the stake and not on the stem, which may get chafed.

Watering

Water will not soak into hard, dry ground. Always loosen the soil with the hoe or fork before watering. Water *thoroughly*, or not at all.

Spraying

In dealing with the majority of pests and diseases, a fine, misty spray is required that leaves no part of the plant unwetted. A given pest or disease may occur on one part of the plant rather than another and you should learn where. For example, glasshouse thrips usually occur on the upper surface of the leaves, red spider on the lower surface.

Applying Fertilizers

The whole art of this job is in applying the fertilizer *evenly*. As an example of how to do this we may take a plot thirty yards long by ten yards wide, to be dressed at the rate of two ounces per square yard. First obtain a measure that holds ten ounces of the fertilizer. Next, measure off a strip one yard wide *across* one end of the plot. Broadcast the ten ounces of fertilizer along the ten yard strip (i.e. one ounce to one square yard). Repeat this on strips one yard wide, judging by eye, from one end of the plot to the other. Now do the same *along* one side of the plot, using three ten-ounce tinfuls to each strip one yard wide (i.e. thirty ounces to thirty square yards) and working across the plot. In this way each square yard receives two ounces of fertilizer, applied one ounce at a time, and an even distribution is ensured.

Hedge Trimming

Hedges and edges need regular attention in decorative gardening. Learn how to shear in a straight line.

Lawn Mowing

The art of mowing with a modern machine lies in the correct adjustment of the machine. There are two adjustments. To get a *clean* cut, bring the bottom blade into closer contact with the rotary cutting blades, until each of them, when revolved by hand, just brushes the bottom blade over its whole length. To get a *close* cut raise the front (in some cases, the back) roller in its frames; to get a longer cut lower the roller. It is important to adjust the two sides equally.

Cuttings

Success with cuttings out of doors depends on three things:

1. The cutting bed must be well drained, of good tilth and in a warm and sheltered spot.
2. The cutting must be well ripened and not too slender or too stout.
3. The cutting must be inserted to a sufficient depth and the soil trodden firmly against it, especially at the base.

Pruning

Use a very sharp knife, or secateurs. When the left hand is used to hold the shoot being pruned, always hold it *below* where the pruning cut is to be made. Failure to observe this may result in bad cuts on the left hand or wrist. Soft shoots (as in glass-house plants) may be cut against the ball of the right thumb.

Budding and Grafting

You can practise making buds and preparing scions on odd shoots cut from trees and bushes. If possible, watch an experienced man and ask him to explain the important points and to criticize your efforts. Remember, it is the cambium tissues which *must* be brought together if bud or graft is to "take".

INDOORS—Seed Sowing

In preparing pots, pans and boxes use soil which is slightly moist. Press it moderately firm, paying attention to the corners of boxes. Keep the surface dead level. Water the vessels an hour or two before using and leave them to drain. After sowing, use an $\frac{1}{8}$ inch sieve to cover small seeds and a $\frac{1}{4}$ inch for larger ones.

Pricking-out

Pricking-out is best done before the radicle (seedling root) is more than one inch long, i.e. before lateral roots have developed. Hold the seedling by one of its cotyledons, not by its stem. With the dibber make the hole for the seedling just deep enough to take the full length of the root—no more. Press the soil firmly round the root, not merely around the collar. Water the plants gently so as not to knock them over.

Potting

See that the plant is in the centre of the pot. The ball should be a little below the surface when potting is finished. Don't overfill the pot with soil, or there will be insufficient space for water. The soil should be of uniform firmness. It should also be slightly firmer than the old ball, otherwise the water will soak away through the new soil, leaving the ball dry, to the detriment of the plant. Ideally, the soil should be made a little firmer at each and every stage from seed sowing to the final potting.

Watering

A great part of the art of gardening under glass is knowing when to water. Here are some general rules:

(*a*) Healthy plants require watering more frequently than sick; fast growing than slow; root-bound than newly potted; on bright days than dull.

(*b*) There are four ways of telling whether a plant needs watering: (1) from the look of the soil, (2) by feeling the soil, (3) by tapping the pot (a dry pot usually "rings"), (4) by lifting it (a wet pot is heavier than a dry one).

(*c*) When you do water fill up the pots, i.e. *water thoroughly.* Hold the spout of the can close to the soil; it doesn't help the plant to wash half the soil out of the pot!

(*d*) In winter-time the last watering of the day should rarely be after 1 p.m. or there will not be time for the excess moisture to evaporate before nightfall, and a clammy atmosphere will result.

Ventilating

Watch out for cold draughts and sudden changes of the direction of the wind. Don't wait until there has been a drastic rise or fall in the temperature of the glasshouse before altering the ventilation. "A little and often" is the rule for ventilating. Learn how to use the thermometer—it's an aid, not a dictator. The "feel" of the house (i.e. relative humidity) is what usually matters most, not the actual temperature.

Shading

Better a little too little, than a little too much. In other words, don't coddle your plants: give them all the light they can take.

