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PLANTS in HEALTH and DISEASE

being

An Abstract of a Course of Lectures delivered in the University of Manchester during the session 1915-16

BY

F. E. WEISS, D.Sc.,
Harrison Professor of Botany,

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AND

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PREFACE.

The course of lectures of which this little book is a summary was undertaken with a view to giving some assistance to those who were endeavouring, to the best of their ability, during the present crisis to increase the productiveness of their gardens or allotments. Was it possible for the University to aid in any way these practical men and women to accomplish their laudable and patriotic endeavour? A knowledge of the structure and life of the plants they cultivate could not fail to be helpful to gardeners and allotment-holders in explaining the reasons for many of the common horticultural practices. Familiarity also with the common animal and fungal parasites of our garden crops, and the methods of combating these pests would enable them to save many doomed plants. For these reasons this course of lectures on "Plants in Health and Disease" was instituted, and, as the size of the audience indicated that the lectures met a real need, it seemed desirable to issue to members of the audience a short eight-page summary of each of the lectures. As we have received many enquiries from persons not attending the lectures both for single abstracts, and since the conclusion of the course, for complete sets, we have decided to reprint them in book form. We trust, however, that the fact will not be overlooked that this issue does not pretend to be more than a somewhat brief summary of a course of lectures, and that all the lecturers were tied down to very narrow limits wherein to compress the subject matter of a much longer discourse. We would also point out that, as the lectures were addressed to a Manchester audience, the lecturers often dealt with the peculiar difficulties that are met with in this neighbourhood, and that the accounts given of the animal and fungal pests do not profess to be exhaustive, but are descriptive of the more common diseases occurring in the gardens and allotments in the vicinity of our large industrial towns. The necessary condensation of many interesting points, which might with advantage have been expanded, and the omission of the illustrations which accompanied the lectures, will probably be less noticeable to those who have attended the course of lectures than to new readers of this little volume; nevertheless, we hope that these latter will also find in it some information, which may be of value to them. Should this hope be realised we shall feel well satisfied.

THE UNIVERSITY,
MANCHESTER,
15th March, 1916.

F. E. WEISS.
A. D. IMMS.
W. ROBINSON.

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Plants in Health and Disease.

Chapter 1.

GENERAL FEATURES OF PLANT LIFE.

Nutrition and propagation, vegetative and seed reproduction. Annuals, biennials, and perennials. General account of vegetative organs.

Gardeners being concerned in the cultivation of plants, it is obviously important that they should be acquainted with their structure and mode of life. They will find it particularly useful to know in what ways plants respond to their environment, for such knowledge will enable them by varying their treatment to modify the development of the plants they cultivate, to accelerate or retard their growth and to ensure the production of a greater number of flowers. The gardener's aim is not always the same. The flower lover is anxious to obtain a wealth of bloom. The allotment holder on the other hand, concerned in raising vegetables, may desire well-developed leaves, roots or tubers. It is important therefore that we should study both *the vegetative and the reproductive organs.*

The former are concerned mainly with nutrition, the latter with the propagation of the plant. These two sets of organs are often differently affected by external conditions. A gardener knows that by over-stimulating the development of foliage he may be endangering the production of flowers. It is a common practice to reduce the supply of water so as to encourage the formation of flower buds. Some of our common British fruit trees when grown in tropical climes will develop into luxuriant trees with a wealth of foliage, but lack the flowers essential for the production of fruit. The practice of pruning and root pruning is based on the same phenomenon, and by reducing the amount of vegetative organs the formation of flower buds is encouraged. Yet though there seems to be this opposition between vegetative and reproductive organs the latter are really dependent upon the former. For it is only at the expense of the food material absorbed and worked up by the roots and leaves that the flowers are produced. The activity of the vegetative organs must therefore always precede the formation of flowers.

This is seen very clearly in the case of *annuals*. These plants complete the whole of their life-cycle in one vegetative season which is usually much shorter than a year, in some arid regions amounting only to a few weeks during and immediately after the wet season. An annual commences as a seedling at the beginning of the favourable vegetative season, and after the production of a limited number of leaves produces its flowers, which are kept supplied with food material by the activities of roots and leaves until the seeds have matured, then the whole plant dies down to be replaced next season by the offspring developed from its seeds. Such is the life history of the mustard and cress and also that of most of our common weeds like chickweed, groundsel, and some of our grasses. The ubiquity of our weeds is due not only to their effective means of dispersal, but also to their rapid growth to maturity which enables them to produce two and even three generations of plants in one season.

Slower in their development and exhibiting a more marked contrast of vegetative and reproductive periods are the so-called *biennials*. In these plants after the vegetative organs are produced they are employed throughout the first summer season in manufacturing and storing a large supply of food material, which is to be used in the formation of flowers and seed during the second year, after which the entire plant dies down having fulfilled its existence and produced a vast number of offspring. For the large store of food material which it has laid up during the first year will enable it to produce a much larger number of flowers than is commonly the case in annual plants. In most biennials the food material is stored in some underground part of the plant such as the swollen 'root' of the turnip or beet, the leaves during the first season forming a tuft or rosette close to the ground.

Lastly we have *perennials* which are much more varied in character than the first two groups of plants. These latter are always comparatively soft in texture, but perennials include both herbaceous and woody forms such as trees and shrubs. The herbaceous again are of two types, firstly those which persist throughout the winter like violets and primroses, and secondly those which die down in the autumn leaving a persistent root or root-stock underground, from which the plant renews its growth in spring. Plants of this kind like the iris, peony, larkspur, Michaelmas daisy and many other favourites of our herbaceous borders have like biennials a large store of food material in their underground organs. This enables them in most instances, not only to produce annually a crop of flowers but to branch out underground and develop into ever-spreading clumps, which in many cases require repeated breaking up and thinning just as we require to cut back our bushes and trees. In some cases these underground portions of perennial plants do not remain attached in one mass, but when the plant dies down, a good deal of the underground part dies away too, leaving isolated portions, so that in place of one individual we find many fragments which would seem to be offspring though they are really only remnants of the original parent. Such offsets we have in the case of the tubers of the potato, which represent the rounded swollen ends of underground shoots that have become entirely separated one from the other. Though this is really only a breaking up of the original plant, it is often spoken of as *vegetative reproduction* but must not be confused with *seed reproduction*, which is always the result of the fertilisation of flowers. It is important to differentiate these two methods of propagation, particularly as in the case of the potato the tubers used for setting in spring are termed "seed potatoes," though they have really nothing to do with seeds. Vegetative reproduction does not replace seed reproduction but is an additional means of propagation, often of the greatest use both in nature and in cultivation.

The potato, for instance, though it produces flowers in this country very rarely contrives to ripen its seeds in our climate and can only be propagated in England by its tubers, which are indeed the sole reason for its cultivation, for these tubers richly stored with food material are of the greatest importance as a staple food of mankind. The Jerusalem artichoke has the same way of vegetative reproduction and a very similar process obtains in all bulbous plants.

Most perennial plants produce a crop of flowers and fruit every season, in some cases after a shorter or longer period of immaturity as is usual for instance in shrubs and trees. These flowers may make their appearance in spring before the foliage. But in that case the flowers are produced at the expense of the food material built up by the leaves of the preceding summer, while the fruits are generally matured by the activity of the leaves of the same season.

Let us now consider some of the effects of external factors upon the growth of plants. If we germinate a seed under suitable conditions on the surface of the soil we find that when the young root breaks through the seed-coat it bends downward and penetrates into the earth. That this is due to the effect exerted by gravity on the young growing root can be demonstrated by slowly rotating a growing plant on a horizontal axis, when it will be found that the root will grow out horizontally as gravity acts first on one side of the root and then on the other, and thus its effect is eliminated and the root is not affected. The main stem of a plant is equally sensitive to the force of gravity, but responds in a different manner growing in the opposite direction to it and, if laid down horizontally, bending upwards at right angles.

Detailed microscopic examination has shown that plants have special regions of perception and it was found by Darwin that as regards its sensitiveness to gravity the seat of perception was the root-tip. and that if this was cut off the root ceased to respond to gravity. In the stem it is known that the perceptive region is not so limited in extent. But while the main root and the main stem tend by their response to gravity to grow in a vertical direction, lateral roots and lateral branches do not respond in a similar manner but tend to place themselves more or less horizontally or obliquely. A most curious feature of plant life, and one very difficult of explanation, is the fact that when the tap root or the main stem of a plant is destroyed, a lateral branch will take its place and assume the vertical position. The importance of this position is self evident when we consider the functions of the root and of the stem. The former acts as the absorbing organ, extracting from the soil the water and valuable salts necessary for the growth of the plant; it is obviously essential therefore that the root should grow downwards in search of moisture. It is also important that the lateral roots should not grow in the same direction as the main root, so that they can search out other regions of the soil in their quest for food material. The spreading habit has the further advantage that it anchors the plant more firmly in the soil and prevents it from being easily uprooted by the wind.

The stem on the other hand growing away from the soil is in an advantageous position for exposing the leaves it bears to the full rays of the sun and thus enabling them to fulfil their main function in the life of the plant. This function is to absorb as much light as possible and by converting the light rays into energy to build up the organic material upon which the formation of flowers and fruits depends. Light being therefore of such vital importance to plants we find that in the course of their evolution they have acquired the power of responding in their growth to the stimulus of light. It is a familiar fact that stems of plants will bend towards the light if instead of being illuminated from all sides they receive the light from one side only. Growing in the open the main stem is erect and the leaves are usually expanded horizontally, that is at right angles to the direction of maximum illumination which is from above. When shaded on one side the stem inclines towards the light and the leaves are placed obliquely, often indeed horizontally, when a plant is grown in a window, in which case it is more or less shaded on three sides. Roots as they are underground do not normally exhibit in their growth any response to light, but if a young seedling plant is grown with its roots in a glass jar it will be found that if illuminated from one side only the roots will bend away from the light. In nature this can be observed in the roots which grow out from the stem of the ivy when clinging to a wall. They are generally produced from the shaded side of the stem and always bend away from the light and towards the wall. These climbing roots are not sensitive to gravity as they have a very definite function to perform in fixing the plant to the wall, and are not concerned in the absorption of food material.

Wherever bending, such as described above, takes place in growing organs, this is due to differences in the amount of growth on different sides of the stem or root. The concave side grows less than the convex side. Thus when a stem, which has been laid horizontally, bends upwards, this is due to the greater amount of growth of the side nearer the ground. If a stem illuminated from one side bends permanently in that direction this is due to the fact that light retards the rate of growth and the side away from the light growing more rapidly the stem becomes convex on this side and bends towards the light. The fact that light retards growth and therefore causes plants to be short and "stocky" is of course a well-known phenomenon, while the lack of illumination acting like darkness causes more rapid growth and we get long "leggy" plants, when they are insufficiently lighted as when grown in the shade, in deep frames or pits, or not close up to the lights in greenhouses.

There are one or two other factors influencing the growth of plants which it may be useful to refer to at this juncture. Besides being sensitive to gravity roots are also sensitive to contact, and when a root tip comes in touch with a solid body such as a stone in the soil it bends away from it. This is brought about as in the case of other bending movements, by the fact that contact causes retardation of growth on this side of the root and this side becomes therefore convex, the root-tip pointing away from the obstacle met with in the soil. In this way it is possible for the root to make its way even through a stony soil, avoiding or rather growing round all obstacles with which it may be met, bending to right or to left in its progress downwards. This sensitiveness to contact is however not only possessed by main roots which grow downwards; it is equally important to lateral roots.

It has been found in the somewhat infrequent cases occurring in nature that where the soil is drier on one side of a plant than on the other the root system develops more abundantly in the moister soil. Experimentally, too, we can prove that a root will grow towards moisture just as the stem of a plant will grow towards the light.

Lastly, we have plenty of evidence that in addition to their need for water the roots of plants, just like the living parts of all plants or animals require for their growth that life-giving constituent of the air, which we also breathe in, namely, oxygen. This need of the roots for air is one of the fundamental facts which governs not only the distribution of plants in nature, but dominates our whole agricultural and horticultural practice. It is this need for air which causes the farmer to drain his fields and the gardener to grow his plants in porous and well-drained pots. If we turn a plant out of such a pot we shall see by the dense felting of the roots in close contact with the sides of the porous pot and among the crocks at the bottom of the pot how eager the roots are for air. If on the other hand we do not secure drainage or if we over-water pot-plants we soon find that they show signs of ill-health. As a matter of fact their roots are being suffocated and may die away unless we alter our treatment. Probably more plants are lost by over-watering than by insufficiency of water. Normally, therefore, though water is a prime necessity of plants its provision must not interfere with the respiratory process of plants, and we must always provide a porous soil for our crops, that is a soil with sufficient air. This is one of the reasons for the practice of hoeing. For apart from the clearing out of weeds, hoeing prevents the ground from becoming caked, a condition which would prevent the free access of air into the soil. At certain stages in their growth this need seems greater than at others. Speaking generally we may say the more actively growth is proceeding, the greater the need for air. Germinating seeds for instance require a large amount of air, and when the formation of new roots is proceeding in the case of cuttings and layerings a porous soil is essential. When a potato starts its new growth and is rapidly developing its new shoots and roots we find that the skin, a hard and impervious layer, becomes interrupted by numerous breathing pores which enable an active respiratory process to take place. These pores can easily be seen with the naked eye on the skin of a sprouting potato. They are equally clearly seen on the twigs of trees such as those of the horse-chestnut. On the leaves the pores through which the plant takes in various constituents from the air are not visible except with such magnification as the microscope affords.

As the leaves of most plants are expanded in a drier medium than that which surrounds the roots, these pores naturally allow a large amount of moisture to escape particularly in dry weather. If we cover a plant with a bell-jar we can see this moisture condensing on the sides of the glass, and in carefully conducted experiments we can actually measure the amount of water so lost. From such calculations we estimate that a fair-sized tree standing in the open may lose ten gallons of water in the course of a summer's day. This loss of water from the leaves might at first be thought to be an accidental phenomenon due to the possession by plants of delicate expanded leaf structures. As a matter of fact, however, this process of transpiration is of vital importance to the plant. In the first place it can be shown by experiment that leaf transpiration exerts a considerable amount of suction, and it is in part by this means that water is raised in tall trees to the upper branches. In shrubs and herbaceous plants this suction alone would be sufficient to raise the water into the leaves and flowers, though the roots too are equally concerned in the ascent of sap. Nor must we consider the water which is given off by the leaves as so much waste. It is indeed important that some of the water absorbed by the roots should be driven off. For the water contained in the soil contains the mineral salts which are necessary for the plant, in very dilute solution, and these salts require therefore to become concentrated in the plant. This can only be done by driving off some of the superfluous water and that is effected by the process of transpiration. The leaves are therefore acting as a condensing apparatus and thus performing a very needful function.

I trust that what I have said regarding the sensitiveness of the various parts of the plant to external forces and surrounding conditions will have impressed the reader with the power of response inherent in plants, and this will indicate how by artificially selecting our medium and method of treatment we can considerably modify the course of development of the plants we cultivate.

Chapter 2.

ROOTS AND ROOT NUTRITION.

Absorption by roots and root pressure. Physical and chemical nature of soil. Manures and their importance. Bacteria in soil. Root tubercles of Leguminous Plants. Rotation of crops. Trenching and ridging.

We have seen that the sap is raised in plants in part by the transpiration of water vapour which takes place through minute pores which are found scattered over the surface, particularly the lower surface, of leaves. In addition to this suction exerted by the leaves there exists a definite upward pressure of the sap by the roots known as *root pressure.* This upward force is due to the fact that the roots of plants are covered in by a porous membrane, and that the cells of the root contain a cell sap of greater concentration than the water contained in the soil. Whenever such a condition of things occurs a physical law determines that water passes through such a permeable membrane from the less dense to the. denser liquid. Water is thus attracted into the cells of the root and, causing them to swell, it forces the liquid up certain conducting channels of the root and into the stem.

If, during a period of active root absorbtion, we cut a plant above the surface of the soil we find that water will be forced out of the exposed wound and, fixing a glass tube tightly in the place of the stem which has been removed, we find that the liquid which exudes can be forced up to a considerable height.

Particularly in spring when root absorbtion is very active the pressure exerted by the roots may be very considerable and causes the "bleeding" of plants, as the active exudation of sap is called. This occurs sometimes when trees and shrubs are pruned too late in the spring after the sap has begun to rise. The active absorption of water takes place in the young roots a little way behind the root-tip, where the root can be seen to be covered by a mass of delicate hairs which, possessing very thin walls, offer great facility for the penetration of the water. It is important, therefore, in transplanting young plants from a seed bed or pan to injure as little as possible the delicate young roots, as by pulling instead of carefully digging up young plants the absorbtive part of the root anchored by its many hairs may be left behind in the seed bed. Plants injured in this way will inevitably suffer a set-back, as they will not be able to absorb nutriment efficiently until they have developed new roots to take the place of those which have been injured.

Let us now consider the nature of the soil in which the roots are growing. We have already seen that to be suitable for the growth of ordinary plants it must be well drained, whether we are dealing with a plot of ground or with pot plants. If the earth becomes water-logged the roots are deprived of the necessary air and soon die away. The *physical condition of the soil* is therefore as important as *its chemical composition.* In nature, soils are not all equally porous. Some therefore require the careful attention of the cultivator. Clay soils particularly are liable to retain too much water and need to be specially treated for successful cultivation. The retentive power of a soil depends largely on the size of the particles of which it is built up. Gravel or coarse sand allows the water to pass through it more rapidly than fine sand, and even the finest sand is composed of larger particles than those of clay. We can easily prove this by stirring up sand and clay in water. The particles of sand soon settle down and allow the water to clear while the water in which clay has been stirred up remains muddy for a long time. If, however, we add a little lime to this cloudy liquid we find that it clears rapidly. This is due to the "coagulation" of the very fine particles of clay which become collected into larger groups, and these being heavier than the single particles of clay, fall to the bottom of the water and allow it therefore to become clear. It is upon this action of lime upon clay that the practice of "liming" heavy soils depends, as the admixture of lime causing the ultimate particles of the clay to become collected together, the ground becomes more coarsely grained and therefore more porous. It is then easier to work, being lighter and more open, and is also warmer. This physical change which is effected by lime is not the only benefit derived from its use. Near our large towns the soil is usually rendered acid by the fumes produced by the combustion of coal. In foggy weather this acidity of the atmosphere becomes very noticeable. It has been shown by experiment that such acid soil, and even ordinary soil, when watered with acid rain-water collected in towns, is very detrimental to plant growth. This acidity can be removed by adding lime to the soil, a practice therefore of the utmost importance to those who cultivate gardens or plots near our industrial towns.

Heavy soils can also be lightened by the admixture of sand to the soil. Good natural loams, which are easily worked soils, consist of fine sand with some clay and a little lime.

Lastly, *farmyard manure*, quite apart from its important chemical effect upon the soil in enriching it with many valuable food substances, is of great value in improving the texture of all soils. To sands it gives great water-retaining power, while it renders clay soils more porous and friable.

Let us now examine some of the chemical needs of the roots of plants. By a chemical analysis of the ashes left after burning plants it has been ascertained that they are mainly built up of four chemical elements, namely, hydrogen, oxygen, carbon, and nitrogen, to which must be added smaller quantities of lime (calcium), magnesium, potash, sulphur, phosphorus, and iron. Of the four essential substances, the first two, hydrogen and oxygen, combined in the form of water are present in all soils in that form. Carbon, though present in the soil largely in the form of lime or calcium carbonate, is mainly obtained by the plant through its leaves from the atmosphere, where it occurs as carbonic acid. Nitrogen, on the other hand, of which there is a large supply in the air, cannot be made use of by the plant in this free form, but is mainly absorbed in the combined form as nitrates by the roots. In comparison to the other substances dissolved in the water, the nitrates are the most important salts in the soil as far as the nutrition of plants is concerned. We can realise therefore the usefulness of nitrate of soda as a fertilizer. In nature the nitrogen for plant food are largely obtained from the humus, or decaying vegetable matter, which is present in all soils. In cultivation, where plants are removed when they die down or where they are taken up to be used as vegetable, it becomes necessary to replace the humus, which would naturally form, by leaf mould or other decaying matter such as manure. The nitrogen contained in rotting manure or in humus is, however, not mainly in the form of nitrates. It is contained in highly complex organic compounds, while in manure it occurs largely in urea, a compound of ammonia. These organic compounds require to be acted upon by *bacteria, which are found in the soil* and in dung before they are available as plant food. On the other hand we find in the soil micro-organisms of another kind which have the power of combining the free nitrogen of the air with the oxygen and ultimately build up the nitrates so important to plants. These nitrifying bacteria are constantly at work, and when a field lies fallow the soil will be found at the end of the fallowing to be richer in nitrogen compounds than it was at the beginning. In addition to these organisms referred to above, there are special forms which are always associated with the roots of plants belonging to the pea family. If we pull up a pea or bean we find that the roots bear curious swellings called *root tubercles*, which are found when examined to contain numerous minute bacteria. The roots must not be considered diseased, though they may look like it. They are in a normal condition, and the bacteria inhabiting these nodules do not injure the plants but enrich them with nitrogenous material which they obtain from the air found in the interstices of the soil. It is therefore particularly important to keep the ground around peas and beans open by hoeing, so that the roots may not only get the necessary oxygen for breathing purposes, but also the nitrogen they require for their nutrition. It is by the activity of these nitrifying bacteria that leguminous plants, as those belonging to the pea family are called, can grow in very poor soil, that is to say, in soil in which there are very few nitrogen compounds, and yet produce seeds which are very rich in nitrogen, and therefore very important as food for mankind. Of further interest in connection with these plants is the fact that when they have yielded their crop they have not exhausted the soil of its nitrogen compounds, but will be found to have actually enriched it. This renders leguminous plants a valuable crop to alternate with other crops which deplete the soil of nitrogenous material. In agriculture it is often found expedient in the case of poor or exhausted fields to dig in a leguminous crop such as lupins or clover, which are often grown for the purpose of enriching the soil.

With a view to increasing the number of the nitrifying organisms in the soil attempts have been made in this and other countries to introduce more of these bacteria, particularly into pots or beds in which sweet peas or other members of that family are to be grown. In England preparations of these bacteria were distributed some years ago as "nitrobacterine," but the use of this preparation was not found profitable in all cases, probably as in many soils there is already a sufficient supply of these bacteria. Professor Bottomley has, however, now discovered a better way of cultivating these bacteria in peat, with which they can be easily distributed. Peat, which represents the partially decayed vegetable remains, differs from leaf mould or humus in undergoing decay under very wet conditions. As a consequence it remains permeated with certain substances which render it acid and unsuited to the growth of most plants, though heaths, azaleas, rhododendrons, and other members of the heather family grow well in peaty soil. When rendered alcaline, however, peat has been found to favour the development of roots, and therefore the whole growth of plants, and containing as it does a large amount of organic material, much of which is rendered soluble when alcaline, it has a high manurial value. This is said to be still further increased by inoculating the peat with nitrifying bacteria, which grow very vigorously in alcaline peat and thus increase the available plant foods. "Bacterised peat," as it is called, is not yet on the market, and has therefore not been extensively tried, but experiments which have been conducted at Kew Gardens with pot plants, and on a farm near Norwich, are of considerable promise.*

* "The Spirit of the Soil." An account of the nitrogen fixation in the soil by bacteria, and of the production of auximones as promoted by bacterised peat. By G. D. Knox. Constable, London, 1915.