Spraying

On a sunny day, use sprays early in the morning or in the evening, when the sun is not too strong, otherwise the plants may be scorched. Always use soft water; it makes a better spray than hard water, which also leaves an unsightly deposit on the foliage.

The jobs mentioned above are those you should become proficient in during the first three years of your career. There are, in addition, many other practices of which you should have some experience. You will find a comprehensive list below. Some of this work may not concern you very much; it depends on the particular branch of horticulture you are following. The list is to assist you to check up on your practical work and see that its foundations are broad and adequate.

Propagation

Layering.
Division.
Root cuttings.

Vegetables

Successional cropping.
Intercropping.
Rotation.
Use of frames.
Storing root crops.

Fruits

TREE FRUITS. Apple, pear, plum, cherry, peach, nectarine.
- Propagation: budding, grafting, top-grafting, frame-working.
- Training: cordon, bush, pyramid, standard and wall-trees.
- Planting: aspect, lay-out, pollinator varieties, inter-planting, staking.
- Pruning: shoot (wood and blossom buds), root.
- Bark ringing.
- Cultivation: manuring, spraying, banding, thinning.
- Harvesting and storing fruits.

SOFT FRUITS. 1. Red and black currant, gooseberry *bushes.*
2. Raspberry, blackberry, loganberry *canes.*
3. Strawberry *plants.*

Propagation: 1. cuttings, 2. division, cane-tips, 3. runners.
Training and pruning.
Planting: aspect, layout, supports.
Cultivation: manuring, spraying.

Flowers (indoor and outdoor)

Annual border: planning, sowing, thinning, seed saving.
Herbaceous border: planning, planting, staking.
Trees and shrubs: planning, planting, pruning.
Roses: planting, pruning.
Bedding plants: planning, planting.
Rock garden: planning, construction, planting.
Conservatory: succession, cultivation, feeding.
Bulbs: planting, lifting, drying, storing, forcing.
Climbers: pruning, training.
Lawns: construction, mowing and edging, aerating, raking, manuring.
Paths: construction, weeding.
Compost heap: construction.

Chapter Fifteen

EXAMINATIONS

ALL keen young horticulturists will prepare and sit for examinations in horticulture as a routine part of their training. The advantages of doing so are very great.

First, an examination gives you something to aim at in your studies. Most of us are probably not heroic enough to be able to study, year in and year out, without committing ourselves to a test of our knowledge. Secondly, an examination sets a time limit to your studies and this encourages steady progress from stage to stage, from examination to examination. Third, the possession of a certificate is definite evidence of your knowledge and ability and should carry that much extra weight in the eyes of a prospective employer.

Just as there are people who profess to despise books, so there are others who have no good word to say for examinations, perhaps in the main because they and their fathers "got along without them". Prolonged verbal battles have raged in the leading horticultural journals and always there are protagonists ready to take up the cudgels for or against. I must confess I have never been able to understand what all the fuss was about. Nor why training your body is an excellent thing, whereas training your mind is a matter for contempt. If you desire to succeed you must aim at all-round efficiency—or you will be left behind.

The only qualification I would ever want to make about examinations is that the questions should be (1) unambiguous, (2) fundamental, and (3) fair. I believe it is true to say that nowadays the questions set in the Royal Horticultural Society's examinations do closely conform to these requirements and are a sound test of the candidate's knowledge.

TABLE VIII

Examination	Fee	Date of Examination	Questions to be Answered	Time allowed	Remarks
General	£1 1 0	*Written:* March	P. 3 out of 5 O. 3 out of 5	1½ hours 1½ hours	Open to canditates of all ages
National Diploma in Horticulture: Preliminary	£1 1 0	*Written:* November	Most	6 hours	Designed to test candidate's general education. Exemption is granted on the production of documentary evidence of sufficiency of general education, e.g. General Certificate of Education.
National Diploma in Horticulture: Intermediate	£4 4 0	*Written:* April *Practical* and viva voce: May-July	P. 6 out of 8 O. 6 out of 8 All questions to be attempted	3 hours 3 hours 1 day	Candidates must: (*a*) have been engaged full-time for at least 4 years in practical horticulture, or (*b*) spent at least 4 years partly as in (*a*) and partly in training at an approved horticultural institute.

TABLE VIII—*continued*

Examination	Fee	Date of Examination	Questions to be Answered	Time allowed	Remarks
National Diploma in Horticulture: Final	£7 7 0	*Written:* April *Practical* and viva voce: May-July	P. 5 out of 8 O. 5 out of 8 All questions to be attempted	3 hours 3 hours 2 days	Candidates must: (*a*) have reached age of 21 by September 30 in year of examination (*b*) have passed Intermediate Examination (*c*) produce evidence that they have been engaged full-time for at least 6 years in vocation of horticulture
National Diploma in Horticulture: Honours	£7 7 0	*Written:* April *Practical:* July–August	3 out of 5 in each of 3 papers give a lecture, give a demonstration, attend viva voce	9 hours 3 hours	Candidates must: (*a*) hold the N.D.H. (*b*) submit a thesis
Teachers' Diploma in School Gardening: Intermediate	£4 4 0	*Written:* April *Practical* and viva voce: August	P. 6 out of 9 O. 6 out of 9 All questions to be attempted	3 hours 3 hours 1 day	Candidates must: (*a*) produce evidence of having successfully completed a course in Teacher training (*b*) subsequently had at least 2 years practical experience in teaching school gardening, or

					(*c*) have taken not less than a 2 years' course at an approved horticultural institute.
Teachers' Diploma in School Gardening: Final	£6 6 0	*Written:* April *Practical* and viva voce: August	P. 5 out of 7 O. 5 out of 7 All questions to be attempted	3 hours 3 hours 1 day	Candidates must: (*a*) have passed the Intermediate Examination (*b*) had at least 2 more years in teaching school gardening
National Certificate in Elementary Horticulture		*Written:* June *Practical:* July	P. 6 out of 9 O. 8 out of 14 All questions to be attempted	3 hours 4 hours 1 day	(*a*) Open only to candidates who have attended a full year's course of instruction in horticulture at one or more approved Institutes for Horticultural teaching. (*b*) Candidates must have reached the age of 16 years by September 30 in year preceding examination year.

* P = Principals. O = Operations.

Notes:

1. Applications to enter for the R.H.S. examinations must be made about the new year. For full particulars write to the Secretary, R.H.S., Vincent Square, Westminster, S.W.1.
2. The National Diploma is awarded for one or more of the following sections of horticulture: General Horticulture, General Commercial Horticulture, Fruit Crop Husbandry, Vegetable Crop Husbandry, Glasshouse Crop Husbandry, Horticulture in Public Parks.
3. For particulars of the Diploma of Park Administration, write to the Secretary, Institute of Park Administration The Grotto, Lower Basildon, Reading, Berks.

What examinations, you ask, should I aim at taking, and when? In Table VIII you will find a summary of the R.H.S. examinations. From this you will see that the usual procedure would be to take the General examination first, followed by the Intermediate and Final N.D.H. examinations.

So much for the preliminaries. Now we must turn to the all-important matter of how to pass your examinations with flying colours. There are two essentials for success: organized knowledge and orderly answers.

Organized Knowledge

All through this book I have been urging you to organize your knowledge. Nowhere will the benefits of doing so be more evident than in answering examination questions. If your mind is a jumble of facts you will fail: *if they are neatly marshalled into their natural groups you will probably succeed.* The person who has studied for an examination, should be able either to (1) run his mental eye over the groups of facts stored in his mind and see them as clearly as when he views the books arranged on the shelves of a library, or (2) recall the facts in terms of words (headings). Try it—now! On soil texture; can you recall the facts in orderly array? Fairly well, perhaps? Good! Try again, this time on nitrogenous manures. Now on respiration. Go on practising this whenever you are engaged on manual work which you can do automatically. Take your time in recalling the facts. Do it often. Practice will help you to marshal your facts with decision, and give you confidence in your knowledge. A good plan when you are working with another young person is to test each other by asking questions along the lines suggested above.

Organized Answers

It is one thing to know facts; it is another thing to be able to express them clearly on paper. Obviously, if your mind is a store of well-arranged facts this will greatly help you to give clear answers. But you need a method of answering; one you can practise until the transference of organized facts in your mind to orderly array on paper is accomplished with ease and confidence.

The Questions

The General examinations last three hours, 1½ hours on horticultural principles and 1½ on horticultural operations. Five questions are set in each half, but only three have to be answered. Thus a total of six answers must be returned in three hours—that is, thirty minutes is allowed for each question. This may seem to be ample time, but though it is sufficient, candidates will find that they haven't a minute to waste. Hence the need for method.

Let us suppose you are sitting for the General Examination. At the hour the examination begins you are given the questions on horticultural principles. First, read the five questions through. Mark with the letter (*a*) the one you can most easily answer, mark the next easiest (*b*) and the next (*c*). This is the order in which you should answer the questions. Always start with the easiest.

Now come back to question (*a*). Read it very carefully, until you are quite sure you understand what is asked of you. Not infrequently candidates include in their answers matters which, while related to the question, are not actually called for. This may be very nice as a display of knowledge but it is wasting your time without earning you marks. So guard against irrelevant answers. It might be safer for you to underline the key words of the question, so that your attention is definitely focused on what is asked for. This may seem a trivial detail, but it is sometimes necessary, as, for example, when candidates, asked to compare root and stem for differences of structure, describe at length similarities also.

THE OUTLINE

Now we come to the most important step of all in answering examination questions, the skeleton outline. *There are few people who can write an answer straight down on paper and, at the same time, arrange it in clear and logical order.* Yet this is absolutely necessary if you are to be sure of getting good marks. *The skeleton outline is indispensable.* How should you draft it? A simple, direct question should give you little trouble. The compound question needs more care in answering. Usually it falls into well-defined parts, these parts being in proper sequence. Sometimes they are not, however, and then you must be extra careful in the arrangement of your answer. The golden rule is: *think of the natural sequence of events*, or if this doesn't apply, *the natural relation of facts.*

Here is a question which illustrates my points:

> "How would you prepare and plant a piece of land intended for herbaceous plants? Name some plants suitable for providing a succession of flowers in the border from June to October."