It should not be forgotten that there are numerous other micro-organisms in the soil, many of which are not only useless to plant life, but may be actually injurious particularly by preventing the full development of the nitrifying bacteria. Dr. E. J. Russell, of the Rothamstead Experimental Station, has discovered that if soil is partially sterilised, either by steam or by volatile disinfectants, some at any rate of the harmful organisms are destroyed, and the subsequent activity of the useful bacteria is greatly increased. The effect of such partial sterilisation has been found particularly beneficial in the case of richly cultivated soil, such as that in use in greenhouses and market gardens, and sterilisation has been successfully adopted in many instances. The chemical antiseptic used by Dr. Russell was toluene, one of the coal tar products. Its action as well as that of steam is generally believed to destroy the numerous protozoa, which are microscopic animal organisms. Some of these are known to feed on bacteria, and are therefore very likely destructive of the nitrifying bacteria.*

Before leaving the subject of the nitrogen nutrition the chief function of the roots of plants, it should be mentioned that excessive use of nitrogenous manures has been found to render many plants more liable to disease, particularly such as are produced by various fungi. It is well, therefore, to practice moderation.

As regards other substances than nitrogen which it has been found useful to add to the soil as fertilizers, the most important are potash and phosphoric acid, the latter in the form of various phosphates, including bone meal.

These plant foods must be used in differing proportions according to the richness of the soil, and also according to the requirements of particular crops. Speaking generally, gardens and allotments which receive an abundance of stable manure do not require much in the way of other fertilizers; but in heavy soils basic slag used occasionally will be found a useful way of adding the necessary phosphorus, while nitrate of soda is often valuable to push on early crops, such as lettuces, peas, etc. In

* See "Reports on the Partial Sterilisation of Soil" Journal of the Board of Agriculture, January, 1912, January. 1913, and May, 1914.

agriculture it is usual to practice a *rotation of crops* whereby plants with different requirements as regards mineral salts succeed each other, and with the periodic introduction of a leguminous crop prevent the exhaustion of the soil. Though this is not so necessary in horticultural practice where the soil is generally richer, yet it is equally useful here to vary the crops in different portions of the plot, firstly because as shown above peas and beans enrich the soil in nitrogen, and secondly because such alternation often puts a stop to certain plant diseases which can only propagate themselves when the same plant is grown year after year on the same plot. This is the case with such diseases as "club root," of turnips and cabbages, and the "wart disease" of potatoes.

Another feature of some importance must be touched upon. Probably every gardener has noticed that the deeper soil of his garden differs very considerably from the surface soil. On heavy land the subsoil, as it is called, consists partly of solid clay, and is not so porous and crumbly as the surface soil. It is also of less nutritive value for it contains little or no decaying organic matter. Both physically and chemically, therefore, it is less suited to the nutrition of plants than the surface soil. It is important, therefore, when cultivating deep-rooted plants to improve the subsoil. This is done by *trenching*, a process which may be regarded as the cultivation of the subsoil. The surface soil is lifted off by removing one spit of soil, and then the subsoil may be improved both chemically and physically by digging in farmyard manure, or other forms of decaying organic matter. In the case of clayey subsoil, the addition of lime should not be forgotten. If the clay of the subsoil is too solid it may be necessary to replace it by loam, or it may be improved by burning it, whereby it is rendered more friable. By thus improving the subsoil, a much better nutrition of deep-rooted crops will be secured. In the case of lighter soils, where there is less difference, at any rate physically, between the surface soil and the subsoil, it is a common and beneficial practice when trenching to put the surface soil at the bottom of the trench and cover it with the subsoil, to which manure has been added.

Another useful process for the amelioration of soil is that of *ridging*, this is particularly beneficial in the case of heavy and tenacious soils. By digging up the soil and heaping it in parallel ridges a larger surface is exposed to the weathering, particularly to the action of frost during the winter. The effect of frost is to disintegrate the large masses of soil, and so to render the earth more permeable both to water and to air. By exposure to the atmosphere moreover the decay of organic matter in the soil is promoted, and thereby valuable nutritive matter is rendered soluble and available for plant nutrition. It is, therefore, sometimes recommended, before ridging, to spread any stable manure which is to be incorporated with the soil evenly over the plot. A trough is then dug two spades wide, one spadeful being deposited to the right and the other to the left of the trough. The soil of the latter can also be lifted, and turned, or merely forked over. This operation of ridging should be commenced in the autumn, and can of course only be undertaken on ground that is to remain empty during the winter.

Further information regarding the nature of soils and manures can be found in the following excellent books:—

E. J. RUSSELL. "Lessons on Soil." Cambridge Nature Study Series, 1/-.

E. J. RUSSELL. "A Student's Book on Soils and Manures." Cambridge Farm Institute Series, 1915, 3/6.

A. D. HALL. "The Soil." John Murray, London, 5/-.

A. D. HALL. "Fertilizers and Manures." John Murray, London, 5/-.

Chapter 3.

STEMS AND LEAVES.

Mechanical requirements of stems and branches. Twining and climbing plants. The food conducting function of stems The work of leaves and their structure. The wilting and recovery of leaves. Protection of leaves against excessive drought. Direct effect of surroundings on leaf development. Hardening off plants.

The stem is not as important an organ of plants as are the roots and leaves. The latter are essential for the nutrition of plants, and their particular work can only be carried on if the leaves are fully exposed to the sunlight. There is consequently considerable competition among plants for "a place in the sun," and in the course of evolution there has been a development of plants of increasing size, which by overlapping the smaller ones have been able to reach the light. This has led gradually to the production of trees and shrubs, but in herbaceous plants too, the stem and branches have the function of displaying the leaves to the best advantage. This and certain mechanical principles which are involved account for the peculiarities of branching typical of different plants. In addition to the stem and branches the leaf stalks are also concerned in the ultimate positions in which the leaves are expanded. By varying growth in length and direction the leaves become so placed that there is little or no overlapping and the dovetailing of the various leaves causes the formation of a regular "leaf mosaic."

This is very clearly seen in the arrangement of the leaves on the horizontal branches of a tree, or in the case of ivy growing up a tree trunk or on a wall. Even in plants possessing no stem, and in which therefore the leaves are found close to the ground forming a rosette, the leaves are found to overlap very little and particularly when they are stalked it can be clearly seen that young leaves which are formed near the middle of the rosette do not overlap the older leaves, as the latter become pushed out more and more from the centre by the elongation of the leaf-stalks.

The function of the stem being to bear and display the leaves it follows that, to carry the foliage and to resist the strain which winds will exert upon leafy plants the stem has to meet certain *mechanical requirements*. The rigidity, and at the same time the elasticity of the stem is attained by the development of certain thick-walled cells which collected into groups are so arranged as to give the greatest amount of strength with the smallest expenditure of material. These strengthening cells are displayed in plants on the principles which have been adopted by engineers in the manufacture of rigid, and at the same time elastic structures. We have, firstly, the hollow cylinder as is seen in grass haulms. The slender grasses can maintain their erect position by virtue of the mechanical properties of their straw. The bamboo cane is perhaps the most powerful of all in this form of construction. In other cases we find the stems developing internally a system of girders which give them the strength they require.

There are some plants in which the stem has not sufficient rigidity to grow erect as it does in most instances. In such cases the stem may trail along the ground, often covering a large area and the plant is then often modified as a shade plant unless it grows among very short vegetation, as in the case of some mountain plants. Sometimes by using the support of the rigid stems of other plants *twiners and climbers* are able to reach the light though they have to compete with much stouter vegetation. Twiners, such as the scarlet runner and the hop, have no special climbing structures, but their slender stems ending in a heavy terminal bud are bent over to one side, and on close examination can be seen to rotate very slowly, either clockwise or counter clockwise. This circular movement of the top of the stem causes it to grow round any upright or nearly vertical object in its neighbourhood, and then as the slender stem tries to straighten itself out it grips firmly the support round which it has grown. As the rotation is always in the same direction for a given species, it is necessary before giving such a plant any artificial aid to see in which way the rotation takes place, for if one twines the plant in the wrong direction it will unwind itself again when left alone. It is difficult to keep a twining plant to a horizontal course as it of itself will never twine round a horizontal support. Climbing plants on the other hand can fix their special climbing organs or tendrils to horizontal supports, partly owing to the sensitiveness of these organs to contact. In some cases, as for instance in the Virginia Creeper (Ampelopsis) the contact stimulus causes the tips of the tendrils to swell up into sticky suckers, which enable this creeper to fix itself to a vertical wall. More frequently however when the tendrils come into touch with some object, they grow round it by virtue of the fact that the side which is touched grows less rapidly, so that it curves round the support. After it has grasped the latter the tendril contracts spirally, and thus tightens the climber to its support. Tendrils are generally formed from parts of the leaf, the leaf-tips in peas, the leaf-stalks in the Nasturtium and Clematis.*

Besides carrying the leaves the stem has the further function of conducting to these leaves the food material absorbed by the roots. As we have seen the forces at work in connection with the supply of water to the leaves are, firstly, the root pressure (lecture 2), and secondly, the transpiration current in leaves (lecture 1), which latter causes a considerable suction to be exerted on the water in the stem. The special channels through which the sap rises are the vessels, long continuous passages, running in the wood of the stem. But this upward passage of water with the inorganic salts it contains, is not the only conduction required. The complex substances formed, as we shall see, in the leaves require to be conducted away partly to nourish the flowers and fruits, partly to enable further growth and development of the roots to take place. This elaborated sap passes through other channels which

* Further information concerning this interesting group of plants can be obtained by the perusal of Charles Darwin's "Movements and Habits of Climbing Plants."

lie outside the wood and are spoken of as the bast-tubes. These are very delicate, and to prevent them from being crushed they are protected on the outside by strong resistant fibres called the bast fibres or hard bast.

With regard to the essential *work of leaves* their primary function is without doubt to build up organic food material from the water taken up by the roots. This they are able to combine with carbon which they take from the atmosphere, where it occurs plentifully in the form of carbonic acid, the gas we breathe out from our lungs. In the presence of sunlight all parts of the plant which contain the characteristic green colouring matter are able to break up the carbonic acid, retaining the carbon and giving back the oxygen which was previously combined with the carbon. In doing this they are constantly purifying as it were the air and enriching it with the life-sustaining oxygen needed by man and all forms of animal life. The carbon which the plants retain is combined with the elements of water to form organic material called carbohydrates, of which starch and sugar are the most important to plants.

Within certain limits the brighter the light the more active is this process of carbon nutrition, or assimilation as it is called. Hence the great importance of giving plants as bright and sunny a position as possible, and hence also the reason why plants seek to secure the most favourable positions for their leaves. The formation of leaf mosaics, mentioned above, is a good instance of means adopted to secure the most effective display of leaves. Unless specially adapted for growing in shade, as are for instance most ferns, the majority of plants will not show their best development unless grown in an open situation. Apart from the essential influence of light upon the process of leaf nutrition, it has been found by experiment that this important nutritive process is affected by temperature being within certain limits proportional to the rise in temperature. This explains why in sheltered places, where the air is heated up in winter many plants are known to make better growth than actually in the open. Shade can be partially counteracted by warmth. In frames in which plants often get less light than in the open, the warmer temperature enables them to grow more rapidly than were they exposed to the colder air. It must not be forgotten too, that not only is the process of leaf nutrition stimulated by warmth but root-absorption also increases with a rise in temperature, so that all nutritive processes are favoured by warmer conditions of soil or climate.

A secondary but important function of leaves was referred to in a preceding lecture, namely, the importance of getting rid of a certain amount of water vapour into the atmosphere. This process of transpiration aids the upward passage of sap and also causes the concentration of the necessary mineral salts, which are only contained in dilute solution in the soil.

Let us now consider how the *structure of leaves* is adapted to perform its important functions. For both of them it is essential that the air should be in close contact with the cells of the leaf. It is essential to prevent too great a loss of water from the leaves and also for protective purposes it is necessary that the surface of the leaf should be covered with a more or less resistant layer. Consequently the passage of air to the interior of the leaf is effected through microscopic pores called stomata, which are usually found in greatest number on the under surface of leaves. These pores have the power of opening and closing so that the aperture can be regulated to the needs of the plant. They open with the approach of daylight and thus enable the carbonic acid to enter the leaves when the conditions are favourable for leaf nutrition. At the same time, of course, water vapour escapes outwards through the pores. The inner parts of the leaf are so arranged that the cells containing most of the green colouring matter are near the upper surface of the leaf where they will receive most light . Throughout the interior of the leaf there are wide spaces through which the air can circulate readily between the cells. The veins which bring up the supply of water and which also have to collect and conduct away through their bast portion the organic material formed by the leaf, become very finely branched so as to be in contact with all parts of the leaf.

If we consider that the larger the leaf surface the larger the amount of light absorbed and hence the greater the nutrition, we might wonder why all plants have not larger leaves. The limitation in the size of leaves is largely due to mechanical considerations. A slender stem cannot bear leaves beyond a certain size. Moreover, though a large leaf would increase the process of carbon assimilation, the loss of water from a large leaf surface might be more rapid than the absorption of water by the roots. Whenever this happens it causes the *wilting or drooping of leaves,* and should that occur too frequently the plant will not survive. As it is, wilting of leaves in the open occurs in hot summer days and affects mainly plants with large delicate leaves, large at all events in proportion to their roots, such as Doronicums, Calceolarias, and young Cauliflowers. In the case of pot plants, which are not only losing water through their leaves but also through the sides of the porous pots, it is a common phenomenon to find plants wilting during the heat of the day, and to prevent this it is necessary to shade the houses during the summer months, at least on very bright days. Wilting is particularly noticeable in recently transplanted plants, in which there is always sure to have been some injury to the roots so that absorption cannot keep pace with transpiration. Transplanting is therefore best undertaken in wet or dull weather, or at the end of the day, when during the succeeding night the stomata of the leaves will be closed, and consequently at the start, at all events, there will be no undue loss of water. Cuttings which have not yet produced an adequate supply of roots require in many cases to be kept in a moisture-laden atmosphere in a frame. It is interesting to note that when plants in the open flag at noon on a hot summer's day, they *recover again at night* even without further water supply. When the leaves droop the stomata usually tend to close, and at night they are certainly closed so that the roots have then the chance of replenishing the drooping leaves with water. Watering the plants while the sun is still on them should be avoided. Drops of water on the leaves are apt to act as lenses and focussing the rays of light upon the leaf often cause burning of the tissues and consequent spotting of the leaves. Watering the soil has also some dangers unless properly done. Merely damping the surface of the soil, apart from the tendency to cause it to cake, stimulates the growth of surface roots, which will constantly require watering in dry weather. It is better to give plants a good soaking from time to time. The water penetrating to some depth causes the development of deep roots, which will keep the plant supplied with water even in dry weather.

It is often thought that leaves, or at any rate the leaves of some plants, have the power of absorbing water. It is not an uncommon practice to spray the leaves of plants in the greenhouse when they are shaded, and also in the open when the sun is no longer upon them and their subsequent recovery, if they were drooping before, is attributed to their having absorbed water. This is however not the case. The spraying of the leaves, besides cooling the foliage, which is often considerably heated by the sun, has the effect by the evaporation of the water to render the atmosphere around the plant moisture-laden, wherefore the transpiration of the leaves is at once decreased. It is this decrease of transpiration and not absorption by the leaves which causes the revival of the plants. No leaves with an impervious covering can take in water and there are very few leaves which are not so protected. Mosses and Filmy Ferns alone among leafy plants can take in water through their leaves, which are adapted to growth in moist if not dripping conditions.

It is interesting to note that when the stomata are closed and transpiration is impossible, some plants are still able to get rid of their superfluous water. At night the leaves of the Nasturtium and the Fuchsia for instance are able to force out little drops of water through water-pores, which are found at the termination of their veins. Many grasses, too, have water-pores at the tips of their leaves, and the drops of water exuded by them often look like the formation of dew.

When growing in very dry soil or in hot arid climes, plants may experience a great difficulty in supplying their leaves with water, often during a very prolonged period. In such cases many remarkable deviations from the normal structure are produced, with the object of *protecting the leaves against drought*. In most cases the leaves are small, often reduced to mere scales or needle-shaped structures. Such are the leaves of many of our moorland plants growing in sandy, well-drained soil and exposed to strong and drying winds. In still more arid regions the leaves may disappear altogether, and we get such curious plants produced as the fleshy Cacti of the New World and the succulent Euphorbias (Spurges) of the Old World. In both of these groups of plants the green stems undertake the process of assimilation, and they also store up sufficient water during the wet season to enable the plant to last out during a prolonged drought.

It is sometimes stated that these strange modifications are the result of the direct action of the environment on vegetation. This is impossible of proof, and we may assume that it is largely by natural selection of forms or varieties most suited to these extremes of climate that desert plants have in the course of ages sprung from ordinary types of vegetation. Nevertheless we must not forget that to some extent climate has a direct modifying action. If, for example, we grow a seedling gorse in a moist greenhouse, we find that it will persist for a long time in producing small ordinary leaves, which precede the spines in the young plant, and this effect is certainly a direct action of the surrounding conditions. It is also well known that the texture of leaves produced by plants grown in a greenhouse differs greatly from that of leaves of the same species growing out of doors. It is necessary therefore before transplanting into the open plants raised under glass, to get them gradually acclimatised to their new surroundings. By transferring them from greenhouse to frame and keeping the latter well ventilated, or by placing plants in a sheltered place in the open, the leaves have an opportunity of becoming *hardened* to more rigorous conditions of existence. The outer layer of the young leaves can become strengthened, and they as well as the new leaves will all be modified to suit the new environment. In transferring a plant from a dry to a very moist house it will often be noted that the older leaves are shed. Being fully developed they are unable to adapt themselves to the new conditions. Not able to transpire freely owing to the moisture-laden atmosphere they become overcharged with water and this probably causes them to fall. The new leaves will be suitably modified to suit the more humid conditions.

Chapter 4.

METHODS OF VEGETATIVE REPRODUCTION AND PROPAGATION.

Tubers. Bulbs and corms. Bulbils. Runners. Layerings and cuttings. Budding and grafting.

As explained in my first lecture *vegetative reproduction* is the multiplication of the plant by means of structures, which partake of the nature of vegetative organs and are not the result of the fertilisation of flowers. This means therefore that the offspring, however numerous they become in the course of years, are not so much descendants as actual portions of the original individual just as the most recently formed buds of a tree are really part of the same tree, which ten or a hundred or even a thousand years before bore similar buds. The only difference is that the buds which the tree produces year after year all remain attached to the same parental stem, while in the case of tubers or bulbs the parent plant dies down each year, so that these structures become so many separate individuals. The very large number of distinct plants which thus arise will perhaps best come home to us if we consider that in the case of a potato plant producing yearly only six new tubers, we should have at the end of ten seasons obtained over ten millions of tubers. If an average of ten tubers were produced by each plant, the number of tubers at the end of ten generations would be 10,000,000,000 potatoes. As the millions of new plants which are thus developed are, properly speaking, all parts of the same plant they should, apart from slight differences of nutrition, not only be all similar but actually of the same constitution. It is true that bud variation does occasionally arise in plants, but it is a comparatively rare phenomenon, and consequently we find that as a rule plants, raised by vegetative methods, maintain the character of the parents and do not show the sporting with which one is familiar when raising plants from seed. The purity of the strain is thus easily maintained by vegetative propagation.

Let us now examine some of nature's methods of vegetative reproduction. In the first place, we have such well-known examples as *tubers* which form the chief method of propagation of the potato and of the Jerusalem artichoke. A tuber is the swollen-up end of an underground branch. This can be clearly seen by digging up a young potato plant and following these subterranean shoots from the parental stem to their tuberous tip. Both the branch and also the tuber show the rudiments of leaves, reduced to small scales and spirally arranged round the potato. On an old potato the sickle-shaped mark below each eye or lateral bud represents the insertion of the leaf or leaf scar, and at one end of the potato where these become more crowded together, we have the terminal bud of the tuber. This is called the "rose" end. At the opposite end we can generally find the scar or heel where the branch of which the tuber is the dilated tip, was joined to it. In all cases tubers are filled with stored food material, mainly starch in the case of the potato. When potatoes are set in the spring, the terminal bud grows up to form the main stem of the new plant, while the other eyes remain generally dormant. The new tubers are formed from specialised underground branches produced from the lower region of the main stem. The latter is therefore often earthed up so as to promote the development of these side shoots. It is a very common practice before setting potatoes, to place them side by side with the "rose" end uppermost and allow the terminal shoot to commence its development in daylight. By this means the shoot does not elongate so rapidly as when grown underground, that is, in the dark, and thus the lateral buds, which will develop into tuber producing shoots, are more closely crowded together and more numerous. This method therefore results in a greater yield of new tubers.

As there is generally a superabundance of food material, it is possible to divide a tuber into several pieces, and provided each piece has enough food material and a sound "eye," it will produce a new plant. It has been found by practice that when cut for "sets" the pieces near the "rose" end give the best results. When a potato is divided up in this way it is necessary to leave the separate pieces spread out to dry before they are planted, so that they may form a protective layer before coming in contact with the soil, the bacteria of which might cause them to decay.

Recently a method of raising new potatoes in the dark has received prominence in the press, and in many quarters erroneous views have been formed concerning this mode of cultivation. It has been thought by some that potato plants could grow like mushrooms and were not dependent upon light for their full development. This is very far from being the truth. Of course it is well known that potato tubers will sprout in the dark, as they do indeed in nature underground, but they are only able to grow without light while there is still a supply of food material in the old tuber upon which they can draw for their development. When that is exhausted the plants must inevitably die, as without light they are like all green plants unable to manufacture new organic material. It has however been found by experiment that if tubers are then half buried in fine dry soil spread out on a table in the cellar, they will soon be surrounded by a crop of small new potatoes close up to the old tubers. Large tubers should be used for this method of cultivation, and they should be placed three or four inches apart. It must of course be remembered that these small new potatoes are produced entirely at the expense of the food material stored in the old potato. We are therefore by this method of cultivation not increasing the food supply of the country but merely replacing old potatoes by a crop of more palatable new ones.

Bulbs and corms, which are the vegetative methods of reproduction of many members of the Lily and Iris Families, must be looked upon as specialised underground buds, which by virtue of their store of food material are able to lead an existence independent of the plants on which they have been produced. Like the ordinary winter buds of a tree, such as the horse-chestnut, they are protected on the outside by a few dry scaly leaves, while at their centre will be found the foliage leaves and flowers of the next season. But between these we find another set of leaves which do not occur in the buds of a tree, namely, thick storage leaves of a fleshy nature. It is the possession of this internal supply of food material which enables these specialised bulbs to produce their leaves and flowers in the next season, though separated from the parent plant which formed these bulbs, while in the case of the tree the winter buds expand in spring by making use of the food material stored in the branch to which they belong.

What is the nature of the parent plant on which the bulbs are borne as lateral buds? Take up a tulip plant after it has flowered and you will find at the base of the upright stem bearing the leaves the storage scales which have made the growth of the stem and leaves possible, and at the base of one or more of these scales will be seen small buds, which are beginning to swell owing to the organic material manufactured by the leaves, passing down to them. This observation will teach us that it is important, if we wish to save our own bulbs for planting, to leave the old bulbs in the ground for some time after flowering and not to cut off the foliage leaves but to preserve them as long as they are fresh and green and capable of manufacturing food material. This is the time, too, to give the plant further food in the form of top dressing or occasional supplies of manure water. It is also important to cut away the dead flowers, so that the food material is not expended in the ripening of the seed vessel.

Another point of importance in bulb growing is to secure the proper ripening of the bulb. In nature bulbs after losing their leaves pass through a resting stage, during which they are kept dry by the vegetation covering the soil in which they grow, whether they occur in woodlands or meadows. In our gardens where the ground above them is usually uncovered, water percolates down to them, and if they are not very deeply buried slugs, too, may attack them. It is therefore often advisable in the case of damp soils, to take up the bulbs when the leaves are dying away, and to allow the bulbs to dry in the sun, storing them afterwards in a dry place until the time for planting arrives.

Corms are very like bulbs and may often be mistaken for the latter, but on cutting them across we find that the dry scales which surround them on the outside are not followed by fleshy storage scales, all the food material being stored in the thick solid stem which makes up the bulk of the corm. In their growth and development, however, they follow very closely the life history of the bulb. Crocuses and Gladioli possess corms, while Lilies, Tulips, Hyacinths and Daffodils have true bulbs. The bud-like nature of bulbs can be clearly recognised by examining the small swollen buds or *bulbils* which arise on the aerial stems of certain species of Lily, and which, though unable to give rise immediately to a new flowering shoot, can gradually be grown on to produce in time a mature bulb.

Runners, such as are produced in the Strawberry and Violet, are delicate lateral shoots creeping over the surface of the soil and becoming readily rooted at their nodes when in contact with the moist soil. In nature they cause the very rapid spreading of these plants, and by the decay of the portion of the stem which joins them to the parent plant they may cause the increase of individuals. They are conveniently used for propagating purposes and should always be removed from the parental stock as they draw nutriment from it and therefore impoverish the latter, with the result that they reduce the number of flowers.

Many plants which do not possess natural means of vegetative reproduction can be caused to give rise to new individuals by separating certain portions, generally lateral shoots, and inducing the same to develop new roots. In some instances the formation of these roots is promoted before the branch is separated from the plant; this process is known as *layering*. The lower branches of such shrubs as Gooseberries and Red Currants may be bent down and partially embedded in a shallow trench dug round the bush, and filled with light and porous soil. When stimulated by moisture the buried portions of these branches, the tips of which must be allowed to project beyond the trench, will produce what are termed adventitious roots, and when these are sufficiently well-established, the branch may be severed from the parent plant, and the new individual will lead an independent existence. It is generally found advisable to cut back the projecting portion of the branch to two or three buds. This method can also be employed for Rhododendrons and for more delicate shrubs, as well as for climbers like Clematis. A similar process has been found advantageous for many herbaceous plants such as Violas, Carnation and Pinks. In these cases, however, it is usual to make a slight incision in the buried portion of the shoot, which should always extend to one of the knots or joints. Such an incision stimulates the production of roots, particularly at the end furthest removed from the parent plant. This is no doubt due to the accumulation at this point of food material which has been produced by the leaves at the tip of the layered shoot, the food material being unable to be carried across the incision. Even in dealing with shrubs it is sometimes found advisable to make an incision partially across the branch which is to be layered, and to peg it down so as to keep it in position until the new roots are formed. It is of great importance that the soil in which the new roots are to form should be well äerated, more particularly in the case of herbaceous plants which are more liable to injury by rotting. It is advisable, therefore, to add a considerable amount of sand to soil in which layerings are to be embedded.

In the case of upright stems or branches, which are far above the soil, the production of adventitious roots can be promoted by removing a ring of outer tissues to the depth of the wood, and then tying a handful of wet moss round the shoot. Such ringing causes the food material formed in the upper part of the plant to accumulate above the wound, and this promotes the rapid development of roots. When these have become sufficiently established the rooted portion of the stem or branch may be severed from the parent.

In many plants the formation of adventitious roots is so rapid that shoots completely detached from a plant can establish themselves as *cuttings*, producing their own roots when placed in suitable conditions. In all cases in which cuttings are made the first need is to cause the covering in, that is, the healing of the cut end of the shoot. This is done by the development from the actively growing cells of a peculiar wound tissue, called callus, which by growing over the wound and developing a layer of cork, prevents the destruction of the exposed cells and the entrance of harmful bacteria. The growth of callus is promoted by the äeration of the tissues, and it is therefore important that the soil in which cuttings are placed should be even better drained than that supplied to normal plants. A soil made porous by the plentiful admixture of sand should always be selected, and in the case of cuttings which are being struck in pots, it is a common practice to insert them close against the inside of the porous pot, through which the air has a free access to the cuttings. The danger of over watering cuttings is even greater than in the case of well-established plants. Cuttings taken from woody plants produce their wound tissues as well as the adventitious roots, which are formed later, at the expense of the food material which is stored in the shoot. They are not therefore so dependent on warmth and light in the early stages as are herbaceous cuttings. They can indeed be struck in the autumn or winter after the leaves have fallen, or in the early spring before the foliage has been developed. If taken in the autumn they often do not produce their roots until the following spring, and they are always later in the development of their leaves than are well-established plants. In the case of herbaceous cuttings which have no store of food material, it is necessary that they should be able to continue to form new organic food material in their leaves so as to promote the growth of callus and the development of roots. It is esential therefore that they should have plenty of light; but in the first few days before they have adapted themselves to their new conditions, they are liable to lose too much water by evaporation, and it is important during this period to keep them slightly shaded, or to grow them in a moisture-laden atmosphere in a closed frame or greenhouse. It is better to prevent the loss of too much water by protecting the leaves in this way than by excessive supply of water to the soil, as herbaceous plants are very liable to decay by the action of bacteria on the cut end of the shoot. As herbaceous cuttings have to continue to manufacture food material, they also require a greater amount of heat than do woody cuttings, the process of leaf nutrition being stimulated by an increase of temperature. Herbaceous cuttings must, therefore, not be taken too late in the autumn unless they are to be grown in artificial heat.

A few plants can be raised from root cuttings. This is possible where plants are endowed by nature with the power of forming adventitious buds on their roots. Raspberries, Pears and Apples are all examples of plants which often produce suckers from their roots in the neighbourhood of the parent plant. Such growths can be separated and developed into new individuals. In the case of Raspberries indeed, this is a common method of propagating the canes.

Lastly, it has been found possible in the case of some plants with somewhat fleshy leaves to cause these, or even portions of a leaf, to produce adventitious buds. This is the case with many Begonias, particularly those belonging to large-leaved varieties. If the leaf is placed on damp soil, the midrib having been cut in several places, new plants may arise from each portion as with the stimulus of warm temperature and moisture the leaf produces a considerable growth of callus, from which adventitious buds soon arise. The fleshy scales forming the bulbs of most lilies are capable when separated from the parent bulb of producing small adventitious buds from which new plants can be grown, and this is a common method of propagating the plants.

Space prevents a detailed discussion of the processes of *budding* and *grafting*, but from the botanical point of view the processes may be regarded as a special case of making cuttings in which the latter, instead of being planted in soil, are inserted in the tissues of a nearly related plant with which they become united by the development of wound tissue or callus. No adventitious roots are formed by the graft as the scion relies for its supply of water entirely upon the roots of the stock.

There has been much discussion as to whether, as a result of grafting, there is any influence of the stock upon the scion, or *vice versa*. A considerable amount of information on this question has accumulated, but it is largely of a negative character, and what positive evidence exists is of a doubtful nature.

Chapter 5.

FLOWERS AND THEIR FORMATION.

Conditions favouring the production of flowers. Structure and functions of the various parts of a flower. Pollination and Fertilisation. Self-fertile and self-sterile flowers. Ripening of fruits and seeds.

In speaking of the difference between vegetative and reproductive organs, in the first chapter I have already mentioned that certain external conditions which favour the development of the former affect adversely the formation of flowers. Long horticultural practice has also proved that *the development of floral organs can be stimulated* in various ways which are well known to gardeners. Thus reduction in the supply of water and consequent stoppage of the luxuriant development of leaves is one of the chief methods employed. It has been found by scientific experiments that these various horticultural practices are based upon definite physiological requirements. In recent years much has been done to confirm and extend our knowledge of this subject. It was proved that bright illumination of plants is essential for the production of flowers. At first it was thought that certain rays of light influenced the development in the plant of special flower-forming substances, and early experiments seemed to indicate that these were produced by definite rays of light from beyond the blue end of the spectrum—rays of light which are known to have great chemical activity. More recently, however, it seems to have been established that it is probably the intensity rather than the quality of light which is required for flower production. Another factor which is important in this respect is *the concentration of organic material in the stem and leaves of the plant*, while an increase of water and inorganic salts tends to the development of foliage rather than flowers. It is for this reason that a reduction in the supply of water is so helpful in producing abundant flower buds. It is sometimes thought that a wealth of blossom on our fruit trees predicts a fine summer; from what has been said above, it is obvious, however, that it is the fine summer or dry autumn of the previous year which is responsible for the prolific bloom. Flower buds on our fruit trees are, of course, already developed in the late autumn. Dealing with herbaceous plants, it has been found possible to arrest the development of flowers even if the flowering shoot has commenced to make its appearance. Thus in specimens of the common House Leek a rosette of vegetative leaves may be caused to appear on the flower shoot if the plant is copiously watered and illuminated with light passing through a red or blue screen. Conversely, the runners of some plants may be made to bend upwards and develop flowers if water is withheld and the plant placed in a very bright light.

The horticultural practice of pruning and root pruning is also intended to further floral development. Each tree or shrub must be treated differently according as to whether flowers normally make their appearance on long shoots or on spurs, *i.e.*, on new or old wood. The removal of non-flowering shoots is therefore what is aimed at. In summer pruning the stoppage of the growth of purely vegetative shoots will actually stimulate the older branches to form flowers, as they will have an increased amount of food material at their disposal. The increased production of flowers effected by root pruning is often remarkable. It will be sometimes observed that apple and other fruit trees produce long and vigorous new shoots, particularly in an upward direction, which are caused by the development of deep roots able to obtain an abundant supply of water even in fairly dry soil. The removal of these deep roots stimulates the growth of fibrous roots in shallow soil, where there is a less abundant supply of water in the summer and early autumn; the result of root pruning is therefore the production of numerous spur shoots, on which alone flowers are produced in the case of the apple and pear. In some of our ornamental shrubs, however, such as Guelder Rose, Weigelia and Forsythia, flowers are borne on the shoots of the previous year, and it is consequently a mistake to cut these back in the autumn, as is so often done thereby reducing the beauty of these shrubs. Old wood, on the other hand, and branches which have already flowered, should be pruned away at the end of the summer. Some plants which are nearly related, differ in the manner in which they bear their flowers and fruit, and it is therefore very important before pruning to know exactly on which kind of branches the flowers will be borne. For instance, the Morello Cherry bears its flowers all along the shoots produced during the previous summer, while others flower at the base of the shoots on short spurs. These kinds must therefore be pruned differently from the former. A similar difference is found in the case of currants. Black Currants flower all along the shoots formed in the previous summer, while Red Currants produce their fruits on small spur shoots found on older wood.

We must distinguish between the methods causing the production of flower buds as described above, and practice—such as *forcing*, which has for its object to cause an early unfolding of the same. Unless bulbs or äerial buds already contain the rudiments of flowers no amount of forcing will cause these to be formed. The application of moist heat, often in faintly lighted pits, is indeed inimical to the production of flower-forming substances and promotes vegetative growth rather than flower production. On the other hand, if flower buds are present their expansion can be materially accelerated. By these means flowers can be obtained in mid-winter when they will be particularly appreciated. Most storage organs, whether tubers, bulbs, or winter buds, require to pass through a resting period before they enter upon a new period of growth. Various methods can be adopted therefore to accelerate either the process of ripening the buds or of reawakening the dormant structures. While dryness promotes the former, heat and moisture effect the latter. It has been found however that the resting period can be shortened by various means. For example particular varieties of potato, which will not sprout in the autumn and cannot therefore be used for the culture of early potatoes, if placed for a fortnight in a cold chamber slightly above freezing point will readily develop when planted. A similar treatment is advantageous for rhubarb plants which are to be forced. Lift them out of the ground and let them dry and be exposed to light autumn frosts and they will then respond more readily to methods of forcing. This practice of thoroughly cooling plants which are to be forced is now regularly used in the case of bulbs, retarded Lily of the Valley crowns, Lilacs, Spiræas, etc. Abroad, other methods have come into vogue with the same object in view. It has been found that the immersion of the branches of plants for ten to twelve hours in a hot-water bath of from 85 deg. to 100 deg. Farenheit, has a remarkable effect in accelerating the unfolding of winter buds. The roots should not be so treated. It is therefore best to invert the plants and allow the stem and branches to hang down into the hot water. The effect of the latter is quite local; so that when partially immersed only those buds which have been under water are affected. Six weeks after this treatment lilacs will be in full bloom, if subsequently grown in the usual way. Professor Johannsen, of Copenhagen, has discovered that exposure of plants to ether vapour for twenty-four to forty-eight hours has a similar accelerating effect. Both methods are largely used on the continent.

Let us now consider the *structure of flowers and the function of their various parts.* So manifold is the appearance of flowers that it might seem at first difficult in a short space to make any general statement on their structure; yet as regards the essential organs of reproduction we find considerable agreement. It is more particularly in the structure of the brightly coloured petals that we find great variety, and largely owing to the adaptation of the flowers to the visits of insects. The colour and scent is developed to direct them to the honey which the flowers provide, and special honey guides, spots in the Rhododendrons and lines in Pansies and Violas, as well as differences in colour, guide them to the nectaries. In making their way to these the insects come in contact with the delicate stamens of the flower and the pollen contained in the pollen sacs at the tip of the stamen becomes dusted on to the insect. When it visits the next flower, some of this pollen will be dusted off on the stigma at the top of the immature seed vessel, and thus the insect effects the *pollination*, which is the necessary preliminary to the *fertilisation* of the flower. The pollen grains left on the sticky surface of the stigma germinate there, and a delicate tube grows down from them to the immature seeds, which become fertilised by the fusion of the vital element of the pollen grain with that of the ovule. Even though a flower may produce both of these essential organs, the pollen producing stamens and the ovule containing seed vessel, self-pollination does not usually take place as the stamens and seed vessel mature at different times. This can easily be seen in such a large flower as that of the Nasturtium, in which the stamens may be observed ripening one after the other and liberating their pollen, and only after the last of the pollen sacs has shed its pollen does the three-pronged stigma open and is then ready to receive pollen brought from another flower in which the stamens are opening. All the various and wonderful mechanisms, by means of which flowers ensure their pollination, have the purpose of securing the fertilisation of the ovules with pollen from another flower and if possible from another plant, for as Darwin has shown * cross fertilisation usually causes the production of more numerous and stronger offspring than self-fertilisation.

Gardeners who grow exotic plants, the flowers of which are adapted to the visits of insects not found in this country, have often to perform this service themselves and to pollinate artificially the flowers using usually a fine camel-hair brush. In plants like the Tomato, tapping the stems with a stick, wrapped round with a cloth to prevent injury to the plant, will generally cause the pollen to drop out of the opened anthers on to the stigma of these pendant flowers. If tomatoes are grown under glass, we must take care that during the period of flowering the house is kept dry, as the pollen sacs will not open in a moist atmosphere and the plants cannot be pollinated. Of course by the method described self-pollination only can be effected, crossing can be obtained by using a fine paint brush and pushing the hairs up between the stamens first of the flower and then of another.

In some plants, such as the Cucumber and Marrow, the flowers are of two kinds, some producing the seed vessel,

Darwin, C. "The Effects of Cross and Self-Fertilization in the Vegetable Kingdom." (Murray, 9/-.)

which can be seen as a thick structure below the petals, and others producing only pollen. In such cases, self-pollination is impossible and cross pollination must be effected either by insects or by the gardener. It is curious that in spite of the many adaptations to cross fertilisation there are many plants in which *self-fertilisation* is the normal process of seed production. This is the case with most of our cultivated grasses. In the wheat and other cereals, though the flowers open and the light powdery pollen is carried from plant to plant, the stigma of the seed vessel is usually pollinated before the flowers open, and as there is only one seed in each seed vessel it is usually self-fertilised before the foreign pollen arrives. Even in flowers, apparently specially adapted to the visits of insects such as the Sweet Pea, which possesses both scent and colour, the immature pod is already pollinated in the bud stage of the flower, and if we wish to effect any crossings between different varieties of this plant, we must cut away the stamens before the flowers open and introduce pollen from another plant. While such normal self-pollination has for horticulturists the advantage that it preserves the purity of the varieties we cultivate, it is probable that it may gradually cause a weakening of the race, and in nature even occasional crossing probably re-invigorates the strain.

Quite a number of members of the Pea Family are *self-fertile*, including the commonly cultivated forms of peas and beans, while many other leguminous plants, such as the clovers are *self-fertile* and cannot be fertilised with their own pollen even when it is placed on the stigma of the flower. An interesting analysis has been made of the behaviour in this respect of the various members of this Family, and it has been found that all the annuals in this group of plants are self-fertile, while the perennial forms are self-sterile. It would seem as if it were of more importance to ensure regular and uninterrupted production of seed in the former, while in perennials, even if in one season owing to the absence of insect visitors, seeds are not produced, the persistence of the plant to the next season when conditions may be more favourable will enable it to reproduce its kind.

The flowers of many varieties of Apple and Pear are self-sterile, and disappointment has often been caused by the failure of a fruit tree to bear when grown singly with no other variety near to it from which pollen could be carried by seed. Even in orchards, if a large number of self-sterile varieties are grown close together, the yield of fruit may not be found to be satisfactory. In both cases it has proved very efficacious to plant near such trees a Siberian or other Crab Apple, which produces a large amount of effective pollen which can be carried by insects from tree to tree.

After fertilisation, when the young plant is beginning to be formed in the seed, the seed vessel too begins to swell, and it is from observing the latter that we can gather that pollination has been successful. Of course the continued growth of the seed-vessel, as well as the development of the embryonic plant and the storage in the seed of enough food material for its subsequent germination, necessitates considerable activity on the part of the vegetative organs particularly of the leaves. It is for this reason advisable in the case of Peas, Scarlet Runners and French Beans, when they begin to set their pods, to encourage their further growth by the use of suitable stimulants such as liquid manure.

It is obvious that as the formation of seeds and fruits require increased supplies of food material, herbaceous plants that are heavily fruiting will have less food wherewith to develop new flower buds, and graduallv the plant will cease to produce flowers. If, therefore, we are cultivating plants for the sake of their flowers it cannot be too strongly recommended to pluck off all flowers as soon as they are dead, so that they should not begin to set their seeds. In the case of Sweet Peas, where the seeds take up a large amount of food material, this is particularly important, but it is a good rule to follow in all cases. The fact that a large supply of food material to fruits may exhaust that available for the production of flower buds will explain reduction in the number of flowers on fruit trees, if an abnormally heavy crop of fruit was produced in the previous season. It is not, however, only the formation of flowers which will be interfered with. Under special circumstances the vegetative organs, too, may suffer. For this reason it is recommended that young fruit trees, which have been recently transplanted, should not be allowed to ripen many of their fruits during the first season after transplantation, as this may interfere with the proper development of the new root system, which is always damaged to some extent when trees are moved. Similarly, it is advisable when Raspberry canes are newly planted to cut them down to within eight or ten inches of the ground, so that they should not exhaust themselves during the first year, as that would prevent the formation of strong new shoots for the next season.

As *ripening fruits* require a large amount of nutrition, it is important to see that the stimulating treatment we give to plants which are bearing, should not be used for the production of vegetative shoots. In Tomatoes the growth of such shoots should be checked when the fruits are maturing. It is also advisable to reduce the foliage a little so that the fruits are not shaded. Excessive defoliation, however, will prevent the fruits from attaining their full size as the leaves are the seat of formation for the organic material which the fruits require.

When fully mature the *seeds* inside the fruits will be found to be surrounded with a hard seed coat, within which we have the minute seedling either containing its store of food material in its fleshy seed leaves as in the Pea or Bean, or surrounded with a supply of nutriment as in the case of the Wheat grain. The food material is usually largely starchy or oily, but in addition there is a smaller amount of the essential nitrogenous material so important to the plant and so essential to man. Of all cereals Wheat is the richest in nitrogenous material, while all leguminous seeds, thanks to the help which their parent plants have received from the nitrogen fixing bacteria in their root tubercles, have a great abundance of organic nitrogen compounds. This is the cause of their great nutritive value to mankind.

Chapter 6.

SEEDS AND SEEDLINGS.

Vitality and longevity of seeds. Conditions favouring germination. Seedlings. Variation. Natural and artificial selection. Sports or mutations. Hybrids and the laws of heredity.

Ripe seeds are surrounded by a hard seed coat which is more or less impervious and prevents complete drying up of the embryonic plant within the seed. The more resistant the coat the longer the seed can preserve its *vitality*. The seeds of some plants germinate almost immediately they are mature, but most of them are adapted for and require a period of rest. During that time it is necessary to keep them dry and fairly cool. Under such conditions they can preserve their power of germination for some years, though a certain number even of resistant seeds will die. It is also more difficult to germinate old seeds, owing probably to the drying of the seed coat, as well as to changes which have taken place in the living cells of the seed. When kept dry little alteration takes place internally, and the seed can remain dormant, practically no loss of matter taking place by respiration. For what length of time this suspension of animation can last is not definitely ascertained, but we may say with certainty that we have no proof that seeds which have lain dormant for a thousand years or more, like those which have been taken from Egyptian mummy cases, can be germinated. That so-called mummy wheat and mummy peas have been originally obtained from Egyptian mummies must be regarded as purely legendary. Accurate investigations which have been made regarding the *longevity of seeds** have proved that so far a hundred years may be taken as the longest period for which seeds have been known to retain their power of germination. The seeds which enjoy such prolonged vitality belong to a restricted number of Natural Orders of which the Pea Family is one, remarkable like the others for the very resistant coat or testa with which its seeds are covered.