Note that the parts of the question fall into a natural sequence—preparation, planting and succession of flowers. Clearly your answer will also be divided into three parts, the headings of which will be *Preparation*, *Planting* and *Succession* of flowers. Now visualize yourself actually doing the work and on a spare piece of paper or on the back of the question paper jot down in pencil the *main* operations involved under each of the three headings. If you remember to visualize the work, you will probably get the main operations in their correct order. But never mind if you don't. When you have jotted them all down and satisfied yourself that no point has been overlooked, then you can number them in their proper sequence.

This is your skeleton outline. Each of the main operations will be a sub-heading in your answer. So that the whole thing shapes up like this:

Preparation		*Planting*	*Succession*
1. Clearing the ground	(a)	1. Height	1. Tall
2. Draining	(a)	2. Flowering season	(a) Delphinium Millicent Blackmore
3. Trenching	(a)	3. Colour	(b) Rudbeckia Herbstonne
4. Manures	(b)	4. Time of planting	(c) Aster Climax
	(b)	5. Planting distances	2. Medium
	(b)	6. Cultivation and staking	(a) —
			(b) —
			(c) —
			3. Dwarf
			(a) —
			(b) —
			(c) —

Can you see what a tremendous advantage the making of an outline is? You have (1) made sure of all the main facts and (2) arranged them in their proper order. Your mind is free to go straight ahead with the answer. You haven't got to think your way through, fumbling for this fact or the other, only to discover that you have omitted to mention something in the early part of the answer and must now drag it in out of place. You have transferred the organized facts from your mind into orderly array on paper.

It will take you, even with practice, perhaps five minutes to make your outline; which leaves about twenty-five minutes for writing the answer. Even if the outline takes you seven or eight minutes it will still be worth while. It is not time wasted, but time gained. In addition, your answer will be properly arranged and that may gain you marks.

The example of a skeleton outline I have given above may seem so easy as to lead you to believe that you can make good outlines without practice. I have no hesitation in saying that this would be a very presumptuous conclusion. Proficiency in drafting skeleton outlines depends on two things: (1) clear knowledge of the relevant facts, and (2) sound judgment of their relative importance. Unless you practise making outlines of actual examination questions, you cannot be certain that you know the facts. *I have not yet met the young man who was so good at sorting out the relevant facts that he needed no practice at all.*

Prove for yourself that what I say is true. First, look at the outline on p. 167 and see if you can tell me why the sub-headings under "Planting" are given in that particular order. The reason is this. In drawing up a plan for planting an herbaceous border, several variables have to be considered: time of flowering, colour of flowers, planting distances, height of plant, and so on. It is a matter of opinion as to the order in which these should be dealt, except in the case of plant height. Tall plants *must* go to the back and short to the front; there is no choice. When you find it difficult to decide on the order of your sub-headings start off with that one which deals with a determined condition and follow it with the more arbitrary matters, e.g. "flowering season" should follow "height of plant".

Try another test. Here are three questions. Make outlines of them, taking no more than five minutes for each one. When you have finished turn up page 181 of this book and compare your outlines with mine.

(1) Describe the process of mulching. When and why is it employed, and what plants need it?

(2) Give an account of the cultivation of the onion. Name a pest and a disease which attack this plant and say how you would deal with them.

(3) In what ways is water important in the life of a plant?

I hope your attempts are good ones. But whether they are or not, do practise making outlines of all the R.H.S. questions you can lay hands on. If possible, get someone else to criticize them. Notice in particular where you go wrong and *why* you do.

The Layout of your Answer

Most, if not all, answers can be dealt with as I have suggested above, namely, by the use of headings and sub-headings. These should be set out in such a way that their relative importance is clear at a glance. The best method is to write the main headings in bold underlined block letters, close up to the marginal line running down the left hand side of the answer page. The sub-headings should be set in about a third of an inch from this line, written in fairly bold script and underlined. The text following each heading is set in about two-thirds of an inch from the marginal line, and written, of course, in long hand. Fig. 20 illustrates this layout.

Why, if examiners only award marks for the accuracy and completeness of your answers, not for their neatness or the way they are arranged—why should you bother so much about the way you write the answers? One thing at least you may be certain of: a well-arranged answer won't lose you any marks on that account. Could you be so certain about an answer which wasn't arranged at all?

Tables and Drawings

You can save a lot of time in answering some questions by using a table or drawing to embody the chief points.

For example, supposing you were asked to distinguish photosynthesis from respiration, then most of the answer can be given in table form:

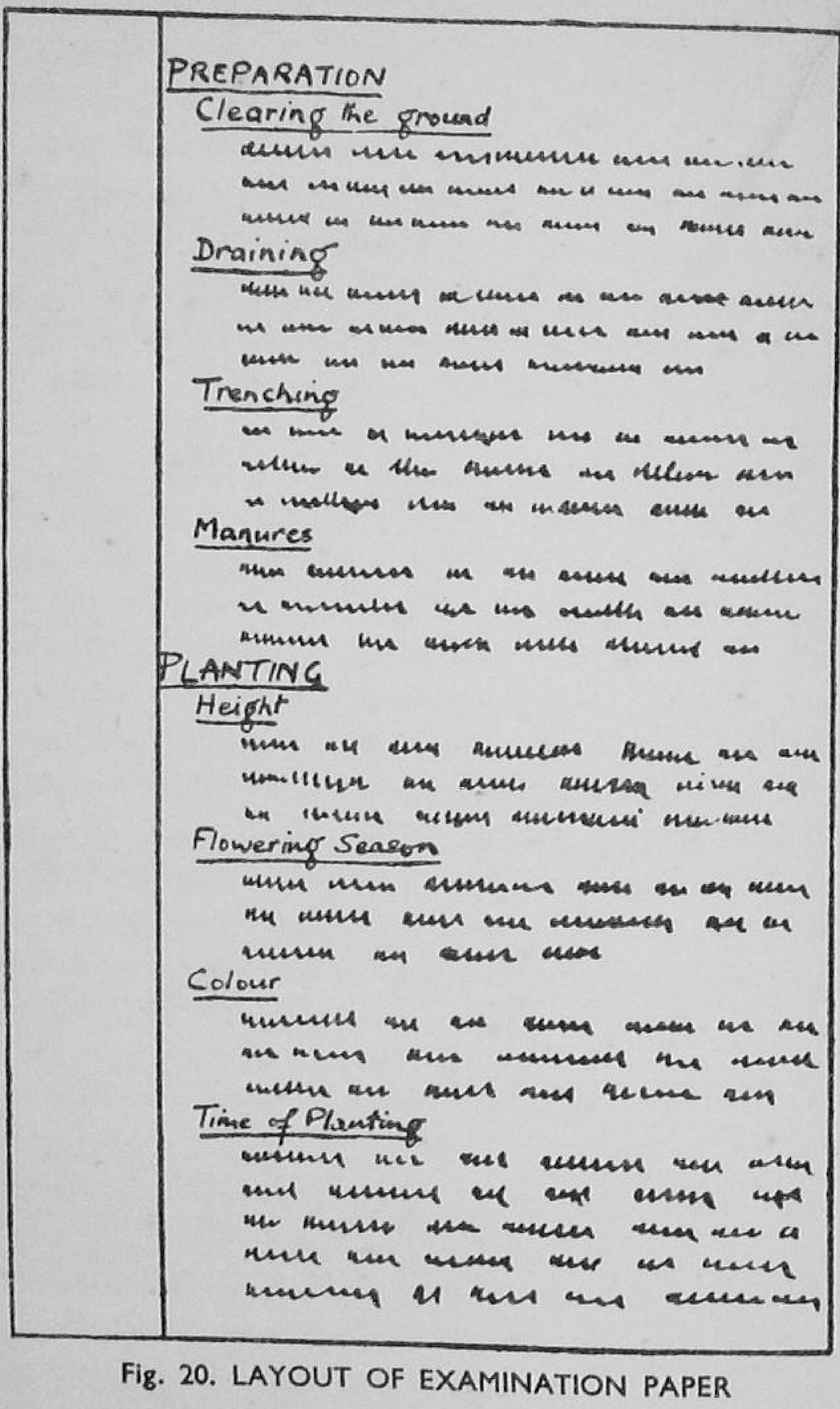


Fig. 20. LAYOUT OF EXAMINATION PAPER

TABLE IX

Photosynthesis	*Respiration*
Occurs only in light	Occurs equally in light or darkness
Occurs only in chloroplasts	Occurs in all living protoplasm
Absorbs CO_2	Releases CO_2
Releases oxygen	Absorbs oxygen
Manufactures food (e.g. carbohydrates)	Uses up food (e.g. carbohydrates)
Stores energy	Releases energy

Another way you can save time is to use short, descriptive sentences, semi-note-like in character. Don't try to write essays. Be terse, be precise; and don't be afraid of the imperative.

Chapter Sixteen

LOOKING AHEAD

WE'VE now come to the end of this book and I want to make sure that your last impressions are the right ones. So let's take a look backward which will help you to look forward—no, drive forward—with full consciousness of what you want and how you are going to achieve it. Here, then, are the things I would deeply impress on your mind.

(1) Be curious, especially about *familiar* things. Familiarity may breed contempt: it certainly bars discovery—unless you have a questioning mind.

(2) Be watchful: facts are rarely discerned at a glance. It's the alert man, not the lucky one, who finds out things.

(3) Cultivate a critical *habit* of mind. Observe carefully, think impartially and don't jump to conclusions.

(4) *Demand the facts:* they are the gardener's tools for making decisions. But facts are not all of equal worth, so learn to estimate their relative values.

(5) Organize your knowledge and your work. Be thorough in both. To be called "reliable" is a fine testimony.