After the resting period, seeds when placed in favourable conditions commence to germinate. *Moisture and a warm temperature favour germination.* Water is absorbed by the seed coat as a whole, or may be taken in at certain points. In some small smooth seeds the outer layers of the seed coat are mucilaginous, and when wetted swell up considerably and become slimy. This is the case with the seeds of the flax plant (linseed) and with those of the cress. The probable reason for this special provision is to cause the seeds to become fixed in the soil so that the seed leaves can be more readily withdrawn from the seeds. There are generally present on the inside of the seed coat certain layers of cells which swell up rapidly when the seeds absorb water, and probably aid in the splitting of the seed coat, thus enabling the embryo to be gradually withdrawn from the seed. Warmth, the other factor essential to germination, is required for certain important chemical changes which need to take place before germination can be effected. The food material stored in the seed is largely of a solid nature and requires to undergo transformation so that it can be dissolved in the cell-sap and can be conducted to the growing root tip and to the developing leaves. By certain fermentative changes starch is converted into sugar, oil and organic nitrogenous compounds are broken up and pass from cell to cell. In some cases as in peas and beans the food material is stored in the two fleshy seed-leaves or cotyledons, while in other seeds like those of the melon, the onion, and in all our cereals it is found in cells outside the young seedling and requires to be absorbed by the latter before it can be made use of at the growing points. The re-awakening of the vital processes indicated by these internal changes is marked by the commencement of respiration, that indispensable accompaniment of all life, whether animal or

* Ewart, A. J. "On the Longevity of Seeds." Proceedings of the Royal Society of Victoria, 1908.

vegetable. We can easily demonstrate the occurrence of this breathing process in germinating seeds if we allow moistened seeds to germinate in a closed jar. The latter will soon lose all the oxygen it previously contained, and carbonic acid will be found to have taken its place, as can easily be seen by the fact that if a lighted taper is introduced into the jar it will be immediately extinguished. Respiration which is inseparable from active growth is a process of slow combustion, and is always accompanied by a rise in temperature. This can best be seen when a large mass of seeds are germinating together as, for instance, during the process of malting, when barley grains in large heaps are passing through the early phases of germination, the starch they contain in the resting stage being transformed into the sugar known as maltose. By plunging the hand into a heap of barley which is undergoing this change one can readily detect the heat which is being evolved. The active need for oxygen by germinating seeds will make us careful to keep our seed beds porous and to prevent the soil above seeds from becoming caked and therefore impervious to air.

Details of the various methods of germination will be found in most botanical textbooks and need not be dealt with in this lecture. I might, however, mention that whilst most seeds germinate best in the absence of light, there are some small seeds which should be sown superficially, as light seems to be beneficial to their development. This is particularly the case with the seeds of some grasses. An important point in sowing seeds, apart from taking care to give them the proper depth, is to ensure that the soil with which they are covered is fine and friable, so that the seedlings have no difficulty in forcing their way up to the light. In the case of mustard, cress and other members of the same family (Cruciferae), care should be taken not to over-water the seedlings as they are liable to " damp-off " owing to the attacks of a parasitic fungus, which will be dealt with in a subsequent chapter. When dealing with some seeds which germinate irregularly, possibly owing to their age or on account of their having been stored during the winter when they should have been sown immediately after maturing, it may be advisable to keep the seedpan going for a considerable time as a succession of seedlings may be produced, all of which may be quite healthy and normal.

Let us now pass on to consider the nature of the *seedlings* themselves. It was pointed out previously that Darwin had shown the beneficial effect of cross-pollination in the more vigorous development of the offspring. Another important feature of seed reproduction as compared with vegetative reproducton, particularly if the seeds are the result of cross-fertilisation is the occurrence of a considerable amount of *variation.* The more dissimilar the parents the more varied are the offspring, and the greater therefore the scope for the play of natural or artificial selection.

The term variation has been used for two very different phenomena noticeable when examining a large number of plants or animals of the same species or kind. It is well known that the offspring of any two parents all have some different individual characteristics, and a close observation of a number of seedling plants will show us that though they all have a general resemblance, we find that they differ slightly one from another in size, in the shape and texture of their leaves, and when they grow up in colour and conformation of their flowers. Indeed, if we had carefully examined the seeds from which they have grown we should have found that the latter showed already a considerable range of variation in shape and size, and possibly also in colour. Such slight individual variations are always found to fluctuate around a mean or average which we may look upon as the general character of the species or race. It is these slight individual variations which Darwin regarded as so important in the evolution of new forms, those least suited to the particular conditions of life gradually dying out and leaving those which were fit to survive. *Natural selection* operating in this way was thought to have produced the innumerable forms which we know as natural species. In the same way man, by making a choice of the plants most suitable to his purposes, has by *artificial selection* produced the strains and varieties now cultivated.

Recently experiments have been carried out in which the seeds of certain plants have been carefully graded and the largest sown separately with a view to ascertaining whether by such constant selection the seeds could be indefinitely increased in size. This was, however, not found to be possible, for though the average size of the seeds was at first considerably raised, a limit was reached beyond which it was impossible to increase the size of the grains. By this process of selection the investigator had probably succeeded in isolating a pure strain of the particular variety with which he was experimenting, characterised by a larger seed than the sample with which he started, which was, no doubt, a mixture of races, some producing smaller and some larger seeds. But once a pure line had been obtained, though it showed slight fluctuations, yet it could not be improved by selection of the extremes of these fluctuating variations.

We know, however, of other variations which arise from time to time in all species of plants, and which are very different from the fluctuations as we may term those described above. Sometimes we come across new forms which differ considerably from the normal type in one or more characters, as, for example, the cut-leaved varieties of so many plants. In this case we do not find a series of forms intermediate between the cut-leaved individual and those with normal foliage. This second type of variation which arises suddenly Darwin called a *sport*, and he considered it to be of comparatively little importance in the evolution of plants, as its very infrequent occurrence would cause it to disappear in nature by constant inter-crossing with the more numerous normal forms. By artificial selection, however, man can perpetuate and establish these sports, as has obviously been the case with many of those forms which took the fancy of the horticulturist. It is to this kind of variation that we owe so many of our interesting and peculiar forms of cultivated plants. Recently a Dutch botanist, De Vries, has endeavoured to show that this second kind of variation, which he calls *mutation*, to distinguish it from the former or fluctuating variation, is of more frequent occurrence than had been supposed by Darwin. He observed that a certain large group of plants of Evening Primrose which had established itself in a wild condition in Holland showed a very considerable amount of mutation, and his experiments and other observations led him to the conclusion that at certain periods, possibly owing to changed environment, plants passed into a phase of mutation, during which numerous new sub-species or races might arise. Interesting and important as De Vries' experiments are, his case cannot be considered proved until we know more about the previous history of the plants which show such considerable mutation. At present we do not know whether the Evening Primrose which he investigated was a pure race or of hybrid origin.

To horticulturists a knowledge of *hybrids* is of the greatest importance, a vast number of new and interesting forms being continually produced through hybridisation. At one time it was thought that hybrids were invariably intermediate between the two parental forms, and that they were generally sterile, and could therefore not be reproduced by seed. Though this is sometimes the case, particularly where the parents are of different species, it is by no means the rule, and certainly not in the case of hybrids between two different varieties. Our exact knowledge of hybrids dates from the careful experiments made in the latter half of the nineteenth century by *Gregor Mendel*, of Brünn. Unfortunately, his important investigations did not become generally known until the beginning of the present century. Mendel's first observations were made on various varieties of the garden pea, and he obtained the striking result that in crossing two different strains the offspring were not of immediate type, but generally inherited the characters of one of the parents in their entirety. Thus in crossing varieties, of which one had round and smooth and the other wrinkled seeds, he obtained seeds all of which were round. He therefore considered this to be *a dominant character*, while he called wrinkledness *recessive*. But when the flowers of the hybrid plant were subsequently fertilised with their own pollen, the seeds they produced were not all round, some of them were wrinkled like those of one of the grand parents. On carefully counting the number of these recessive types, he found that one in four had reverted to the wrinkled tvpe. Moreover, he found that of the round seeds some were of pure type, and when further cultivated always produced round seeds, while others were of hybrid nature and these always produced reversions to the parents which had been originally crossed.

He was able, finally, to demonstrate that of the offspring of every hybrid when self-fertilised one quarter reverted completely to the female parent, one quarter to the male parent, while half of the offspring remained of hybrid nature. These resembled the parent, which possessed the dominant character but preserved the recessive character in a dormant or latent form as was shown by its reappearance in a subsequent generation. The accurate numerical results, which Mendel obtained, can be readily explained on mathematical grounds by what we know of the various combinations which are possible between egg-cells and pollen-grains when differing in two characters. Of course, if the parental forms differ in several characters the possible combinations are much more numerous and the numerical chances of complete reversion to the parent forms is much smaller. On the other hand, while we obtain a large number of hybrid forms which will show reversions to the original parents, we shall find some new combinations which are pure forms and therefore breed true. These we can isolate from the rest by the rejection of all strains which show reversion, and thus we can obtain new and permanent varieties. This no doubt has been the means adopted by plant breeders in the past from practical experience, but thanks to Mendel and those who have followed up the path shown us by his investigations, a scientific basis has been laid to the practice of hybridisation.

In the course of these scientific enquiries some remarkable facts have come to light. It has, for instance, been discovered in crossing a white and a yellow variety of the Marvel of Peru (Mirabilis) that the hybrid produced was not intermediate in character, that is, of pale yellow colour, neither was it like either of the parents, but of a pink colour and marked with red stripes. The white form must evidently have possessed some chemical factor which changed the yellow colour into red, while the character producing striping, which could not show itself in the white form, became visible in the hybrid by reason of the coloured sap. The offspring produced by self-fertilisation of this hybrid were of twelve different kinds: five with different shades or striping in yellow, five corresponding forms in red, and two white forms, which, though resembling each other externally, differed in constitution as could be seen from their progeny.

A somewhat similar and equally remarkable result was obtained by crossing two white Sweet Peas belonging to the variety, Emily Henderson, the offspring having a partly-coloured flower, red with blue keel, probably very like the ancestral form. Of the two white forms evidently each one contained a special factor, which combined with that of the other white form caused the formation of a coloured sap. The offspring of the coloured hybrid were mostly coloured but in different degrees, while white forms similar to the two original parents were also produced, the two colour-producing factors separating out in these particular descendants.

Though in a comparatively short space of time great advances have been made in our knowledge of the laws of hybridisation and heredity, much remains still to be learnt in this important branch of scientific knowledge and the co-operation of the plant breeder with the scientific investigator is much to be desired. The success already attained in this country is of good augury for the future.

Further information on some of the subjects discussed in this lecture can be obtained from the following books:—

Darwin, C. "Origin of Species," and "Animals and Plants under domestication."

De Vries, H. "Species and Varieties, their Origin by Mutation." Chicago, 1905. Also "The Mutation Theory," London, 1909.

Bateson, W. "Mendel's Principles of Heredity," Cambridge University Press, 1909.

Punnett, R. C. "Mendelism," Macmillan & Bowes, Cambridge, 1905, 1/-.

Chapter 7.

MALFORMATIONS AND INJURIES.

Malformations arising as sports or by malnutrition. Healing of wounds. Injuries due to lightning, frost, etc. Harmful effect of smoke and fog.

Abnormal development of various parts of plants whether of vegetative or of reproductive organs may be regarded as *malformations*. Many of these arise as sports or mutations, and may be transmitted to the progeny of the plant. In the case of the vegetative organs such occurrences as pitcher-shaped leaves have been noted in many instances. Leaves of this type are of no special advantage to the plant, they may indeed be a disadvantage, causing water to collect on the leaf surface and thus increasing the liability to fungal attacks. Among ferns an excessive development of the margin of the frond leads to the development of so-called crested varieties, which being pleasing to some tastes, have been perpetuated by artificial selection. We have no knowledge of the causes of such excessive development of the leaves, nor are we certain of the origin of similar unnatural developments in stems, such as appear in the case of " fasciation " (from the Latin *fascis*, a bundle). This term is applied to the abnormal development of the stem into a broad flattened structure, often caused by the fusion of several stems, or by the union of lateral shoots with the main stem. Superabundance of food supply may in some cases be responsible for this abnormal growth. Sometimes these forms occur spontaneously without apparent cause, and have been cultivated by horticulturists, as in certain species of *Echinocactus* and in the flowering shoots of the Coxcomb (*Celosia cristata*).

Almost all cultivated plants are known to produce occasionally variegated leaves, and in some cases leaves which are entirely devoid of green colour. In some instances these have been traced to lack of nutrition. We know of course that if seedlings are raised in the dark or potato tubers are allowed to sprout in the absence of light, the leaves will be of a sickly yellow nature, as light is essential for the production of the green colouring matter characteristic of foliage. Similarly, absence of iron salts in the soil will prevent the formation of chlorophyll. It has also been noticed that young shoots arising below a graft in the case of hollies are often white in colour. This must be regarded as due to an interference in the downward conduction of material caused by the artificial union of the tissues at the graft. Some cases are also known of wild plants with variegated foliage, which under cultivation in richer soil have developed normal green leaves. It has also been possible by growing plants in the greenhouse at higher temperatures to change the variegated into green leaves, and to prevent the formation of further variegated leaves in the case of some plants.

Some botanists have considered that a special substance or "virus" is developed in certain parts of a leaf which has prevented the formation of the green colouring matter; but as we do not know anything of the nature of such a substance it is perhaps simpler to consider that the chlorophyll granules in certain portions of the leaf have remained in a more youthful condition, in which they produce the pale yellow colour which always precedes the green colouring matter. Apparently this stoppage in the development occurs more commonly in plants under cultivation than in their natural condition. Variegated leaves are obviously less efficient as nutritive organs, and variegated plants are therefore often less resistant than normal forms. Their foliage is more easily affected by heat or frost and the leaves are less long lived.

There are some cases in which variegation is considered to be a disease produced by bacterial action. The so-called "mosaic disease" of Tobacco plants and of Tomatoes is supposed to be due to this cause, and certain experiments indicate that it is highly infectious.

Most gardeners will have come across examples of abnormal formations in flowers. Often the sepals may become leafy as in Jack-in-the-Green Primroses, sometimes the petals have a leaf-like appearance as in the Green Rose. To the flower-lover these transformations are more curious than beautiful, but to the botanist they are of considerable interest as cases of reversion. For we must assume that the various floral organs are all modifications of leaves which have become adapted to the special function of reproduction, and in such foliaceous developments we may see a retrogression to a more primitive type of leaf. More rarely, but still occasionally, we may find stamens or pistil becoming transformed into vegetative leaves; the latter is often the case in the flowers of the Double Cherry. In both cases sterility of the flower is caused. In other sports the outermost leaves of the flower, the calyx, may become coloured and delicate in texture like the corolla. This is the condition in the hose-in-hose variety of the Polyanthus. More frequently it is the inner leaves of the flower, the stamens, that become petaloid. The "doubling" of flowers is sometimes found to take place in wild plants when transplanted into garden soil. In all probability the tendency to doubling is independent of the cultivation of the plant, but the rich nutrition which the plant receives accentuates the effect. Certainly double varieties to be kept in perfect condition require an abundant supply of food, and are liable to degenerate when grown in poor soil. Degenerate is perhaps not a good term to use, as the plant is in a more perfect condition from the reproductive point of view when the stamens and pistil are normally developed and fertile than when they are transformed into showy petals. In that case the flower is generally completely sterile, though it may sometimes retain a few serviceable stamens or a receptive seed vessel.

From the doubling of flowers such as the Rose, we must distinguish the doubling of the so-called "flowers" of Daisies, Chrysanthemums, and other members of the Composites. In this Family the apparent flower is really a head of small flowerlets or florets closely crowded together. These are often of two kinds, showy ray florets and small central disk-florets usually of a different colour.

When these "flowers" are said to double, it is by transformation of the tubular flowers of the centre into conspicuous strap-shaped flowers, like those of the margin of the inflorescence. In that case they need not necessarily become sterile, for in many Composites like the Dandelion, all the florets are normally of the ray-floret type. Another curious freak met with in some of the Compositæ when they receive abundant nutrition is the development of some of the ray-florets into small heads of flowers on stalks of their own, so that the large central head is surrounded by a number of lesser ones. This is the condition in the Hen-and-Chicken Daisies, and similar modifications are found in other plants.

A not uncommon abnormality in gardens is the development of a terminal flower of large dimensions and regular shaped at the top of the flowering spike of the Foxglove; in the Snap Dragon, too, flowers showing radial symmetry instead of the usual two-lipped condition may be formed. A plant may indeed bear nothing but "peloric" flowers as these are called.

Monstrosities may also occur in the development of fruits. Double-fruited oranges with two whorls of carpels (pegs) one inside the other are occasionally found, while in one variety known as Buddha's fingers, the various carpels are only united below and taper off above into finely divided pod-like segments.

While most of these malformations are due to little understood internal causes, many cases of excessive development of plant structures are produced as the response to irritation. Thus, numerous kinds of galls and tumours may be developed by animal and vegetable parasites. insects and fungi, which injure the tissues and cause them to swell or grow more vigorously. These will be dealt with in later chapters.

Plants like animals have the power of protecting themselves against external injury and of *healing* any *wounds* that are caused thereby. The most usual method is by the formation of layers of cork, which will protect any exposed part from the atmosphere, thereby preventing the excessive loss of moisture through the wounded surface and also reducing the chances of invasion of the tissues by disease or decay producing organisms. This development of a resistant layer of cork is due to the active growth of the living cells of the plant in the exposed region. This active growth requiring energy, which plants gain by their respiratory process, we find that the healing of wounds is marked in plants as in animals by a local rise in temperature. The wound tissue which is developed at first is soft and termed callus; it is that excrescence of cells which is produced as we have seen around the base of a shoot in making cuttings. Within this callus layer impervious cork is then formed and this is usually sufficient for the healing of herbaceous plants or soft tissues. In trees and shrubs, however, if the stem or branches are deeply cut, the wound will subsequently be covered up by woody layers as well. The formation of these liquified tissues commences at the margin of the wound and they gradually cover over the entire wounded area. It is thus that branches broken at their base become covered up in nature, and are found as knots buried in the wood. In cultivation, of course, much larger branches are often amputated than usually break off in nature, and though their stumps will ultimately be covered up, it takes a considerable time in the case of a thick branch, and before the wound is closed up there is plenty of time for the wood exposed by the cut to commence to decay. To prevent this from taking place, it is advisable to coat the surface of the stump immediately after the removal of the branch, with tar or some antiseptic substance, which will prevent the entrance of bacteria or of other harmful fungi.

Injury by lightning, if it is deep and considerable, may be beyond the power of the plant to repair; but where only the outer layers have been damaged, in which case a single longitudinal fissure is generally found running vertically down the side of the stem, callus and cork usually heal up the gap completely.

Frost is in all probability one of the most frequent of external factors causing injury to plants. Though we cannot as a rule prevent the havoc wrought by frost, it is not without interest to note what is the effect of freezing upon plant structures. It is particularly the young growing parts of plants which are nipped by frost, while the mature leaves are often undamaged. On the other hand, somewhat fleshy plants like the Nasturtium, do not resist frost very well. The cell sap containing a good many organic acids and often sugar in solution, does not freeze readily. The denser the sap is, the less danger there is of its being frozen. As a protection against the effect of frost, we find that with a lowering of temperature some of the water from the cell-sap passes into the spaces which exist between the cells in mature tissues. Thus the sap becomes more concentrated and less liable to injury, while the water which may become frozen in the intercellular spaces does no damage if the latter are of fair size. If they are small, then the expansion of the water in freezing may tear the tissues asunder and thus injure them. In the growing parts of the plant there are tiny intercellular spaces, so that little water can be passed out of the cells, and consequently the sap itself may be frozen, in which case the protoplasm, the living substance of the cells, is killed and the tissues become blackened. A very sudden frost is always more harmful than a long spell of frost preceded by a gradual lowering of the atmospheric temperature, as plants are able to prepare themselves by a condensation of their cell sap. It is the same with recovery from frost. Plants in a frozen condition may recover readily if they are slowly thawed. When exposed to bright sunshine on a frosty morning they may be permanently injured as often happens with Wallflowers. It is therefore well to shade frozen plants from the direct rays of the sun, so that they are thawed less rapidly. We must remember that in bright sunshine the pores of the leaves open and the plants are rapidly transpiring, and if this takes place while the ground is still frozen and the roots are unable to absorb water, the consequences may be serious.

Those of us who have laboured in town gardens are only too familiar with disappointment due to general sickliness of some of our plants and to the *harmful effect of a smoky atmosphere.* Worse in winter than in summer it is nevertheless pronounced even in the latter, and records taken show that there are quite a number of gloomy days in July and August, and that air pollution is quite appreciable during these months. From actual measurements made during the month of July, it has been calculated that if we draw a circle of a mile radius around the Town Hall of Manchester, 195 tons of impurities would be collected during the month from this area, and of this 100 tons would consist of soot or other insoluble matter;*

* See First Annual Report of the Sanitary Committee of the City of Manchester on "The Work of the Air Pollution Advisory Board." March, 1915.

and Manchester is by no means the worst town in this respect. It is gratifying to know that efforts are being made in many of our industrial centres to understand, and let us hope, also to cope with this problem of air pollution, and all such movements deserve the hearty support and co-operation of gardeners and flower-lovers.

From what has been said in earlier chapters, it will be clear that bright sunshine is the most important factor in the nutrition of plants, as it is only in the presence of light that the green chlorophyll of the leaves is able to form starch, the food so essential for the further growth of the plant. A murky atmosphere therefore lowers considerably this prime nutritive activity of the leaves. If in addition to that the leaf, as is always the case with town evergreens, has become coated with a more or less opaque layer of sooty matter, the normal power of leaf nutrition is still further reduced. What wonder then that our town and suburban gardens suffer many serious losses. It is only hardy plants which can survive these adverse conditions. Conifers are usually regarded as fairly resistant plants, and so they are to drought or cold, but smoke is most harmful to them as their breathing pores or stomata are situated at the base of a depression on the surface of the leaf, and this pit becomes partiallv filled with soot and the pore is thus blocked. In ordinary leaves these pores are usually on the protected under surface and are therefore not endangered by the smoke, but in the case of the needle-shaped leaves of the conifers they are freely exposed to smoke and fog. As a consequence we find that conifers do not thrive in the neighbourhood of our industrial towns. A blackening of leaves is, however, not the only noticeable effect of air pollution on vegetation. We observe, particularly on evergreens, that many of the leaves have brown spots or dead margins, and in both cases this is traceable to the acidity of the atmosphere, which kills the tissues, particularly those near the stomata or breathing pores. It is particularly *in winter fogs* that *the air becomes very acid*, owing to the sulphur contained in the coal, and our own sense organs enable us easily to detect the presence of the sulphuric acid. Even in summer the acidity of the atmosphere causes the discolouration and the early fall of the leaves of trees in our parks and town gardens.

It is obvious that the rain washes this acid into the soil, so that not only the leaves but the roots also suffer from its effect. Rain water collected in or near our towns is always slightly acid, and a great difference can be observed in the growth of seedlings, some of which are watered with ordinary rain water and others with rain water in which the acid has been neutralised. A considerable number of striking experiments on this point have been made by Mr. Ruston, of the Leeds University. The lesson they teach us is that the soil of gardens or allotments near our large towns should be well treated with lime, so as to neutralise as far as possible the acidity which is caused by the rain washing the smoky atmosphere. A consideration of the fact that this smokiness and acidity of the air is greater in winter than summer suggests that a dressing with lime in the spring before growth recommences would be especially beneficial. Experience has also taught us that many biennials are better wintered under glass than when left in the open, even when they readily withstand the frost. A glance at the condition of the lights of a cold frame will show us what a coating of soot we have prevented from collecting on the leaves. A really penetrating fog, however, will get into frames and greenhouses, and may often do considerable damage to the delicate blooms of Orchids and to many other flowers, besides causing in some plants the leaves to become discoloured or to fall.*

* See F. W. Oliver on "The Effects of Urban Fog on Cultivated Plants." Journal of the Royal Horticultural Society, vol. xiii, 1891.

Chapter 8.

FUNGI AS A CAUSE OF DISEASE IN PLANTS.

Common fungi, mushrooms, toadstools and moulds. How they live. Saprophytes and Parasites. The "Damping off" disease of Seedlings caused by the fungus Pythium. Life Story, means of spreading and living in the soil, precautionary measures.

In preceding chapters you have become acquainted with the normal uses of the parts of healthy green plants. We are now to consider plants in disease and especially the disturbances of the structure and functions of plants produced by parasitic fungi. It is obviously impossible within the limits of a few chapters to deal with the whole subject of diseases of plants caused by fungi, but by a consideration of some of the diseases most common in fields, gardens and greenhouses, the main features of the subject may be illustrated. By this treatment you will not only become more familiar with the causes of these particular diseases, but also with the sort of precautions and remedial measures it is worth while to adopt in relation to the various types of plant disease.

Practically all parts of plants are subject to disease. In some cases we have immediate and complete destruction of the plant or part attacked, but in others the death may be delayed or the plant may support the parasite indefinitely. We have diseases of seedlings, diseases of roots, of stems and of leaves, and a very large class of plant diseases comprises those which attack fruits. In this lecture we shall consider the most common disease of seedlings which is known as the "Damping off" disease.

Before dealing in detail with this, however, let me recall some of the more essential features in the structure, nutrition and life history of the more common fungi, facts with which you are no doubt, to some extent, already familiar. In any of the fields and lanes around our large towns, especially in autumn, it is possible to find examples of the larger fungi such as mushrooms and toadstools. Whilst the colour and form of the part which we see above ground are often striking, in reality this is only the reproductive part of the toadstool or mushroom plant, just as much as the flower and fruit are the reproductive parts of the higher plant. It is true that the mushroom as we generally see it, appears above ground, sheds its spores and decays all within a few weeks; but the vegetative part of the plant lives in the ground for a very considerable time before it enters on the reproductive phase.

The bricks of so-called mushroom spawn contain quantities of fine interlacing threads of fungus in manure which are really the vegetative part of the mushroom. Under the microscope these filaments are seen to consist of long branched tubes. These tubes are divided up into chambers or cells by cross partitions, and each cell is lined with the jelly-like semi-transparent living substance, protoplasm. Within this are drops of water and oil as well as certain denser granules, but filaments of fungi never contain the green colouring matter found in higher plants. The protoplasm is the living part of the cell, and food material is taken in from the soil or manure through the protecting cell membrane. Such food material often appears stored in the tubes as drops of oil.

Although the filaments of the vegetating mushroom plant are not bound together into a complex plant body like the cells of flowering plants, yet the loosely interwoven threads behave as a whole, and after weeks or months of vegetative growth give rise to the definite fruit bodies consisting of numberless aggregated filaments. These reproductive bodies usually possess a stalk bearing an expanded cap from the under side of which project the radiating gills. Upon the surface of the gills are borne large numbers of minute round or oval spores. Each spore is really a single tiny cell so small that it can only be seen if very highly magnified. If, however, the stalk is removed from a not over-ripe mushroom, and the latter placed on a sheet of white paper, in the course of a few hours so many spores are shed from the gills that a print of the gills is produced on the paper. This print consists of myriads of spores which have fallen like dust from the gills. The spores are the reproductive cells of the fungus and, falling to the ground, they grow out to produce tiny filaments. They soon begin to absorb water and food substances from decaying vegetable matter in the soil and manure, and so the vegetable life of the plant is carried on.

Many fungi are much more minute than the mushroom, indeed are so small that they can only be properly studied under the microscope. As an example of such a fungus we have *Mucor*, the common white mould which often appears on damp bread or dung. If a piece of bread is kept moist for a few days under a bell-jar in a warm place the mould soon appears as a dense growth of fungus covering the surface of the bread. Erect silky threads stand up from the surface like a miniature forest. Microscopic examination shows that the fungus consists of two sorts of filaments: fine ones which branch and ramify in all directions forming a felt on and in the substratum, and the coarser erect ones which stand free. The finer network on the substratum is the vegetative part of this fungus, while the erect coarser aerial threads are the reproductive organs. The individual branching filaments are very similar to those described for the mushroom, except that in this case there are no cross walls dividing up the tubes. When the aerial filaments have grown for a few days there appears at the extreme tip of each a minute round swelling like an inflated ball about the size of a pin head. The protoplasmic contents of this globular body or spore-case soon become divided up to form a large number of spores, and then it has the appearance of a miniature ball full of shot. As the wall of the spore-case becomes dry it breaks, scattering its spores into the air as a fine dust in all directions; the spores of *Mucor* and, indeed, of many fungi, are very light and easily carried by the slightest current of air. When placed in water the spores germinate in a few hours, the protoplasm within absorbs water, the spore wall bulges in one place and grows out forming a fine filament which, given suitable food material, rapidly grows and branches to form a dense felt such as we saw on the moist bread.

We have seen that suitable food material for this fungus is provided by bread, dung, etc.; that is to say by dead or decaying plant or animal matter, just as the mushroom or toadstool lives on similar dead organic remains in the ground. Fungi, which in this way draw all their nutriment from the rotting remains of plants or animals, are known as *saprophytes*, and although they are unable to injure living plants they readily feed on their remains after death.

Fungi, unlike green plants, possess no chlorophyll and are therefore unable to construct their own carbon compounds such as starch and sugar from the carbonic acid of the air. They, however, take in such complex organic substances ready-made from the remains of plants which have previously manufactured them, and saprophytic fungi play an important part in Nature in living upon and decomposing the dead organic remains of plants and animals. The saprophytes as a rule cannot attack living plants, and therefore do not give rise to plant diseases.

A large number of fungi, however, are unable to live even upon decaying plant remains, and derive nutriment from the cells of living plants. Such fungi are *parasites*, and not only do they require to take in the carbon compounds of their food material ready-made, but they can only take their food substances from living cells. Now it is clear that in obtaining substances forcibly from plants while still alive, such parasitic fungi rob the plants attacked of materials which otherwise would have been used for their own life and growth, and may harm them more directly in doing so. A plant which harbours a parasitic fungus is spoken of as the host plant, and in most cases the host suffers injury not only because it is robbed of substance by the fungus, but also because the work of the particular parts of the plant infected are seriously interfered with. We shall see for example how the stores of food material in roots like turnips, or tubers like potatoes, are raided by fungi, and on the other hand how mildews and rusts prevent leaves from manufacturing food supplies.

Most of the larger and more prominent fungi are saprophytes and live, as we have seen, on decaying organic matter. Some of them, however, are parasites. The bracket fungi and the honey agaric, for instance, live as parasites on trees. The vegetative filaments of these fungi ramify in the tissues of the tree, gaining entrance often through wounds, and only the reproductive bodies are produced outside. But very many diseases of plants are caused by fungi which, like the saprophytic mould *Mucor*, are so small that they can only be studied with the aid of the microscope. Such a minute parasitic fungus called *Pythium de Baryanum* often causes the "Damping-off" of seedlings.

The "Damping-off" disease very frequently appears when the seeds of many plants are sown too thickly and grown under conditions which are too warm and moist. Young seedlings begin to die off in patches and soon present a very characteristic rotten appearance. The disease is very commonly met with in gardens and greenhouses, occurring in seed-beds of all kinds a few days after the germination of the seeds. It is most abundant in very wet weather and when the beds are kept too shaded and badly ventilated; crowding of seedlings also favours the progress of the disease. At first a few individual seedlings are attacked at or near the surface of the ground, the tissues in this region having a water-soaked appearance. Soon the cells collapse, and being unable to support the weight of the cotyledons the seedlings fall prostrate. Those immediately around are similarly affected, the disease spreading through the seed-bed in ever widening circles until practically the whole may be destroyed. When the plants fall over they become pale and rotten, and soon the whole bed is reduced to a moist mass of decaying seedlings. This mass is seen, on closer examination, to be covered with the very delicate threads of a fungus somewhat like the mould on bread. Often the filaments can be seen to have spread from the first diseased seedlings to the outer parts of the circle. These filaments most often belong to the fungus *Pythium*, which is so called because of its ability to produce rotting. The fungus continues to grow in the dying seedlings, and the filaments may form a dense felt over the whole seed-bed.

If a seedling is examined under the microscope shortly after it is attacked, the collapse of the tissues just above the ground is seen to be due to the destruction of the cells at that spot. This destruction is caused by the filaments of the fungus which at this stage are seldom visible to the naked eye. They are, however, almost exactly like those found on the mouldy bread, and they run both between and within the dead and dying cells. They can also be traced into and between adjoining living cells, and when the seedling falls prostrate the remainder of the plant is soon invaded, for it is kept moist by contact with the damp soil. As the tissues further decay the filaments of the fungus spread out over the soil reaching across to other seedlings which then succumb in the same sort of way. The fungus attacks the cells of the seedlings by first extracting water, then boring through the cell walls and finally killing the living protoplasm and feeding upon the cell contents. Since the fungus grows very rapidly a seedling may be reduced to a putrid mass in a few hours.

The life story of *Pythium* is typical of the most thorough and destructive of plant parasites. The filaments at first grow in the air spaces between the cells, but later they enter and kill the living protoplasm. The spread of the fungus at first is due to the growth over the soil from its earlier victims to healthy seedlings which are attacked in turn; but soon a more rapid means of spreading comes into play. When a seedling has become thoroughly infected by the filaments of the fungus the ends of many of the branches of the latter begin to swell out into globular bodies very like the spore-cases of *Mucor*, only much smaller. These swollen bodies are full of protoplasm and serve a somewhat similar purpose to those in *Mucor*. They are really special spore-cases, but in further development they differ considerably from those of *Mucor*. In that fungus the spore-cases were borne on filaments standing erect from the surface, the spores being shed into the air. In *Pythium*, however, the spore-cases are submerged in the film of moisture around the decaying seedling, and the different behaviour probably depends on this. When the spore case is mature a short tube grows from the side and swells to form a globular body with a very thin wall. Into this the whole of the protoplasm passes from the spore-case; it then rapidly divides into 9 or 10 small rather oval masses of protoplasm, which begin to writhe and wriggle within the thin vesicle. This soon bursts, liberating the minute writhing spores which swim about in the slight film of water on the soil or surface of the seedling. When examined under high magnification each of the colourless swimming spores is seen to be furnished with two excessively fine hair-like threads of protoplasm which, by lashing the water incessantly, bring about the movement of the spore. The active movements continue for twenty minutes or half an hour, then the spore comes to rest, rounds off and withdraws the whips of protoplasm. If favourably situated on a seedling it sends out a fine filament which bores its way through the outer wall of one of the cells and grows into the interior. It has been proved that the tip of the filament is able to do this, because it secretes a substance which enables it to digest its way through cell walls pretty much as gastric juice renders our food materials soluble. Once within the cells of the victim the fungus branches and grows rapidly from cell to cell, spreading destruction as it goes and deriving nourishment from the product of this destruction. In a diseased seed-bed these processes are going on so continuously that the fungus soon produces many thousands of the motile spores which are able to attack new seedlings, thus accelerating the progress of the disease. In addition, as we have already seen, even the threads of the fungus grow across the soil between the seedlings and directly produce new infection.

It is well known that "Damping off" will recur with even greater virulence in seed-beds which showed the disease the previous season. This is explained by the existence of yet another chapter in the life history of *Pythium*, by which resting spores are formed that can pass the winter in the soil. At a late stage in the decay of diseased seedlings many threads of the fungus give rise to the resting spores. These possess the power of lying dormant over a long period, and in this resemble the seeds of higher plants, though they only consist of a single thick-walled cell. When, however, the temperature is favourable and the conditions are sufficiently moist, the thick coat bursts and a fungal filament grows out which soon attacks any seedling that may be near, producing spore-cases and motile spores as before. The resting spores are produced in myriads in a diseased seed-bed; in fact, on one occasion, I estimated the presence of upwards of half a million in a single diseased seedling observed under the microscope. As the seedlings rot these spores all find their way into the soil where they spend the winter.

In considering methods for preventing this disease it is necessary to make use of the facts which are known of the means of spreading of the fungus causing the disease. We have seen that once a seed-bed is infected the fungus rapidly spreads, first by an abundant growth of filaments over the soil from seedling to seedling, and secondly by means of spores which swim in the water in the soil. Any treatment to be successful must check the vegetative growth of fungus in the soil and also the production of spores. It has been shown that the fungus only grows in this way in warm, very moist, badly ventilated seed-beds. Moreover, the effect of excessive moisture and lack of sufficient air is two-fold. Not only do such conditions favour the growth of *Pythium*, but these very conditions tend to produce weak drawn seedlings which of course are more susceptible to attack. Very careful attention to cultural conditions will therefore make it possible to ward off and, in most cases, entirely prevent the disease. The seedlings should never be overcrowded, and they should be given as much air and as little water as possible. If through inattention to these conditions a few of the seedlings in a bed should show signs of disease they should be immediately removed and burned, and more air and less water given to those that remain. In any treatment it is also necessary to prevent the infection of the seed-bed at the beginning of the season. This infection invariably arises from the presence of resting spores in the soil. Naturally, then, soil known to have previously produced the disease should not be used, but since the resting spores are present in most garden soils it is wisest to endeavour to get rid of them. They can be killed by partially sterilising the soil by heating with steam or with boiling water. It has been shown in an earlier lecture that the partial sterilisation of soil is valuable for other reasons. By adopting the practice it is possible to eliminate the resting cells note only of *Pythium* but also of other harmful organisms.

Chapter 9.

DISEASES OF ROOTS AND TUBERS.

Fingers-and-Toes of Turnips, Cabbages, etc. Habits and life history of the fungus. Remedial treatment. "Liming" of the soil, etc. Similar diseases, e.g., Black Scab or Wart Disease of Potatoes, "Spongy Scab," etc.

The disease commonly known as Fingers-and-Toes, or Club-Root disease, attacks all cruciferous crops, including Cabbages, Cauliflowers, Brussels Sprouts, Kohl Rabi, Broccoli, Turnips and Swedes. It is produced by a fungus known as *Plasmodiophora Brassicae*, and causes considerable damage both in the gardens and fields in many districts of England; its ravages are even greater on the Continent, and it is also abundant in America.

The general appearance of the disease is well known. Plants, which are attacked, show irregular warty swellings on the root, and in bad cases the whole root may simply consist of a mass of these excrescences. The disease can often be recognised in its earliest stages on pulling up young cabbages for transplanting. If such seedlings are planted they prove practically useless, for the disease simply increases at the expense of the roots, any leaves developed being feeble and unable to provide for healthy growth.

Seedling cabbages, which show by the nodular swellings that they are attacked by Club-Root, are often exposed for sale. Of course it is inadvisable to plant such seedlings, for not only is it extremely unlikely that they will produce healthy plants, but when they decay in the ground they will infect the soil. If any plants of the cabbage family are grow in the same soil within two or three years of this infection, they will almost certainly suffer from the disease to an even greater extent.

The disease with which we are dealing should not be confused with the gall-like swellings on the roots of cabbages and turnips, sometimes caused by the larva of a beetle that lives within the cavity of the swollen tissue. Eelworms, as well as certain bacteria, are also able to produce small swellings on the roots of many plants, including Crucifers. It is a little unfortunate that frequently any swellings on roots of cruciferous plants are spoken of as Club-Root without reference to the causal organism. Since, however, in the vast majority of such cases the slime fungus, *Plasmodiophora Brassicae*, is the cause, I am restricting the name Club-Root or Fingers-and-Toes to the disease of which it is the cause. Whilst the life history of *Pythium* and of the other fungi mentioned in the last chapter is typical the Club-Root fungus differs somewhat in life story and mode of nutrition.

When one of the diseased roots, say of turnip, is cut across and examined under a microscope it is found that the tissues of the root are altogether abnormal, many of the cells being strangely altered. In the healthy root of the turnip we can distinguish an outer band of softer tissues surrounding a central core containing a certain number of woody elements arranged like the spokes of a wheel. Between the last-named are broad wedges of softer cells which are packed with the reserve food material that is stored in the root of the turnip in the form of sugar. The root increases in thickness by the growth and division of a layer of cells near the outer part of the central core. When attacked by the fungus of which we are speaking, the whole machinery for the growth of the root is, as it were, thrown out of gear; cells which normally would produce woody tissue simply give rise to giant thin-walled cells, and the result is an excessive production of thin-walled tissues. This also occurs in the position of the tissues which normally serve for the conveyance and storage of the food materials manufactured in the leaves. The reserve supplies are thus tapped by the fungus, with the result that the quantity of sugar stored by the growing root rapidly diminishes. In such instances many of the cells of the root are enormously enlarged and differs as regards their contents from those of a healthy root.

The healthy cells are lined by the colourless, jelly-like, living protoplasm with its nucleus and contain cell-sap rich in sugar. Diseased cells differ from these in several respects. They are generally much larger; protoplasm is present as before, but it looks frothy and in it can be seen granular masses of other slimy substance which is the protoplasm of the fungus slowly absorbing that of its victim. It is a remarkable fact that the early effect of the parasite upon the cell is to stimulate it to enlarge and even to divide, and thus obtain more food material from the adjoining cells, and this is ultimately used by the unbidden guest. Gradually the protoplasm of the fungus increases in size until the whole of the protoplasm of the cell disappears. Then the fungus undergoes certain changes and soon the cell is seen to be filled with a large number of tiny round bodies. These are the spores of the fungus, and as they only measure one fifteen thousandth of an inch in diameter they can only be seen when very highly magnified. A single diseased cell will contain at least 100,000 of these spores, and since the diseased part of a turnip, for example, contains many thousands of such cells it is easy to see that in one such root millions of the spores of the fungus are produced.

If a very small piece of a diseased root is broken up in water myriads of the spores are liberated from the cells. After a few hours very remarkable changes can be observed to take place in these. Each tiny spore swells somewhat and then bursts producing a small hole in one side of the colourless membrane. Gradually the living protoplasm within squeezes its way through the aperture thus formed. As soon as it is free it begins to wriggle and move about as a minute speck of living protoplasm. The protoplasm at one end is drawn out into a fine hair, and the lashing of the water by this hair causes the movement of the minute organism. After a time the movements of these specks of protoplasm become more sluggish and soon they only creep about by slow movements, first pushing one part of the protoplasm forward and dragging the rest after it. While it is unknown how long they can move about and live in the soil, they can certainly do so for many days.

In the field and garden the spores of this fungus are liberated into the soil by the decay of the diseased tissues of the infected roots. If diseased roots are left in the ground for any length of time the decay takes place rapidly and is generally accompanied by an offensive odour. The spores pass into the soil and there remain until conditions are favourable for their germination. If liberated during the summer or early autumn they probably germinate at once, but if later it is likely that they remain in the spore condition over the winter and germinate in the warmer spring days. The smallest quantity of water is sufficient to allow the minute specks of protoplasm which are liberated, to swim about. If young cabbages, turnips, etc., are grown in the infected ground the organism soon gains entrance to the younger roots and sets up the disturbances described above. Whenever seeds of these cruciferous plants are sown in soil known to contain the spores of this fungus the swellings typical of the disease appear on the young roots in a few weeks.

We have seen that this organism differs from a fungus like *Pythium* in several important respects. At no stage in its life history does it possess filaments as do the vast majority of fungi. It passes through the vegetative stage of its life as a naked speck of protoplasm living and growing inside the protoplasm of the cells of a root. Unlike *Pythium* it does not kill the cells of its host plant outright, but rather stimulates them to enlarge. divide and draw food supplies to them which it then utilises. Like *Pythium*, however, it rests in the form of spores in the decaying roots and in the soil; it also passes part of its life as a naked free-swimming speck of protoplasm, but in order to complete its life cycle it must enter the living cells of the root of a cruciferous plant.

In considering methods of preventing the attack of this organism it is necessary, as in all such cases of plant disease, to bear in mind the habits and life history of the parasite. As has already been shown, a single diseased turnip or cabbage, if left to rot will liberate many millions of spores into the soil. Some of these doubtless die, but many remain as a source of infection for future crops. Most important therefore, of all the means of combatting this disease are the measures taken to prevent the spores of the fungus reaching and infecting the soil. It would seem to be obvious to anyone who has observed the damage this disease can cause, that the greatest care ought to be taken to collect and destroy by burning all diseased roots. Again and again this disease occurs both in fields and gardens, and in almost every case diseased roots can be seen left lying about, to rot and infect the land. Quite recently the writer watched a farmer carting the least diseased portion of a crop of swedes, scarcely a root of which had escaped attack. The most badly diseased plants, already putrid and rotten, were being left in heaps to rot on the field, and then doubtless would be ploughed into the soil. In such cases not only does the soil of the field or part of the garden where diseased plants were grown become infected, but the fungus is carried on the boots of workers, on tools, or if, as so frequently happens, diseased roots are thrown on to the rubbish heap to rot, the disease ultimately gets spread over the whole field or garden. Diseased turnips are fed to animals, and though there is no direct evidence, it is quite possible that the spores pass uninjured through the bodies of the animals and return to the soil in farmyard manure. The greatest care ought to be exercised to destroy all diseased material. Burning is the safest plan or, failing that, it should be gathered into a heap and thoroughly mixed with quicklime.

The Club-Root disease has been noticed to be particularly abundant on soils which are badly drained, at all sour, or deficient in lime; the disease is practically unknown in chalky or limestone soils. As direct methods of treatment therefore, the drainage of the soil should be improved, and a most drastic system of "liming" adopted. Wherever the disease has been prevalent it is best to treat the ground immediately with freshly slacked quicklime at the rate of ½ to 1 cwt. per square rod, spreading it evenly over the ground and digging it in. Freshly prepared quicklime is much better for this purpose than ground lime, which varies considerably in the amount of active quicklime which it contains. Gas lime, though valuable as an insecticide, is a poor substitute for quicklime, since it contains a much smaller proportion of active lime than either of the other forms.

The use of certain acid artificial manures and, indeed, also of ordinary stable manure in excess, tends to make the soil acid, and this favours the growth of the Fingers-and-Toes fungus. In infected soil, therefore, Basic Slag, or other alkaline artificials, might be advantageously used in addition to treatment with lime.

Needless to say, even after such treatment as outlined above, ground known to be infected should not be planted with cruciferous crops for at least three years. Other vegetables, including potatoes, can of course be grown without any danger, since they are not attacked by the fungus. The soil of beds in which seedling cabbages are raised should be partially sterilised as for the " Damping-off " Disease, and also should contain a fair sprinkling of lime.

By strict care in disposing of rubbish, by improving the drainage of the soil, and by regularly dressing the ground with quicklime, it should be possible to do something towards eradicating this pest. A recent visit to some allotments within the Manchester area afforded evidence of this possibility. Some of the plots had not grown a healthy cabbage for two or three years, while adjoining plots never show a sign of the disease. The infected plots were badly drained, the soil was sour, liming had been tried, but in too small quantities. On the other hand the adjoining plots had been thoroughly and regularly limed, were well drained, not soured by over manuring, and they had therefore always borne healthy crops. It is needless to add that on the infected plots diseased cabbages had been pulled up and the roots simply thrown aside to rot and prove a further source of infection. It might be well if allotment societies had some stringent rules for dealing with the spread of such diseases *via* the rubbish heap.