(6) Be patient (i.e. not docile, but disciplined); be persistent. You have to *win* success.

One last word. This book is a guide, not a prop. *Do your own thinking.* There is no room in horticulture for stereotyped growers or growing. You won't achieve success merely by learning certain things in certain ways. The successful man will be the one who understands plants in theory and experience, and who can adapt his knowledge and his work to the ever-changing requirements of both nature and man.

ADDRESSES

Ministry of Agriculture, 55, Whitehall, London, S.W.1.

Royal Horticultural Society, Vincent Square, London, S.W.1.

Her Majesty's Stationery Office, Kingsway, London, W.C.2.

ESTABLISHMENTS OFFERING COURSES IN HORTICULTURE:

Degree

University of Reading.

University of London.

University of Nottingham.

Diploma

University of Reading (post-graduate).

University of Bristol (post-graduate).

East of Scotland College of Agriculture, Edinburgh.

West of Scotland Agricultural College, Glasgow.

Studley College, Warwickshire.

Waterperry Horticultural School, Oxford.

Institute of Parks Administration, Disley, Yorks.

Certificate

Cambridgeshire: Isle of Ely, Horticulture Institution, Wisbech.

Durham: School of Agriculture, Houghall.

Essex: Institute of Agriculture, Writtle, Chelmsford.

Flintshire: Celyn Horticultural Institute, Northop.

Hampshire: County Farm Institute, Sparsholt, Winchester.

Hertfordshire: Institute of Agriculture, St. Albans.

Kent: Farm Institute, Sittingbourne (Fruit Growing).
Horticultural Institute, Swanley.

Lancashire: Institute of Agriculture, Hutton, Preston.

Monmouth: Institute of Agriculture, Usk.

Somerset: Farm Institute, Cannington, Bridgwater.

Staffs: Farm Institute, Penkridge.

Surrey: Farm Institute, Worplesdon, Guildford.

Sussex, East: School of Agriculture, Plumpton.

Worcestershire: Institute of Horticulture, Pershore.

Yorks: Institute of Agriculture, Askham Bryan, York.

Diploma in Landscape Architecture —

University of Reading (3 years).

Diploma in Landscape Design —

University of Durham (1 year).

University of London (2 years, part-time, evening).

Instruction for women is provided at all of the above establishments. The Horticultural College at Studley and the School at Waterperry are reserved entirely for women.

Establishments offering Training for Student Gardeners:

Royal Botanic Gardens, Kew, Surrey.

Royal Botanic Gardens, Edinburgh.

Royal Horticultural Society's Gardens, Wisley, Ripley, Surrey.

University Botanic Garden, Cambridge.

Department of Botany, University, Manchester.

Correspondence Courses:

International Correspondence Schools, Kingsway, London, W.C.2.

Horticultural Correspondence College, 9. Priory Park Road, Dawlish, S. Devon.

BOOKS

The books listed below are those most suitable for beginners. Those marked with an asterisk are specially recommended for study, and the student should endeavour to get them for himself. The "Books for Reference" will be found useful when detailed information is required on a special subject. Many of the books can be procured through the nearest public library; or if the books are not in stock the librarian will get them for you from the County or Central Libraries.

Botany

***Botany*. R. H. Yapp. Cambridge University Press, 1949. 6s. 6d.
An excellent book for those studying botany for the first time.

***School Botany*. M. Skene. Oxford University Press, 1934. 10s. 6d.
A more advanced book, covering the subject up to G.C.E. Ordinary standard.

The Living Garden. E. J. Salisbury. Bell, 1948. 6s.
Contains a wealth of information on plants and gardens. Should be read as a background to the study of formal botany.

Background to Gardening. W. O. James. Allen & Unwin. 1957, 18s. 0d.

Science

***General Science*. I. C. Joslin. Macmillan, 1947. 10s. 6d.
A very good book for the beginner.

Simple Science. E. N. da C. Andrade and J. S. Huxley. Blackwell, 1934. 15s.

More Simple Science. E. N. da C. Andrade and J. S. Huxley. Blackwell, 1934. 10s. 6d.
Every young gardener should have these two books in his library. They are simply written, freely illustrated, and fascinating to read.

The Weather. G. H. T. Kimble. Penguin Books. 7s. 6d.

Soils

**Lessons on Soil.* E. J. Russell. Cambridge University Press. 8s. 6d.

Soil Sterilization. W. J. C. Lawrence. Allen & Unwin, 1956, 18s. 0d.

General Gardening

Gardening for Schools and Students. J. Hardy and S. Foxman Allman, 1958, 19s. 9d.

Manures and Fertilizers

Manures and Fertilizers. M. of A. Bulletin, No. 36. H.M.S.O.* 3s. 6d. A general guide on manures and fertilizers.

Manuring of Commercial Vegetable Crops. M. of A. "Growmore" No. 6. H.M.S.O. 9d.

Manuring of Fruit Crops. M. of A. "Growmore" No. 4. H.M.S.O. 9d.

The Use of Lime in Agriculture. M. of A. Bulletin No. 35. H.M.S.O. 3s. 6d.