Brief reference must now be made to some diseases of the potato tuber that present certain features in common with the Fingers-and-Toes disease. The Wart Disease, or Black Scab of Potatoes, is caused by *Synchytrium endobioticum.* It is notoriously prevalent in the districts round large towns, and the restrictions of the Board of Agriculture have rendered its symptoms well known. In the early stages small warty swellings appear in the "eyes" or buds of the potato, or they may even occur on the stem near the ground level. These warts rapidly increase in size, and several often run together till the potato becomes a mass of excrescences. Plants which are attacked often grow larger and bear green leaves for a longer time than healthy plants.

The fungus causing the disease, like the *Plasmodiophora*, lives in the cells of the potato buds as minute specks of naked protoplasm. In this case the presence of the fungus causes the invaded cells to enlarge, but renders them incapable of further division. On the other hand the healthy cells around are stimulated to such active growth and division that the warts are soon produced. Infection always occurs by motile spores from the soil, which can only penetrate the healthy cells of a potato in the young condition. Later the potato forms a skin of corky cells through which the fungus cannot penetrate. After growing at the expense of the invaded cells the fungus ultimately occupies the whole of the cell cavity, and then taking on a thick, very resistant wall, forms a resting spore. With the decay of the warty tubers these resting spores find their way into the soil and may remain there as a source of infection for many years. When they germinate after an exceptionally long period of rest the thick wall bursts and liberates large numbers of actively moving spores, each possessed of a single whip of protoplasm to propel it. These are the spores which infect new potato tubers. So far no method of successfully treating this disease by adding chemicals to the soil has been devised, but certain varieties of potato are much less susceptible to the disease than others, and it is advisable to grow these if the disease is present. Indeed, it is now compulsory for every person growing potatoes to do this and to follow certain other stringent regulations in areas where the Wart Disease is prevalent.*

In addition to the Wart Disease there are several other scab diseases of potato tubers which, owing to a certain degree of similarity, may at times be confused with the Wart Disease. The Black Speck, or Violet Rhizoctonia Disease, caused by *Rhizoctonia Violacea*, can be detected by the minute size of the blackish warts which can be

* See Board of Agriculture leaflet 105 and Wart Disease Order, 1914, to be obtained free from 4, Whitehall Place, London, S.W.

rubbed off the surface of the tuber without causing any evident injury. The spongy or powdery scab, caused by *Spongospora solani*, a fungus akin to the Wart Disease organism, is easily recognised by the light brown colour of the rather powdery warts, or cankers, it produces. Brown Scab, or Ordinary Scab, of the tuber also shows as light brown warts, but usually evenly distributed over the surface of the potato. It may be due to a variety of causes, in which mechanical irritation by gritty particles of soil and infection by definite parasitic fungi probably play an important part. None of these diseases, however, are so destructive as the Wart Disease; further particulars of them may be obtained from the leaflets issued by the Board of Agriculture.† It is quite certain that these scab-like injuries are caused by different fungi, but it is not surprising that the resulting diseases present certain superficial similarities. In each case the presence of a parasitic fungus irritates the cells of a potato, causing them to actively divide and thus give rise to the warts. Even in the Fingers-and-Toes disease the result is similar, and in all the cases with which we have dealt the attack arises from the presence of the organism in the soil. By, therefore, adopting precautions to prevent the infection of the soil, and by appropriate treatment similar to that advised for the Club-Root disease, such diseases can, in some measure, be controlled.

† See Leaflets 171, 137 and 232.

Chapter 10.

A DISEASE OF LEAVES, SHOOTS, AND TUBERS.

The Late-Blight disease of potatoes. Symptoms and means of spreading. Diseased tubers and the wintering of the fungus. Treatment of the disease, spraying and the use of resistant varieties.

The Late-Blight of potatoes caused by *Phytophthora infestans* is so common and wide-spread that it is generally spoken of as the Potato Disease. Historically, it is certainly the oldest of the potato diseases, and it is probably responsible for more loss to potato growers than all the other diseases of the potato put together. The malady first made its appearance in Europe about 1840, and the Irish Potato Famine of 1845 was the result of a very severe attack of *Phytophthora.* Whilst its ravages are seldom so severe nowadays as they were in that year, the disease is never altogether absent. In most seasons it makes a first appearance about the middle of July, and from that date to the end of the potato season it is often difficult to find a field of potatoes wholly free from attack. Farmers and growers generally, however, do not seem to be seriously concerned so long as the tubers are not badly diseased. It is an important fact, however, that wherever the disease is present at all, there is a risk of a proportion of the tubers becoming diseased; further, the attack of the fungus on the leaves invariably results in a diminished crop. The first outbreak of the disease in the season is usually dependent upon the weather conditions. In this country a few days of close, moist weather about the middle of July are often followed by an outbreak of the disease, and, if such weather persists, an epidemic frequently results.

The disease is easily detected by the characteristic spots on the leaves. These often appear near the margin or tip of the leaf and they usually present a dull, water-soaked appearance. As the disease progresses the infected spots increase in size, become darker in colour, and may rapidly involve the whole leaf-blade, extending from the latter to the petiole and even to the stem. Ultimately the leaves hang limp and the whole plant becomes moist and blackened. Such diseased plants emit a peculiar, offensive odour which is very characteristic of the disease. If the attack is a severe one, it is generally found on lifting the tubers that they also are diseased. If in the earliest stages of the disease, the dark spots on the leaves are closely examined on the under surface, a delicate, white, mildew-like growth will be evident round the margin of the discoloured spot. This growth follows the advancing margin as the diseased area increases in size. Microscopic examination shows the mildew appearance to be produced by filaments of the fungus *Phytophthora*, which project from the lower surface of the leaf. The growth as a rule has a somewhat powdery appearance produced by large numbers of spore-like bodies, which readily fall free from the filaments bearing them. Thin sections through a diseased spot show that at this stage the threads of fungus run between and within the cells of the leaf. Many of these cells are shrivelled and dead, and the contents having turned brown, they contrast strangely with the taut living cells lined with colourless protoplasm and green granules of chlorophyll.

In many places branches from the filaments of the fungus pass out through the air pores or stomata, which are especially abundant on the lower surface of the leaf. These aerial filaments become branched and bear small lemon-shaped bodies, called conidia, on the tips of the branches. The production of such conidia enables the fungus to spread with amazing rapidity; when mature they are easily detached, and being extremely small the slightest current of air carries them in large numbers to the leaves of adjoining plants. The conidia are only produced when the air is moist and sultry. Alighting upon the healthy leaf of the potato, under such atmospheric conditions they germinate in one of two ways. Either, each conidium behaves as a spore-case and liberates motile spores, or it germinates by sending out a fine filament. By the former method it opens at the tip and liberates about eight small motile spores which swim about vigorously in the thin film of water on the surface of the leaf. As in the case of *Pythium*, the fungus causing "Damping-off" of seedlings, these motile spores are each furnished with two hairs of protoplasm, by means of which they are enabled to move in the water. After a short period the motile spores come to rest, withdraw the minute hairs and give rise to a short filament which either grows through one of the stomata into the leaf, or dissolves a way through the outer skin of the leaf, and so starts a disease spot. In other cases the conidium simply sends out a fine tube and produces an infection by the same methods as do the motile spores. After infection the fungus, feeding on the cells of the host, grows rapidly, in the form of branched threads, within the tissues of the leaf. The conidia are extremely small, being less than one-thousandth of an inch in length. Enormous numbers are produced from a single diseased area of a leaf, and, further, under suitable conditions the fungus grows and reproduces itself very rapidly. It is therefore easy to see why, in weather conditions favourable to its growth, the fungus spreads in a few days over whole fields of potatoes.

In the earlier chapters it has been shown that a leaf, such as that of the potato, is really a complicated machine for the manufacture of food material. Many of the cells contain chlorophyll, the green colouring matter which, in the presence of sunlight, utilises carbon-di-oxide obtained from the air to produce organic chemical compounds like sugar and starch. The complex organic substances elaborated in the leaves are passed on to the stem and ultimately stored in the potato tubers in the form of starch. Thus it is obvious that by injuring the leaves, the potato disease reduces the weight of tubers obtained from a given plant, and the earlier the attack occurs in the season, the more serious is this effect on the crop. In most years potato plants which are attacked by Late-Blight, die down much earlier than they would normally.

When a field has been badly attacked by Late-Blight the tubers almost invariably become infected. This either takes place by spores being washed down into the soil and directly infecting tubers near the surface, or by the growth of the fungus down the tissues of the dying stalks into the tubers. Potato tubers infected by this disease can readily be recognised by the purplish discoloration and rather sunken appearance of the skin in diseased parts. These features are caused by the brown colour of the cells immediately under the skin. Living filaments of the fungus infest the discoloured cells, and if such tubers are stored the fungus slowly invades healthy cells, often producing the so-called dry rot of the tuber. In addition to this, the presence of the fungus in the potatoes renders them extremely susceptible to the attacks of secondary rotting fungi and also of bacteria. In some such cases the potato shows the characters of the winter rot disease caused by *Fusarium solani*. The tuber gradually shrivels and at a late stage small white tufts of that fungus appear over the sunken parts. In other cases the potato becomes changed into a moist, putrid mass infested by bacteria and mites. These diseases are extremely likely to appear in stored tubers that are to any degree infected by *Phytophthora*. Much, however, can be done to prevent healthy tubers developing these rots by careful attention to the method of storage. It is well known that the favourable conditions for the growth of most fungi are a moist, warm atmosphere and absence of light. If, therefore, the storage clamp is not carefully made, it is possible that very favourable conditions for the growth of fungi will be provided. If the tubers are stored moist, or if they are too closely covered, and if no provision is made for adequate access of air to all parts of the "pie," the temperature will rise and harmful fungi will become rampant. To avoid these dangers then, potatoes should be stored in a dry, well-ventilated shed; or, failing that, the "pie" or clamp should be in a dry situation and well ventilated. By such precautions the conditions are rendered unfavourable for the growth of rotting organisms; and even though a few of the tubers are diseased the trouble is then unlikely to spread to the healthy tubers. Too frequently, however, it is found on opening a clamp that the whole store is a putrifying mass, simply owing to neglect of the essential facts of ventilation and dryness.

We have seen that the *Phytophthora* spreads throughout the summer months with amazing rapidity by air-borne conidia. If, however, these are to produce infection they must germinate immediately, for being only provided with a thin wall they cannot resist drying up or frost. They, therefore, never serve for carrying over the fungus from one season to the next.

The question then arises as to whether this fungus, like *Pythium*, produces resting spores that are able to survive the winter in the soil. The most diligent search of many investigators has failed to show that such resistant resting spores are ever produced in Nature. On the other hand, Dr. Pethybridge, in Dublin recently, has found it possible to obtain resting spores of this fungus by growing it artificially on a medium consisting of cooked Quaker Oats stiffened with a gelatinous substance called agar. The fungus forms a dense, white growth on the surface of this, and after some months produces the resting spores within the medium. These are quite characteristic resting spores and possess a thick resistant wall. Interesting as these artificially-produced resting spores are from the scientific point of view, the fact that their presence has never been demonstrated in Nature, renders it necessary to consider other means by which the fungus may survive the winter. It has been repeatedly shown that diseased tubers kept over winter in the open may give rise to a growth of *Phytophthora* bearing spores in the warm, moist days of early summer. During the colder months filaments of the fungus in diseased tubers grow very slowly indeed, especially if the tubers are kept dry. If, however, such tubers are kept warm and moist the fungus rapidly extends through the whole tuber and even produces a network of threads bearing powdery conidia on the outside. Such conidia, carried in the air, infect leaves of potato plants in the vicinity, and in this way start an epidemic. It has frequently been noticed that portions of a potato field, near to old potato pits or refuse heaps, have been the starting points for the disease. This mode of initial infection is, however, scarcely enough to account for the very wide-spread frequency of the disease.

Recent investigations, especially in Ireland and America, have done much to make it clear how most epidemics of "Late-Blight" originate. We have seen that the potato tubers very frequently become infected by the fungus. If badly diseased tubers are used for seed it has been found that they either wholly decay in the ground or occasionally send up a few perfectly healthy shoots. Recently, however, very careful field experiments have shown that if only slightly diseased tubers are planted a much larger proportion of them send up shoots, and under certain weather conditions some of these become diseased. It has also been proved that the disease arises in such young shoots by the growth into them of the fungus from the slightly diseased tuber. Dr. Melhus has confirmed De Bary's earlier observations that such diseased shoots occasionally reach the surface where conidia of the fungus are produced. These conidia are then carried to the leaves of adjoining plants, which very soon show typical disease spots. Upon these, more conidia arise and so starting with a single diseased shoot as a centre the disease spreads over the whole field in a few warm moist days.

In taking measures to prevent the Late-Blight disease, it is necessary, as in other plant diseases caused by fungi, to consider the means by which the fungus spreads during the season, and also the manner in which it is carried over to the following year. It has been shown that this disease spreads very rapidly throughout the summer, by means of air-borne conidia that infect the leaves on which they alight. If the germination of conidia can be prevented then the spread of the disease will be controlled. This may be accomplished by spraying with a fungicide, that is, a poisonous substance which is harmful to germinating spores. It has been found by experience that one of the most powerful mixtures for preventing infection by filaments from germinating spores of fungi is Bordeaux mixture. This consists of a solution of Blue stone, that is copper sulphate, to which slaked lime or lime water is added. The lime is added to prevent the copper sulphate injuring the leaves of the plants treated, and also to make the mixture form a fine film on the surface of the leaves.

Bordeaux mixture should always be freshly prepared, and the home-made article is much better than any advertised preparations. It is a fairly simple matter to make the mixture, and full directions for its preparation and use are given by the Board of Agriculture in Leaflet 23. Once the disease is evident in the field it is too late to attempt to control it by spraying, but the first application should be made some time before the first outbreak of disease is expected, *i.e.*, about the end of June or beginning of July in most districts. The mixture should be well stirred before use and both surfaces of the leaves of the plants should be thoroughly sprayed. Three or four sprayings at intervals of a fortnight or ten days should generally be sufficient to prevent any serious epidemic. The cost of such sprayings is relatively small, working out in normal times to about 25/- an acre for three applications (*i.e.*, 2d. per square rod). Apart even from the prevention of Late-Blight spraying has been proved beneficial to the plant; for sprayed plants usually retain their leaves at least a fortnight longer than unsprayed. In certain districts of America where spraying is regularly adopted the increased profit is usually from £3 to £5 per acre.

The subject of the resistance of different varieties of potatoes to this disease has received the attention of experimental growers for many years. Darwin himself was for some years interested in the matter, and as a result, various species of wild potatoes growing in South America were experimented with and used for crossing. At the present time, therefore, something can be done to avoid the disastrous effects of the Late-Blight disease by growing varieties known to be resistant to this disease. It must be said, however, that though a variety is highly resistant in one locality it may be equally susceptible in another district where the conditions of environment differ. It is also notorious that disease-proof varieties lose their resistance after a few years, either because the plant, in time, deviates from the original type, or because the fungus becomes slightly modified so that it is able to break down the resistance. Needless to say, a variety which is resistant to Late-Blight disease will not necessarily be resistant to the Wart disease and other diseases of the potato. Since the Late-Blight disease usually affects the crop most seriously towards the end of the season, it follows that early varieties do not suffer from the disease to the same extent as the main-crop and later varieties. By, therefore, selecting varieties proved to be resistant in recent years in the given district, and by choosing early varieties it is possible to avoid this disease to some extent.

It is even more important, however, to endeavour to prevent the first outbreak of the disease in a given area. All possible sources of infection such as diseased tubers and stalks should be carefully collected and burned at the end of the season. Since the disease is propagated from year to year in slightly diseased tubers, seed potatoes should only be used from a crop which never showed any sign of the disease even on the leaves.

We have seen that tubers become infected either, by the growth of fungus down the stalks, or by spores being washed into the soil. If, therefore, the attack occurs late in the season all haulms should be removed and destroyed before the tubers are lifted; and infection from the latter source may be prevented, to some extent, by seeing that the tubers near the surface are well covered with soil. This should be done as soon as possible after the haulm has died down, for apart from the risks of the *Phytophthora* disease, tubers left too long in the ground are more liable to be attacked later by rots in the store. The tubers should be stored under dry conditions in such a way that air has free access to them, and diseased haulms should never be used for covering the "pie" or clamp.

If potato plants are sprayed three or four times at fortnightly intervals, beginning when they are about six inches high, it should usually be possible to prevent any serious epidemic in a given field or garden. Much can also be done to prevent infection by the immediate destruction of diseased tubers and haulms, and by only using seed potatoes from a perfectly healthy crop. By such precautionary measures, in addition to the use of varieties, known by experience to be resistant in the district, it should be possible to reduce the effects of this disease to a minimum.

Chapter 11.

DISEASES OF LEAVES AND SHOOTS (contd.).

Black-Leg or Wilt Disease of Asters. Tomato-leaf rust or mould Leaf-blotch of Cucumber. Mildews of Roses, Gooseberries, etc.

The Black-Leg or wilt disease of asters is extremely prevalent wherever asters are grown. It is caused by a species of *Phytophthora*, which differs in several respects from *Phytophthora infestans*, the cause of the Late-Blight disease of potatoes. The disease may manifest itself at any stage in the life of the aster, but the initial attack is always upon the seedlings. In severe cases the seedlings collapse, as in the "Damping-off" disease caused by Pythium, but more frequently they harbour the fungus without showing any outward sign of disease at this stage. Such seedlings may wilt and collapse when transplanted, but many succeed in surviving even to the flowering stage without showing external signs of injury. In the latter cases the plants succumb quite suddenly, almost without warning. The leaves wilt, hang limp and flaccid, and in a few days the whole plant shrivels and dies. Even, though affected plants show little direct sign of the disease until the wilt sets in, they are often much dwarfed in size and produce fewer flowering branches than healthy plants. The fact that this disease may be present in apparently healthy asters, which only wilt after they come into flower, renders it all the more objectionable and difficult to combat. When wilted plants are pulled up, the parts of the stem a few inches above the level of the ground are found to be blackened and often decaying; these symptoms have given the disease its popular name.

The parasitic fungus which causes the aster disease, unlike *Phytophthora infestans* of the potato, never attacks the leaves directly but enters the plant from the soil through the root of the seedling. Once within the young plant it may, either grow slowly not seriously interfering with the work of the vital parts of the seedling, or it may extend rapidly through these and cause immediate collapse. Microscopic examination of the blackened portion of the stem shows the distribution of the fungus in the tissues. The cells of the rind as well as the spaces between them are occupied by filaments of the fungus. The former are not so rapidly killed by the fungus as are those of the potato plant by *Phytophthora infestans.* The ultimate collapse of the plant, however, is brought about by the extension of the fungus to the vascular cylinder of the stem, and the consequent reduction of the supply of water to the leaves.

In moist weather the fungus gives rise to conidia on the diseased stem. Unlike those of *Phytophthora infestans* they are only produced under water, and do not become detached from the filaments bearing them. A few hours after their first appearance they burst at the apex liberating about fourteen motile spores which, after swimming about for a short time, come to rest and are able to infect other seedlings.

In studying this disease the writer has up to the present failed to find any resting spores of the *Phytophthora* in the tissues of diseased asters, and attempts to obtain such spores by artificial cultivation have been equally unsuccessful. Experience however has shown quite conclusively that the disease originates each season from the presence of the fungus in the soil, especially of the seed bed; and the ease with which it may be cultivated on dead organic substances suggests that it may be able to persist in a vegetative condition in the rich soil used for seed-beds. On the other hand, further research may prove the existence of resting spores.

It is often stated that this disease is caused by a species of *Fusarium*, which is frequently found on the decaying tissues of diseased asters. The writer,* however, has proved that a species of *Phytophthora* is the primary cause of the Black-Leg disease and that *Fusarium* only appears later as a saprophyte living upon tissues previously killed by the other fungus. The *Phytophthora* is always present in the diseased asters even in the earliest stages; it has been isolated and grown separately from all other organisms, and the disease has been produced artificially from such growths. Other organisms found on diseased asters, including *Fusarium*, are unable to infect and produce wilting in healthy plants; such saprophytes only succeed after the tissues have been killed by the *Phytophthora*.

The insidious nature of this disease renders it extremely difficult to deal with, for it is usually almost impossible to detect diseased plants until the wilting actually sets in. Whilst sufficient scientific trials of remedial measures have not yet been made to warrant promise of complete success in all cases still some precautions may be indicated. The soil of the seed-bed should be partially sterilised by steam or hot water and asters should not be planted in ground which produced diseased plants the previous season. All diseased material should be removed and burned and the infested soil thoroughly drenched with Formalin (1 pint per 10 galls. water) and covered with sacking for a few days. Many growers raise aster seedlings on hot-beds of stable manure, but these conditions should be avoided since they are much more favourable to the fungus than when alkaline artificial manures are used.

As a first example of the common diseases of leaves, the Tomato-leaf rust or mould caused by *Cladosporium fulvum* may next be considered. This is more strictly a disease of the leaves than is the Late-Blight of potato, but even in this case the whole tomato plant suffers because of the attack on the leaves. The disease, which has been known in this country for over a quarter of a century, first appears on the leaves in the form of small, yellowish spots. These gradually increase in size and often run together, and the under surface of the leaf in the diseased areas becomes covered with a rusty, velvety growth. This is the reproductive part of the fungus pro-

* "Annals of Applied Biology." Vol. II., Nos. 2 and 3, July, 1915, pp. 125-137.

ducing the disease. The vegetative filaments ramifying in the tissues of the leaf give rise to branches which pass out through the stomata and stand erect from the surface of the leaf. Food material is absorbed from the host plant by the vegetative filaments and is passed on to the reproductive branches. These produce large numbers of small two-celled spores, which being readily detached are disseminated by air currents. Under suitable conditions they germinate immediately on the surface of tomato leaves; each of the cells of the spore may send out a filament, which growing through one of the stomata, into the interior of the leaf produces a new infection. The careless watering of slightly diseased plants may carry spores to healthy leaves and thus spread the disease which is highly infectious.

The disease only occurs in this country on tomatoes grown under glass, and though the spores described above are the only kind known, it is certain that they are able to survive the winter in the greenhouse and give rise to infection the following season. If the houses are kept sufficiently well ventilated the disease seldom assumes serious importance; neglect of this precaution may, on the other hand, prove disastrous. It is possible to prevent any bad outbreak by regularly spraying with a Bordeaux mixture of half the usual strength, until the young fruit is beginning to set, when, owing to the poisonous character of Bordeaux mixture, Liver of Sulphur (1 oz. per 4 galls. of water) should be substituted. In order to prevent the disease recurring, all diseased leaves should be picked off immediately and dropped into a vessel containing a solution of copper sulphate; at the end of the season remains of plants should be burned and the greenhouse disinfected in the manner to be described in connection with the Cucumber-leaf disease.