Pests and Diseases

Pests and Diseases in the Vegetable Garden. M. of A. "Growmore" No. 2. H.M.S.O. 9d.

Diseases of Vegetables. M. of A. Bulletin No. 123. H.M.S.O. 4s. 0d.

Pests of Flowers and Shrubs. M. of A. Bulletin No. 97. H.M.S.O. 7s. 6d.

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Vegetables

**The Vegetable Garden Displayed.* Royal Horticultural Society, 3s. 6d.

Root Vegetables. M. of A. Bulletin No. 120. H.M.S.O. 1s. 9d.

Outdoor Salad Crops. M. of A. Bulletin No. 55. H.M.S.O. 2s. 6d.

Cabbages, Brussels Sprouts and Miscellaneous Green Crops. M. of A. Bulletin No. 132. H.M.S.O. 2s. 0d.

Onions and Related Crops. M. of A. Bulletin No. 69. H.M.S.O 2s. 6d.

Fruits

**The Fruit Garden Displayed.* Royal Horticultural Society. 6s. 6d.

Apples and Pears. M. of A. Bulletin No. 133 H.M.S.O. 4s. 6d.

Plums and Cherries. M. of A. Bulletin No. 119. 2s. 6d.

Bush Fruits. M. of A. Bulletin No. 4. H.M.S.O. 2s. 6d.

Glasshouse Plants

**Seed and Potting Composts.* W. J. C. Lawrence and J. Newell. George Allen & Unwin, 1952. 8s. 6d.

Tomatoes. M. of A. Bulletin No. 77. H.M.S.O. 4s. 6d.

The Cool Greenhouse. L. N. Sutton. Putnam, 1956. 10s. 6d.

Modern Glasshouse Flowers for Profit. W. E. Shewell-Cooper. Benn, 1949. 7s. 6d.

Trees and Shrubs

The Propagation of Hardy Trees and Shrubs. Taylor and Knight. B. H. Blackwell, Oxford, 1947. 7s. 0d.

Pruning. A. OSBORN and N. B. BAGENAL. Ward, Lock & Co., Ltd., 1952. 12s. 6d.

FLOWERS

The Herbaceous Border. F. PERRY. Collingridge, 1948. 6s.

Flower Garden. E. R. JANES. Penguin. 3s. 6d.

ALPINES

The Alpine House and its Plants. S. BOOTHMAN. Rush and Warwick (Bedford), 5s. 0d.

LAWNS

The Establishment and Care of Fine Turf. D. CLOUSTON. Wyllie, 1939. 3s. 6d.

A complete list of the Ministry of Agriculture's publications can be obtained, post free, from Her Majesty's Stationery Office.

BOOKS FOR REFERENCE

Botany. E. W. SINNOTT

Soils and Manures. E. J. RUSSELL

Agricultural Entomology. D. H. ROBINSON and S. C. JARY

Diseases of Cultivated Plants and Trees. G. MASSEE

Basic Horticulture. V. R. GARDNER

Commercial Glasshouse Crops. W. F. BEWLEY

Practical Plant Breeding. W. J. C. LAWRENCE

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Dictionary of Gardening. F. J. CHITTENDEN

Flora of the British Isles. A. R. CLAPHAM, T. G. Tutin and E. F. Warburg.

Flora of the British Isles, Illustrated, A. R. CLAPHAM, *et al.*

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The Profitable Culture of Vegetables. T. SMITH and J. RHODES

The English Rock Garden. Vols. I and II. R. FARRER

The English Rock Garden. Vol. III. S. CLAY

MODEL SKELETON OUTLINES

Mulching

*Definition:**

When to mulch:

(1) Before possible drought.

(2) Before frost.

(3) After transplanting evergreens.

Why mulch:

(1) To conserve soil moisture.

(2) To cool the soil (summertime).

(3) To protect plants from frost.

Plants needing mulching:

(1) Surface rooting (e.g. raspberry).

(2) Transplanted plants (sometimes).

(3) Tender plants (frost).

Onion

Cultivation:

(1) *Preparation of land:*
Rotation, digging, manures and fertilizers.

(2) *Onions from seed:*

(*a*) autumn sown; sowing date, transplanting.

(*b*) sown under glass; sowing date, hardening, transplanting.

(*c*) sown out of doors; sowing date, thinning.

* It is sometimes desirable to describe a material, plant, etc., before going on to discuss it. Thus: A mulch is a covering of non-conducting material spread on the soil over the roots of plants, e.g. litter, long manure, leaves, peat, straw; also "dry mulch" (soil).

(3) *Onions from sets:*

Planting date.

(4) *General Notes:*

Feeding, hoeing, harvesting.

Pest—Onion Fly:

(*a*) Brief description.

(*b*) Control measures.

Disease—Downy Mildew:

(*a*) Brief description.

(*b*) Control measures.

Water

Water is a food material.

Water carries food materials.

Water keeps cells turgid and plants rigid.