Several other diseases of the tomato plant, which are readily distinguished from the Leaf-rust described above, may be mentioned. The Sleepy disease caused by *Fusarium lycopersici*, is a wilt disease somewhat similar in symptoms to the Black-Leg of asters although caused by a very different fungus. The Black-Stripe disease shows itself on the fruit and also sometimes on the stem as a dark, velvety growth of fungus. This disease, caused by *Macrosporium solani*, should not be confused with the Bacteriosis of the tomato in which blackening of the parts attacked is also produced. In the latter case, *Bacillus solanacearum* is the cause. The Septoria disease of the leaves produced by *Septoria lycopersici* is the only other malady likely to be confused with the leaf-rust, but in this case the spots are always small and concentric, and the spores are produced in minute black bodies scattered over the patches.

The Leaf-Blotch of the Cucumber caused by *Cercospora melonis* is another destructive disease of leaves. It was first described in this country by Dr. M. C. Cooke in 1896, and since then it has become so wide-spread that many horticulturists have been compelled to cease growing cucumbers. Once the fungus appears in greenhouses it is extremely difficult to eradicate. The leaves are most often attacked, but the fungus frequently spreads to the fruit. An outbreak of the disease is usually first indicated by the appearance of pale, scattered spots on the leaves. These spots gradually increase in size, become brown, and the leaves are so rapidly killed that death of the plant may soon result.

Microscopic examination shows that, in the region of the spots, the tissues of the leaf are occupied by filaments of the fungus, that the chlorophyll bodies are pale in colour and many of the cells of the leaf are shrivelling and dying. From the fungus within the leaf stiff branched filaments grow out and stand more or less erect from the surface. These aerial threads are dark in colour, and bear numbers of large conidia which fall free as they mature. Each somewhat spindle-shaped conidium is divided into about seven or eight cells, and may germinate in a warm, moist atmosphere by sending out filamentous germ-tubes from any of the cells. The germ-tubes may then produce new infections by growing through the stomata into the healthy tissues of the leaf. This spreading by means of conidia that germinate immediately, takes place very rapidly under favourable conditions. In addition to producing large conidia on the leaves the fungus is said to grow as a saprophyte on decaying leaves and damp soil producing myriads of smaller spores which also rapidly spread the disease. If the conditions are unfavourable to the germination of the spores, and especially at the end of the season, the large conidia persist alive as resting spores. Filaments of the fungus are also able to pass into a resting condition in the soil, only to begin active growth with the production of spores, when the conditions are once more favourable. In this way the disease survives in greenhouses from one season to the next, and once a house is infected the disease is almost certain to recur year after year unless precautions are taken to thoroughly disinfect the soil and all parts of the house.

The practice of disinfecting greenhouses with burning sulphur is largely employed in some districts. Whilst this is an excellent preventative of insect pests and of certain mildews, it is useless against the Leaf-Blotch of cucumbers. The writer recently established this with certainty. A large house which had been badly infected with the disease was cleared out and thoroughly disinfected with burning sulphur. A few fragments of diseased leaves and fruits were then collected from the soil of this greenhouse and brought into the laboratory. Spores of the *Cercospora*, taken from this material, germinated in water in a few hours and cultures of the fungus were readily obtained on suitable media. From this experiment it is clear that the spores and resting filaments of *Cercospora melonis* remain uninjured in houses disinfected by burning sulphur alone. Probably more certain results would be obtained by spraying the house thoroughly, and also drenching the soil with Formalin (1 pint per 20 galls. of water). The Board of Agriculture * recommends the use of Jeyes fluid (1 oz. per gall. of water) for this purpose, but the writer has no experience of this as a disinfectant against parasitic fungi. Needless to say all diseased material should be destroyed by burning. It is possible to control this disease to some extent by spraying with Liver of Sulphur (potassium sulphide) two ounces in three gallons of water, to which two ounces of soft soap is added to facilitate the sticking of the solution to the leaves, which should be thoroughly wetted by the spray. The disease is only prevalent where cucumbers are forced under glass, but if the ventilation is carefully regulated much can be done to reduce the possibility of an epidemic. A most effective way of combating it is by growing disease-resisting varieties of the cucumber, of which there are a number on the market. The most reliable of these have rather coarse, hard foliage, but unfortunately the

* Leaflet No. 76.

fruit is not so highly valued as that of some of the more susceptible varieties. At the same time it ought to be quite possible to produce, by crossing, a variety which combines the qualities of disease-resistance and those most acceptable in the fruit.

Many diseases of leaves belong to the class spoken of as mildews and are caused by fungi belonging to the family *Erysiphaceæ*. The Rose mildew, caused by *Sphaerotheca pannosa*, is one of the most familiar of these diseases and is typical of the class. The diseased leaves become covered with a white, powdery growth of the fungus, which causes them to curl up and die. The fungus grows mainly on the surface of the leaves, swollen branches from the filaments acting as sucker-like organs of attachment, while other branches penetrate the outer walls of the epidermal cells and swell out within the surface cells in the form of bladder-like haustoria. These absorb food material from the cells occupied as well as from the adjoining cells. The substances thus absorbed from the living leaf are passed on to the vegetative filaments of the fungus outside which is thus enabled to grow and multiply. Erect threads arise from the creeping filaments on the surface and bear single chains of colourless, thin-walled, oval spores or conidia. Myriads of these are produced on the surface of mildewed leaves and give to the latter the characteristic powdery appearance. Being extremely light they are easily spread by the wind to healthy leaves and produce new infections throughout the summer. Later in the season, the production of conidia gradually gives place to another means of spreading. The fungus on the shrivelling leaves and also on the twigs assumes a brown colour and gives rise to minute dark bodies about the size of a pin head. This is the winter or resting stage of the fungus. Each of the minute dark bodies or perithecia is furnished with a thick wall made up of a number of closely interwoven fungal threads · and within this resistant coat a club-shaped spore-case (*ascus*) containing eight oval spores, gradually develops. When mature the perithecium splits across and the ascus is squeezed out. The latter then opens at the apex and the oval spores are forcibly ejected. These are able to infect leaves with the mildew and serve to start the disease afresh each spring. As has been stated above, many destructive mildews are caused by fungi having a life history closely corresponding to that of the Rose mildew. The mildews of apple, chrysanthemums, peas, hops, strawberries, and gooseberries are all common in this country. The American Gooseberry mildew is the most destructive of these, and growers of gooseberries have to observe certain restrictions prescribed by the Government in regard to this disease. Full particulars of the symptoms and treatment may be obtained from the Board of Agriculture.*

Preventive measures against most of these mildews are similar. The main facts to consider are the means of spreading during the season and the method of carrying over from autumn to spring. Sulphur, or one of its compounds, is the most effective fungicide for use in combatting mildews. Plants may be dusted with flowers of sulphur or sprayed with liver of sulphur. Sprays, containing lime and sulphur, are now extensively used with success, especially in America, against the mildews of hops and gooseberries.† The treatment with sulphur, or its compounds, however, is only effective against the summer stage of the fungus and other measures must be taken to destroy the resting fungus. The only satisfactory method of dealing with this is by the removal and immediate destruction of all branches and leaves bearing perithecia. Otherwise no amount of spraying will prevent the disease recurring year after year.

* Leaflet No. 105.

† Eyre and Salmon have recently recommended the use of ammonium sulphide against American Gooseberry Mildew. "Journal Board Agric.," Feb., 1916.

Chapter 12.

DISEASES OF LEAVES (contd.).

Rusts. The Wheat Rust. Life Story of the fungus, relation to the Barberry. The Mint Rust and Hollyhock Rust as examples of other Rust diseases.

The Rusts constitute a very important group of plant diseases, which includes some of the most widely distributed and highly destructive of parasitic fungi. The grain-producing plants and grasses of our fields, the plants of our gardens and greenhouses, and even forest and fruit trees are attacked by members of the rust family of fungi. Of all plant diseases they are in many respects the most remarkable, as they are also the most difficult to combat. Whilst the nature and the life history of the fungi causing them have only been known for a relatively short period, the blighting effects caused by outbreaks of these maladies are referred to by writers of the remotest antiquity. Throughout the centuries wheat rusts have been responsible for great damage wherever wheat has been grown, and at the present time the loss caused to the wheat crop alone throughout the world amounts to many millions of pounds annually.

Since the life story of the fungus causing the Black Rust of wheat (*Puccinia graminis*) is typical of many rusts, it will be described in some detail. The disease usually appears in the summer on the leaves and stalks of the growing wheat in the form of yellowish streaks, at first shining through the epidermis. The orange patches on the leaves consist of the developing uredospores of the fungus causing the disease. As this progresses, the epidermis is ruptured and the bright orange uredospores are liberated as a fine powder. These spores bring about the rapid spread of the malady from one plant to another throughout the summer months, so that in a short space of time whole fields of wheat may be rusted. As the disease pustules increase in number and size the leaves lose colour and become paler day by day and a badly diseased field may thus give the appearance of premature ripening.

With the advance of the season the streaks on the plants gradually change colour from orange almost to black, and although for a time some uredospores continue to arise in the pustules, mingled with them are now dark, brown spores of a different appearance. Finally, in the autumn, none but the dark spores are produced in the pustules. These spores are the teleutospores which serve for carrying the fungus over to the next season Before considering in detail the form and behaviour of the uredospores and teleutospores, reference must be made to an opinion which prevailed at least a hundred and fifty years ago with regard to the wheat rust.

It was strongly held by farmers that the presence of bushes of the common barberry near to wheat fields, bore some relation to outbreaks of rust, but no very definite reasons were given for this belief. The farmers of Massachusetts were so convinced of the connection between the barberry plant and the wheat rust, that a law was passed in 1755 compelling the destruction of all the barberry bushes. About a century ago Sir Joseph Banks suggested that a certain bright yellow fungus common on the barberry might be the same as that causing the rust of wheat. This fungus on the barberry, however, when examined microscopically was so unlike the fungus on wheat that for a long time the relationship was not understood.

If a leaf of wheat is cut across through one of the yellow streaks and examined under the microscope, it is found that the pustule is formed by the rupture of the epidermis of the leaf. Large numbers of the orange uredospores arise under the skin and burst through to the outside. The torn edges of the epidermis thus act as a boundary to the pustule. The filaments of the fungus ramify in the tissues of the leaf often sending special branches called haustoria into the living cells from which nutriment is thus absorbed. The reproductive branches of the fungus grow outwards and accumulate in rows under the skin of the leaf. The round, orange uredospores are produced on the tips of such branches, and are liberated when the epidermis bursts under the pressure. Each uredospore is a single, oval cell about a thousandth of an inch in length, and readily falls free from the stalk bearing it. The wall of the spore is studded with minute warts and has four thin round pores near the middle part. The uredospores are able to germinate, immediately they are liberated, in a film of water or in damp air. Through the pores mentioned above two or three fine filaments grow out; one of these usually outstrips the rest and may become a long, branched, wavy filament. If in water alone, or indeed apart from a living leaf of the wheat plant, this filament is only able to survive until the small store of reserve food material in the spore is exhausted. If, however, the spore germinates on the leaf of a wheat plant the germ tube grows to one of the stomata, and passing through the pore enters the tissues of the leaf. Here the fungus absorbing food material grows and produces a new pustule with uredospores in about a fortnight. In this way very large numbers of uredospores are produced during the summer months and hence the disease spreads rapidly.

The teleutospores, like the uredospores, arise from branches of the filaments of the fungus in the leaf and they appear towards the end of summer in the same pustules as the uredospores. With the advance of the season, however, the pustules give rise to teleutospores only. Microscopically, these are longer than the uredospores, are more spindle-shaped, but are also borne on stalks. Each spore consists of two cells and is furnished with a thick, resistant wall. Unlike the uredospores the teleutospores do not germinate immediately when placed under moist conditions, but they require to rest for a period of months. If, however, teleutospores which are produced in the autumn are allowed to remain exposed to the weather through the winter, they will, under suitable conditions, germinate in a few hours in March or April. In this case the process of germination of the spore differs from any of those dealt with in previous chapters. Each of the two cells of the spore sends out a delicate tube, which, after growing to two or three times the length of the spore, becomes divided into four cells or segments. Then a delicate peg-like branch is put out from each of these segments, and a minute, oval spore is formed at the tip of each peg. The question now arises as to what becomes of these teleutospores and the small oval spores or sporidia they produce. For many years this was not understood, although trials again and again proved that the teleutospores or their sporidia were unable to cause new infection on the wheat plant.

The clue to the problem was discovered by De Bary in the old belief of farmers that outbreaks of rust were in some way connected with the presence of barberry. He first made a careful study of the yellow fungus which occurs on barberry, and then proved the connection of this with the rust on wheat. If one of the diseased areas on the barberry is closely examined it is found to arise on a swollen part of the leaf, and on the under side a number of small, yellow, cup-like bodies are produced. From these cluster-cups yellow spores, known as aecidiospores, are liberated as a fine dust. A section through the diseased area shows that the cluster-cups arise as round masses of fungal filaments beneath the skin of the leaf. Within the ball of fungus, aecidiospores are produced in chains, and when this growing ball bursts the skin of the leaf, it opens at the apex and the edges turning back give the structure the appearance of a minute cup or bowl. The aecidiospores arise from threads at the base of this, and as they ripen and are set free new spores are produced. Now De Bary discovered that when sporidia from the teleutospores on wheat are sown on barberry leaves in the spring, infection takes place and the cluster-cups just described are produced in two or three weeks. Not only did he prove this, but he also showed that when the aecidiospores from the cluster-cups are sown on the leaves of wheat, they germinate, and like the uredospores send germ tubes through the stomata and thus infect the leaf. Pustules containing uredospores and later teleutospores are produced from this infection. The connection between the fungus on the barberry and that on wheat was thus established, and it was shown that, although the appearances of the fungus on the two host plants differ so materially, each represents a stage in the life history of one fungus.

Since De Bary's remarkable discovery very many rust fungi, showing this type of life history, have been studied. The rust which frequently appears on the leaves of the pear, for example, is the aecidiospore stage of *Gymnosporangium* which produces swellings on the branches of juniper, where the teleutospores arise. The Blister-Rust of the Weymouth or white pine, a disease which is very prevalent on the continent of Europe, is the aecidiospore stage of a fungus which forms its uredospores and teleutospores on the leaves of currants. Similarly, the Gooseberry rust is the cluster-cup stage of a fungus which forms the uredospores and teleutospores on the leaves of sedges. Many other similar cases occur as diseases of cultivated plants and trees.

When the facts became known for the wheat rust it was thought that in order to eliminate the disease from a given district all that was necessary was to destroy the barberry plants in the district. It was soon found, however, that in some countries, for example, Australia, where the rusts of wheat are most destructive, the barberry is almost unknown. In such cases it seems likely that the rust fungus is able to maintain itself without passing through the barberry. It probably does this by means of the uredospores, which have been shown to be capable of resisting a mild winter.

Apart from the destruction of the barberry other means of combatting the wheat rust had to be devised. Up to the present this has proved a very difficult problem. The most satisfactory progress has been attained along the lines of breeding disease-resistant wheats. It has long been known that certain wheats are much more resistant to rust diseases than others. The chief difficulty lay in the fact that the most resistant forms, *e.g.*, certain semi-wild wheats, were almost valueless as crops. In recent years, however, much has been done, especially by Professor Biffen, of Cambridge, to produce by crossing, wheats which combine qualities of rust-resistance with good cropping and milling capacities. The subject is nevertheless still beset with difficulties, both in regard to the permanence of the rust-resistance, and to the fact that a wheat, which is resistant to one form of rust may be equally susceptible to another. Further, wheats which are resistant, say in England, are not necessarily so in India or Australia. It has been essential therefore for each country to establish its own rust-resistant varieties of wheat.

Many of our common garden plants are liable to attacks by different rust fungi. The Mint rust caused by *Puccinia menthæ* is one of the most prevalent of these in some districts. In this example the three forms of spore appear in succession, and there is no intervention of a second host plant in the life cycle of the rust. In the spring diseased plants send up shoots which are often swollen and distorted, and bear the cluster-cups of the fungus. The aecidiospores are liberated as a bright yellow dust and infect the leaves of healthy shoots so spreading the disease. The pustules produced by this infection are brown in colour and are scattered, as minute dark spots, over the leaves. Uredospores arise from these pustules throughout the summer, and towards the end of the season teleutospores are produced from similar disease spots. The teleutospores remain in a resting condition in the soil for some months, but germinate in the early spring giving rise to sporidia, which infect the young buds on the underground stem. Such infected buds are not killed outright by the fungus, but grow out to produce the distorted shoots bearing the aecidiospores, described above. It has also been shown that once the underground stem is infected, the fungus lives there perennially and grows into the young buds as they are formed. This renders the disease all the more difficult to eradicate. Indeed, the best plan is to destroy all infected material and only use for planting, rhizomes known to be free from the fungus. Care should also be taken to prevent infection by teleutospores from soil which has grown diseased plants.

As an example of a rust caused by a fungus with a simpler life history, the Hollyhock rust produced by *Puccinia malvacearum* may be considered. This disease occurs on a large number of the members of the Mallow family; it is widely distributed throughout the world and is abundant in this country, both on wild mallows and on the cultivated Hollyhock. The fungus, which is a native of Chile, was introduced into Europe about 1875, and for some years its ravages were so severe that it was scarcely possible to grow the Hollyhock free from rust. Even at present the disease causes considerable trouble in some districts.

The disease pustules chiefly occur on the leaves, but the stem and even the flower buds and fruits are often attacked. As in the rusts already described, the developing cushion of spores bursts through the epidermis. The filaments of the fungus ramify in the tissues of the host sending haustoria into the living cells, which are slowly depleted of nutritive substances. The pustules arise on both surfaces of the leaf, are small and circular in outline and produce teleutospores only. These germinate *in situ* under suitable conditions, immediately they mature, giving rise to sporidia as in other rusts. The sporidia, falling on to the surface of any part of a hollyhock plant germinate and penetrate the epidermis producing an infection. From this region a new pustule of teleutospores is produced in about fourteen days. The Hollyhock rust thus omits both the aecidiospore and uredospore stages from its life story.

The fungus probably passes the winter by teleutospores which fail to germinate owing to unfavourable conditions. In addition it is likely that it also is carried over in the few radical leaves which generally survive the winter in this country. The writer has frequently observed incipient disease spots on such leaves in the winter, and it is probable that these develop much more slowly in the cold weather than those produced in the warmer months. By destroying diseased leaves as soon as the spots appear, it is usually possible to restrict the damage caused by this rust.

From the examples described in this chapter it will be evident that, although the fungi causing the rust diseases belong to one group, yet they present certain differences from one another. A large number, like the rust of wheat, produce aecidiospores on one host, and the uredospores and teleutospores on an entirely different species of plant. Others, however, like the rust of mint pass the whole life cycle on one host and give rise to aecidiospores, uredospores and teleutospores in succession on the same species. Still others like the Hollyhock rust, in addition to living wholly on one host plant, altogether omit some of the spore forms from the life story. Whilst showing these variations, however, the rust fungi are all highly specialised parasites; they cannot grow apart from living plants, and with rare exceptions, a specific rust fungus is restricted to a single species of plant.

Further information on the subject of diseases of plants caused by parasitic fungi may be obtained from the following books:—

Ward, H. M. "Diseases of Plants," S.P.C.K., London.

Duggar, B. M. "Fungous Diseases of Plants," 1909, Ginn and Company.

Massee, G. "Diseases of Cultivated Plants and Trees," Duckworth, 1910.

Chapter 13.

INJURIOUS ANIMALS OTHER THAN INSECTS.

Injurious and beneficial Animals. Birds and the need for scientific investigation with reference to their food at different seasons of the year. Eelworms and more especially the Stem Eelworm and the Knot Root Eelworm. Pulmonate Molluscs (Snails and Slugs). The Black Currant Gall Mite.

All who engage in agricultural or horticultural pursuits sooner or later have to concern themselves with some of the forms of animal life which are associated with their plants. Very frequently certain of these animals are directly injurious to the operations of man, but there are others which, on the contrary, are distinctly beneficial in their effects. It is, therefore, a matter of considerable importance to be able to discriminate between these two classes, for it is obviously bad policy to devote time and money in destroying organisms which are beneficial in their action. The animal kingdom comprises a vast assemblage of different forms, but fortunately for our present purpose we need only concern ourselves with a relatively small proportion of their number. These include certain birds, species of Nematodes or Eelworms, Oligochaeta or Earthworms, Pulmonate Molluscs or Slugs and Snails, land Isopods or Wood-lice, certain Acari or Mites, and the great class of the Insects.

Dealing first with INJURIOUS ANIMALS. BIRDS (1), (2), *(3) merit some amount of attention, but the fact cannot be emphasised too strongly that we possess extraordinarily little reliable knowledge concerning the food of some of our very commonest birds. Both the British Association and the Board of Agriculture recognise that, before any effective legislation can be recommended, a very full scientific enquiry is needed. It is necessary, for instance, to examine and tabulate the contents of the crops of certain common birds in each month of the year so that an opinion may be formed of the benefits or injuries caused by them at the different seasons. It is further necessary that some estimate should be made of the available food in the district where the birds were feeding when killed, in order to decide whether the foods discovered in the crops were selected from choice or necessity. Much information is also desirable as to the food of nestling birds. Fortunately some progress is being made towards supplying this much needed information, and the Department of Economic Zoology in this University is performing a useful part in the work on behalf of the Board of Agriculture. Certain species of wild birds may be direct-injurious by feeding upon or injuring plants or parts of plants; others are indirectly harmful in that they may feed upon forms of animal life which are in themselves beneficial. Fortunately there are very few species of birds which we may declare to be wholly destructive and, of these, the House Sparrow and Wood Pigeon are the most important. The Blackbird also appears to have very little utility in the eyes of man, and is a most persistent devourer of fruit. On the other hand, there is a large number of birds whose rôle is doubtful; in many cases we lack adequate knowledge to judge fairly as to their feeding habits, but they all appear to have a good deal of utility in their favour. Among these may be cited the Song Thrush, Great and Blue Tit, Greenfinch, Chaffinch, Rook, Robin, Linnet, Yellow-hammer, Skylark, Starling, Woodpeckers and

* The numbers in brackets refer to the literature which is listed at the end of this series of lectures.

others. The Rook, for instance, is a bird concerning which it is at present impossible to say whether it is a beneficial or harmful species. It consumes a vast amount of grain but, on the other hand, during the summer it devours a great many injurious insects of various kinds, including both leather-jackets and wireworms. The Starling also devours a large amount of grain during certain times of the year, but this appears to be compensated by the great quantity of injurious insects which the bird consumes at other periods. As many as 197 leather-jackets, for instance, have been found by Mr. Leigh in the crop of a single bird. The Chaffinch is by no means as destructive as is commonly believed. It consumes large quantities of seeds of such troublesome weeds as, dock, knotgrass, hawkweed, and especially chickweed. Mr. Leigh informs me that although he found grain in the crops of 41 per cent. of the birds which he examined, it appeared to have been taken in most cases from manure or ricks in farmyards and not from cultivated land. It must be further added that evidence points to the fact that the majority of species of birds feed their nestlings on soft-bodied insects and other invertebrates. Consequently even the most destructive birds may perform a useful function during that stage in their life.