MEASURES

Long, Square and Cubic Measures

Unit		*Linear*	*Square*	*Cube*
1 foot	=	12 inches	144 inches	1,728 inches
1 yard	=	3 feet	9 feet	27 feet
1 rod	=	$5\frac{1}{2}$ yards	$30\frac{1}{4}$ yards	
1 acre	=	—	160 rods 4,840 yards	

Weight Measures (Avoirdupois)

16 ounces	=	1 lb.
14 lb.	=	1 stone
8 stones 112 lb.	=	1 cwt.
20 cwt. 2,240 lb.	=	1 ton

1 gallon water = 10 lb.

1 cubic foot water = 62·3 lb. (approx. 1,000 oz.)

1 oz. = 28.350 grammes

1 gramme = 0·0353 oz.

1 inch rain = 100 tons per acre

12 inches loose snow = 1 inch of rain

Capacity Measures

4 gills	=	1 pint
2 pints	=	1 quart
4 quarts	=	1 gallon
1 gallon	=	0·1605 cubic foot 277·274 cubic inches
2 gallons	=	1 peck
4 pecks	=	1 bushel
1 bushel	=	2219.368 cubic inches 1·284 cubic feet

21·03 bushels = 1 cubic yard
6·23 (approx. 6¼) galls. = 1 cubic foot
1 litre = 1·76 pints or 0·22 gall.
1 pint = 0·568 litre
1 gallon = 4·546 litres
1 level wheelbarrow load = 2½ bushels

Metric Measures

Length	10 millimetres	= 1 centimetre
	10 centimetres	= 1 decimetre
	10 decimetres	= 1 metre
	1 millimetre	= 0·03937 inch
	1 inch	= 25·4 millimetres
	1 metre	= 39·37 inches
Weight	1 gramme	= the weight of 1 cubic cent. of water at 4° C.
	1 kilogramme	= 2·2 lb.
Capacity	1 litre	= 1,000 cubic centimetres

Rates of Application per Acre of Long Horse Manure

Tons	Loads (yards)	Heaped wheelbarrow loads (3½ bushels)	Distances between barrow loads
1	2½	15	—
2	5	29	—
5	12½	75	24′ × 24′
10	25	150	17′ × 17′
20	50	300	12′ × 12′
30	75	450	10′ × 10′

Rates of Application of Fertilizers

1 cwt. per acre = (*a*) 0·37 oz. per sq. yd. (= approx. ⅜ oz.)
(*b*) 11·2 oz. per sq. rod (= approx. ¾ lb.)
1 ton per acre = 1 stone per square rod

Weight/Bulk Ratios of Garden Soils, etc.

1 ton of loam		= 1¼ to 1½	cubic yards
1 ,,	leaf-mould	= 3 to 3½	,, ,,
1 ,,	dry peat	= 6 to 8	,, ,,
1 ,,	dry sand	= approx 1	,, ,,
1 ,,	cow manure	= 1 to 1½	,, ,,
1 ,,	horse manure	= 2 to 2½	,, ,,
1 ,,	compost	= 2 to 2½	,, ,,

A dressing of organic material, ¾ inch deep, is equal to 100 cubic yards per acre.

Sizes of Flower Pots

Number to cast	Inside diameter at top (inches)	Outside depth (inches)
72 (small)	1½	2
72 (medium)	2	3
72 (large)	2½	3
60 (small)	2¾	3¼
60 (medium)	3	3½
60 (large)	3½	4
54 (small)	4	4¼
54 (large)	4¼	4½
48 (small)	4¾	4¾
48	5	5
40	5½	5½
32	6¼	6¼
28	7	7
24	7½	7½
16	8½	8½
12	10	10
8	11	11
6	12½	12½
4	14	14
2	15½	15½
1	18	18

Amounts of Soil required for Potting, etc.

One bushel of potting compost is approximately sufficient to pot:—

90 to 100 plants in 60 size pots
40 to 45 plants in 48 size pots
45 to 50 plants potted from thumbs to 48's
50 to 55 plants potted from 60's to 48's
20 to 25 plants potted from 60's to 32's
16 to 18 plants potted from 48's to 24's
3 to 4 plants potted from 48's to 12's

The nursery seed tray measures $14 \times 8\frac{1}{2}$ inches inside.

Nine shallow trays (2 inches) or six deep trays (3 inches) can be prepared from a bushel of soil.

Capacity of Tanks

To find the capacity of rectangular tanks:—

Multiply in feet the length by the width by the depth and multiply the result by $6\frac{1}{4}$ to get the capacity in gallons.

To find the capacity of circular tanks:—

Multiply in feet half the circumference by half the diameter by the depth and multiply the result by $6\frac{1}{4}$ to get the capacity in gallons.

Thermometers

1. To convert Fahrenheit into Centigrade readings subtract 32. multiply by 5 and divide by 9.

2. To convert Centigrade into Fahrenheit readings divide by 5 multiply by 9 and add 32.

3. $32°$ F. = $0°$ C.; $60°$ F. = $15{\cdot}5°$ C.; $212°$ F. = $100°$ C.

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