EELWORMS (4), (5), belong to the group of the Nematoda. They are always small in size and have thread-like bodies, the two ends being more or less pointed. They can be readily distinguished from the Oligochaeta or Earthworms by the total absence of body rings or segments. Those which are plant parasites are microscopic forms living free in damp soil or inside the tissues of plants. Others live in decaying vegetation, and both the parasitic and saprophytic forms can be recognised by the presence of a spine which can be protruded through the mouth and serves to penetrate the cell-walls of plants. The Eelworms spread from one plant to another by wandering through the soil, and when they leave the dead plants they lie near the surface of the ground. Frequently when these animals are numerous it is useless to grow susceptible plants in the same patch of soil during successive seasons, and then as long an interval as possible should elapse between the growing of two crops of the same plant. The STEM EELWORM (*Tylenchus devastatrix*, Kuhn) attacks a great variety of plants including strawberries, onions, beans and peas, hyacinths, and also field crops. It is an extremely slender species, about 1-25th of an inch long, and the males and females closely resemble one another. Strawberries when attacked decay away at the level of the soil or just below it, and the crowns and roots rot away. A remedy is to pull up and burn the affected plants and dress the soil with either lime or sulphate of potash in the proportion of 1 cwt. to the acre. The KNOT ROOT EELWORM (*Heterodera radicicola*, Greef) differs from the previous species in the male, being thread-like, while the female is greatly swollen except at the head end. It also goes through a more complex life-history. This species renders its presence evident by forming knot-like swellings or galls upon the roots of the affected plants. It is a great enemy of cucumbers and tomatoes grown in glass houses, but also attacks vines, potatoes, lettuces, and many other plants in the open.

As a temporary measure to save a growing crop, one part of permanganate of potash to 200 of water applied at intervals of ten days is recommended in the *Kew Bulletin*. It does not harm the plants, but since it does not destroy the eggs of Eelworms, no permanent value can be ascribed to it. Treatment of the soil with one part of carbolic acid to twenty of water, with a dressing of sulphate of potash, 3 cwt. per acre, intimately mixing the soil with gas lime or naphthaline, are among the remedies that are recommended. When applying remedial measures the soil must remain unused for at least six weeks for any permanent benefit to be derived. This species, however, is extremely difficult to eradicate owing to the fact it produces vast numbers of eggs throughout the year, and the young Eelworms are thus constantly being liberated into the soil. Furthermore, most of the above methods are not lasting in their effects, owing to the fact that frequently a number of eggs remain over undestroyed, and serve to start the infection afresh. When a glass house is infested with Eelworms, it is often necessary where possible, to remove the soil bodily and treat it by one of the methods already mentioned. In the case of plants grown under glass the horticulturist soon finds that the conditions encourage a host of other living things. In addition to Eelworms, Woodlice, insects of various kinds, and fungi often enforce their presence, and under the warmth and moisture that is provided they are liable to multiply exceedingly. Experiments carried out at the Rothamsted Station have shown that we can very considerably reduce this undesirable population by partial sterilization of the soil by means of steam. In cases of very bad infestations of Eelworm this method is said to be the only effective remedy at present available.

SLUGS and SNAILS (6), (7), belong to the class of the Mollusca, which is a large assemblage of animals including such divers forms as Oysters, Whelks, Scallops, Octopi, and the familiar fossils which are known as Ammonites and Belemnites. Both Slugs and Snails differ from other Molluscs in being land and not aquatic animals. They are always provided with a pulmonary chamber, which is a kind of lung enabling them to breathe in the air. In aquatic Molluscs this pulmonary chamber is almost always absent, respiration taking place by other means.

SNAILS or Helicidæ are provided with an external spiral shell into which the animal can withdraw itself, and there are three species which are commonly met with. The Garden Snail (*Helix aspersa*, Mull.) is the largest and its shell measures about 1½ inches in diameter. It is well enough known to need no description, being easily recognisable by its brown shell marked with pale irregular lines. The Strawberry Snail (*H. rufescens*, Pen.) has a shell which seldom exceeds half an inch in diameter and is more flattened in form. It also varies in colour from dirty grey to brown or reddish-brown, often with a number of transverse streaks of a darker tint. The Wood Snail (*H. nemoralis*) has an extremely variable shell being white, grey, pinkish, yellow or brown, and is marked with one to five or more conspicuous brown spiral bands. It is, moreover, considerably larger than the Strawberry Snail.

SLUGS or Limacidæ are naked and only possess a vestigal shell, which is placed near the hinder end of the body or buried beneath the skin of the back; all the injurious species have the shell in the latter position. The situation of the shell is clearly marked externally and the area of skin covering it is known as the shield or mantle. Closely related to the margin of the latter, on the right side of the body, is the respiratory pore—a well-defined aperture leading into the pulmonary chamber. Slugs secrete an abundance of mucous, which serves to lubricate the skin; it is very tenacious and capable of being drawn out into a thread which is used as a means of descent from trees and bushes. The most injurious species are: (1) The Black Slug (*Arion ater*, Linn.) notwithstanding its name this species varies greatly in colour and may be either black, grey, reddish, or reddish brown. When at rest the animal can be further recognised by its contracted and almost hemispherical form. (2) The Grey Field Slug (*Agriolimax agrestis*, Linn.) is perhaps the most injurious species we have in this country. It is ashy-grey in colour with a yellowish or reddish tinge, and occasionally specimens have a mottled appearance; longitudinal markings are entirely absent. (3) The Black Striped Slug (*Limax maximus*, L.) is the largest of the three and may attain a length of over six inches. It is usually some shade of grey, with longitudinal markings of a darker colour, frequently black. Individuals inclining to brown or dull yellow are also not infrequently met with.

It is well known that both Slugs and Snails confine their operations to night, and are seldom evident during the day except after rain. It is consequently useless to apply remedial measures during the warm parts of the day, or in very dry weather, the evening and early morning being the most suitable times. The mucous secreted by Slugs enables them to resist the action of obnoxious substances in the powered condition, they have the faculty of crawling out of their mucous investment, and in that way leave the powdered material behind them. This mucous, however, cannot be secreted indefinitely, and if two or more dressings are applied with an interval of about fifteen minutes between each application the Slugs are usually killed. A mixture of lime and soot applied two or three times is an effective remedy, but the lime should be quite fresh and very finely powdered. According to Theobald the most effective substance is hydro-oxide of calcium, a 1 to 2 per cent. solution in water. Snails, on the other hand, are more difficult to destroy from the fact that they retract themselves into the shell and can close the mouth of the latter. In this condition they can remain completely dormant for several years. Dressings of soot is a well-known remedy against Snails, it acts as a deterrent making the plants and surface of the soil obnoxious to these animals. Nitrate of soda is an effective dressing for use on a large scale against both

Slugs and Snails and, moreover, is beneficial to the plants. Natural enemies are also an important factor: thrushes, blackbirds, starlings, and also ducks and fowl render help in keeping down an excess of Slugs and Snails.

Among other injurious animals WOODLICE (8) and MILLIPEDES (7) were also referred to but, owing to the limited space at my disposal, I must pass over these and deal with the Acari or MITES. They are classified as a group of the Arachnida, which also includes Spiders, Harvestmen, and Scorpions. All can be recognised by the presence of eight pairs of legs, the absence of feelers or antennae, and the fusion of the head and thorax into one compact region or cephalothorax. Acari are further distinguished by the abdomen not being definitely marked off from the rest of the body. The Red Spiders or Trombididae belong to this group, but the most important for our purpose are the Eriophyidae or Gall Mites. *Eriophyes ribis* (4) or the BLACK CURRANT GALL MITE is responsible for the "Big-Bud" disease which has spread throughout the country. Its presence can be readily detected by the swollen and distorted appearance of the buds which harbour the Mite. Badly infested buds seldom develop into shoots, they remain unopened and, after retaining their green colour for a time, become brown and die off. The damage is caused by the jaws of the Mite cutting through the epidermis of the delicate young leaves, followed by the inserting of the sucking tube which extracts the sap. Throughout the winter the Mites feed and shelter in the galled buds. Migration takes place from the infected buds, which open from about the middle of April until well on in June. The Mites then crawl out in great numbers in order to find new and succulent buds to serve for their future sustenance. This migration is aided by the habit the Mites possess of often attaching themselves to passing insects wandering over the twigs. By this means they become distributed to other branches and to fresh bushes. Strong winds are also a factor aiding their dispersal. Having entered new buds the Mites commence laying their eggs and thereby multiply rapidly until the end of the summer. Shoots examined during the end of August and in September, exhibit the "Big-Bud" appearance, and are filled with the new generation of the Mite, which will carry on infection for the next season. A certain number of eggs are to be found all the year round but are most abundant in the summer. Our knowledge of the life-history of this Mite is incomplete, we still require definite information as to whether the species can pass the winter elsewhere than in the buds—whether it can survive under the bark, in the roots, or beneath the soil.

With regard to remedial measures, so far as I am aware, no completely successful methods of treatment have yet been devised. Instances are known where all diseased bushes in a plantation have been cut down, the stumps and root stocks subjected to treatment, and yet the young shoots came up infested with this Mite. It is of first importance to cultivate from perfectly clean stock, and cuttings taken for setting should also be selected from such plants. Hand picking of the infected buds at the end of winter is valuable, and all buds collected should be burned as soon as possible; with badly infected shoots extensive pruning is necessary. When the bushes are very badly infected there is no remedy beyond taking up and burning them, followed by replanting with clean new stock. Spraying or dusting with a mixture of lime and sulphur during the migratory period has been recommended, but often the results are unsatisfactory. An efficient spraying mixture still remains to be discovered. Some varieties of currant are claimed to be less severely attacked than others, and among them may be mentioned the Boskoop Giant, Lee's Prolific, and Edina. Varieties claimed to be immune have been placed on the market, but whether they will remain so time alone will determine. There is a possibility that careful selection and intercrossing of likely varieties along scientific lines may lead to the production of resistant stock.

Chapter 14.

INJURIOUS INSECTS.

General observations on Insects and their feeding habits. Insecticides and their use. Earwigs. Destructive Caterpillars of Cabbage Butterflies, and the Currant, Winter, and Codling Moths. The Gooseberry Saw-fly. The Pea Thrips. Wireworms.

The next class to be considered is that of the INSECTS (9), (10),* and, viewed from our present standpoint, they are of greater importance than the whole of the rest of the Animal Kingdom. Insects can be readily recognised by the presence of a pair of antennae or feelers, six pairs of legs, and the division of the body into head, thorax and abdomen. Either one or two pairs of wings are almost always present in adult Insects. The most remarkable feature in their life-history is the fact that they pass through a series of changes which we term metamorphosis. On hatching from the egg, the first stage is the larva, which is succeeded by that of the pupa, and from the latter emerges the perfect Insect. In many Insects, however, the pupa is absent, and then there is a gradual growth from the larva to the perfect Insect. Larvæ are variously known as caterpillars, maggots, or grubs, and, being exclusively concerned with feeding, they are as a general rule more destructive than the perfect Insects. The pupa or chrysalis is purely a resting stage, no food is taken, and during this period the organs and tissues of the future Insect are gradually built up. It is of great importance

* The numbers in brackets refer to the literature given at the end of the final lecture.

to understand the method by which an Insect feeds, whether it be in the larval or adult condition. Almost all remedial measures have to be based upon this factor. We can recognise three methods by which Insects feed: (1) By means of the biting action of their jaws. (2) By means of sucking, and in this case the mouth organs are modified to form a suctorial apparatus. (3) By means of a combination of both of these methods.

Various chemical substances are used for destroying Insects and are known as *Insecticides*. Biting Insects are mainly destroyed by poisoning their food, while sucking Insects can usually only be destroyed by using contact insecticides—those which kill by means of surface contact. This method is adopted for the simple reason that we cannot poison the food when it consists of the internal juices of plants, as is the case with sucking Insects. When using insecticides the grower should proceed with caution until experience has been acquired. Also contact insecticides are liable to injure the foliage under certain conditions. Many of the insecticides that have been recommended are inefficient, while others need scientific testing to fully determine their value. Insecticides are *artificial methods of control*, but it is necessary to point out that the utilisation of *natural methods of control* should not be neglected. Natural methods consist in the preservation and increase of those organisms which are directly beneficial to man, in that they destroy the injurious forms of animal life. This latter method will be dealt with in a subsequent lecture.

The first order of Insects that I shall deal with is the *Orthoptera*, and the only member thereof that concerns us is the common Earwig (*Forficula auricularia*) (10). It is a good example of an Insect which undergoes incomplete metamorphosis. The adult Earwig lays its eggs in a group either beneath stones or in the soil. During the incubation period she guards the eggs until they hatch, exhibiting in this respect a rudimentary instance of parental care. The young larvæ are minute white creatures, with very slender forceps and no traces of wings. After they have passed through several moults rudiments of wings appear, and subsequent growth chiefly consists of an increase in the size of the Insect and the gradual development of the wings. No pupa or resting stage is passed through. The Earwig is almost exclusively nocturnal in its habits, and has been very seldom observed to use its wings in flight. During the day Earwigs hide away beneath the soil, among vegetation, under stones, bark, and in other dark situations. They cause some amount of harm to cultivated plants, particularly dahlias, but their diet may include animal matter also. Earwigs can be most readily got rid of by means of traps. Plant pots filled with straw or dead moss placed in an inverted position upon the ground, or upon stakes, are usually effective. The pots should be examined frequently, and the Insects shaken out into boiling water, or the straw and other rubbish containing them burnt.

The next order of Insects which concern us is the *Lepidoptera*. Their larvæ are known as caterpillars, while the perfect Insects are recognised as Butterflies and Moths. Butterflies can be readily distinguished from Moths by their feelers or antennae terminating in a club or knob, while those of Moths taper off to a point. Furthermore, Butterflies are diurnal while most Moths are nocturnal. *Lepidoptera* are only injurious in the caterpillar stage; the adults feed entirely upon the nectar and juices of flowers which they imbibe by means of a flexible sucking tube, and never pierce or injure the tissues of plants. Four wings are present and they are closely covered with microscopic scales which easily rub off, revealing the transparent wing membrane beneath. The eggs of Butterflies and Moths are almost always laid on or near the leaves of the plants which are to serve as food for the future caterpillars. Very few Butterfly larvæ are injurious, and only two species need concern us, viz., the Large and Small Cabbage Whites (*Pieris brassicae* and *P. rapae*) (10). The larvæ of the former species are partial to the outer leaves of cabbages, while those of the smaller species also attack turnips. Both kinds frequently devour the leaves of "nasturtiums" and other plants. When very abundant hand picking of the larvæ is the best method. The pupæ occur on palings, walls, and similar objects in the immediate vicinity, but a quick eye is needed to distinguish them, and for this reason their destruction is not likely to very materially reduce their numbers. The eggs of the Large Cabbage Butterfly are pale yellow and laid in clusters on the under sides of the leaves of the food plants. Every cluster destroyed means the reduction of a whole brood of the larvæ. The eggs of the Small Cabbage Butterfly are laid singly and, consequently, their detection and destruction is too laborious to be worth while. Insecticides are of very little value against these two species. Among Moths, the larvæ of the common Currant Moth (*Abraxas grossulariata*) (4) are very destructive in that they defoliate currants and gooseberries. The Moth is conspicuously spotted with black on a white ground, and is on the wing during July and August. The larva is similarly conspicuous, being deeply spotted with black on an ochreous-white ground, with an orange coloured line along each side. It is prevalent at the end of the summer and hibernates during the winter among dead leaves, in chinks of walls, under bark, etc. During the spring it recommences feeding and turns to the pupa in May or June. The pronounced colouration of this larva renders hand picking a very easy and effective measure. In extensive infestations spraying with lead arsenate at the end of the summer kills large numbers of the young larvæ through poisoning their food. If they are still abundant during the following spring the operation should be repeated. Since lead arsenate is a poison it must not be applied later than four weeks before the fruit is to be gathered. The grower will do best to utilise Swift's arsenate paste rather than prepare his own compound. From 8 to 10 ozs. of the paste mixed in 10 gallons of soft water is a suitable strength; weaker solutions, however, are often equally effective. The Winter Moth (*Cheimatobia brumata*) (4) does immense damage to the foliage of apple, pear, plum and cherry trees and is universally common in this country. The male is a thin-bodied brown Moth, measuring 1¼in. across the expanded wings. The female is wingless and spider-like in appearance. The Insect occurs from October until the beginning of January, the eggs are laid on or near the bases of the buds, and the green larvæ belong to the type commonly known as "loopers." They commence feeding upon the leaf buds, and then the flower buds, which they spin together with the leaves to form shelters. Later on they attack the foliage and even the fruit. During June they are fully fed and pass to the soil, where they change to the chrysalis a few inches below the surface. The most effective measure is "grease banding" the trees. Strips of grease-proof paper, 6 to 8 inches wide, and sufficiently long to encircle the trunks, should be tied tightly with string above and below, and placed on the trees during the first week in October. The most suitable height is from 2 to 4 feet from the ground. The paper is to be well smeared with cart grease, which must never be allowed to become dry. To ensure this, three applications during the season are usually sufficient. "Tree tanglefoot" may be used instead of cart grease, and has the advantage of not requiring renewal during the whole winter. By means of this device the wingless females are trapped in large numbers as they crawl up the tree trunks from the soil. If the grease bands be retained until the end of March, large numbers of females of the destructive March Moth (*Anisopteryx aescularia*) (4), which are likewise wingless, also meet with a similar fate. If the grease bands are neglected many of the female Moths succeed in making their way up to the buds to lay their eggs. When the larvæ are very abundant the only measure is to spray with lead arsenate, using an ordinary knapsack sprayer, except for very large trees, which demand a more powerful instrument. The spray should be distributed as a fine mist, as all that is needed is to render the leaves poisonous. It is not advisable to spray during blossoming, and spraying with winter washes is useless. The Codling Moth (*Carpocapsa pomonella*) (4) is one of the most important of apple pests, attacking many varieties besides the Codling, and also pears. Those types such as the Russet and Nonpareil, in which the "eyes" are more or less closed, are less susceptible than the Blenheim Orange and many others. The perfect Insect is a pretty brown Moth with coppery reflections, and measures about ¾in. from tip to tip of the expanded wings. It flies during June and July, laying its eggs singly on the young fruit, but occasionally it may select the leaves. They hatch just about the time when the petals have fallen and the fruit set. The young larvæ are whitish, pale yellow, or often pink, with the head and the shield immediately behind dark brown. They make their way to the calyx end of the fruits and gradually eat their way to the core. The entrance hole can always be detected, and through it the larvæ ejects particles of excrement to the exterior, thereby avoiding contamination of its burrow. About midsummer they eat their way out of the fruit, and if the latter are still on the tree the larvæ crawl down until they reach the trunk. In the case of fallen fruit the larvæ make their way back to the trees and crawl up the trunk. In either case when the trunk is reached they spin cocoons among loose bark, moss or lichens, and there remain dormant until the following spring, when they turn to the pupa and shortly afterwards give rise to the next generation of Moths. In a few instances two broods have been noticed to occur in one year. The attacks of this Insect cause the fruit to fall prematurely or decay rapidy when stored. As a remedial measure all loose bark, moss, etc., should be scraped off the trunks, and artificial shelters in the form of one or more bands of loose straw or old sacking should be tied round the trees, not very far from the ground. It is safest to do this in June, and the bands can be examined at leisure during the winter and burnt. By this means large numbers of the cocoons containing the larvæ are often destroyed. Fallen apples should be cleared away as soon as possible. Lofts and rooms utilised for storage should be well swept out, and the walls, floors, shelves, and window frames lime-washed. In severe attacks spraying the fruit-bearing portions of the trees with arsenate of lead is advisable, and should be carried out a few davs after the petals have fallen. The larvæ have to eat the coating of this mixture in order to make their way into the calyx, and are poisoned thereby, if the application has been successful.

The order Hymenoptera is characterised by the presence of (1) two pairs of transparent wings provided with relatively few veins, (2) biting and sucking mouth organs, and (3) complete metamorphosis. The Sawflies are the only group that directly concerns us, and they may be easily separated from other Hymenoptera by the absence of a "waist," or constriction of the body. The Gooseberry Sawfly (*Nematus ribesii*) (4), (10), is very destructive to red currants and gooseberries, but seldom harms black currants. The perfect Insects appear in April and May; they have yellow bodies marked with black, and measure about $\frac{3}{4}$in. in wing expanse. The eggs are laid in neat rows along the veins on the undersides of the leaves of the host plant. They hatch into bluish-green caterpillars spotted with black, and also marked laterally with blue and yellow. Unlike Moth caterpillars they possess ten pairs of feet, and when fully grown measure about $\frac{3}{4}$in. long. The bushes may be very quickly stripped of their foliage by these larvæ, and the fruit are not exempt from attack. About the beginning of June, they enter the soil beneath or near the bushes in order to spin their brown papery cocoons within which the pupal stage is passed. From ten to twenty-one days, according to the temperature, are passed beneath the ground until the flies emerge, and there are three broods during the year. The autumn larvæ pass the winter in their cocoons, turning to pupæ early the following spring. Leaves bearing the eggs of this Insect should be destroyed whenever met with, while hand picking is an effective means of getting rid of the larvæ if done thoroughly. In the autumn wholesale removal of the surface soil beneath and around the bushes to a depth of five inches is valuable. It needs to be buried in a deep hole dug for the purpose. By this means the winged Insects are buried beneath the earth and perish on emergence from the pupæ. Fresh soil and manure should be placed round the bushes. Spraying with arsenate of lead is an effective poison for the larvæ, and can be applied any time they are abundant after the fruit has been gathered.

The Thysanoptera form a very small order of Insects, comprising only those minute forms which are known as "Thrips." They are provided with four strap-like wings with long "fringes" all round, and are entirely suctorial in their feeding habits. The Pea Thrips (*Kakothrips robustus*) (11) is a dark brown Insect, about $\frac{1}{14}$in. long, attacking edible peas and broad beans, often causing much damage. The adults occur from May until August, and the eggs are laid within the flowers on the stamen sheath or on the young developing pods. The larvæ resemble the adults with the exception of having no wings; when fully fed they descend to the ground, penetrating to a depth of 3-12in. They remain in the soil until spring, when the adults emerge from the pupæ, there being thus only one brood in the year. Both the larvæ and the adults are injurious, and in bad attacks no pods are formed or are curled and undersized. The terminal buds and shoots may also be infested, and damage is stated to be most severe in light soil. This Insect sometimes spoils a whole crop, and no varieties appear to be immune, but it has not so far been found on sweet peas or scarlet runner beans, though they are mentioned as host plants in France. Control is difficult to achieve, but early sown plants are less severely attacked. Spraying is useless when the Insects are in the flowers as it does not reach them in that situation. When they feed openly on the pods in large numbers, spraying by means of contact insecticides is then likely to be effective. A mixture of 1 lb. soft soap in 10 gallons of water is a cheap remedy and worthy of a trial, or better still 3 lbs. tobacco powder (or 1 lb. of Voss' tobacco extract), ½ lb. soft soap in 10 gallons of water. Treatment of the soil during the winter does not offer much promise on account of the depth to which the Insect descends.

Coleoptera or Beetles are characterised by the anterior pair of wings being modified to form horny sheaths which usually cover the upper side of the abdomen. They are exclusively biting in their feeding habits and pass through a direct metamorphosis. Wireworms (12) are the larvæ of Click Beetles (family Elateridæ) and are known to attack almost any kind of crop. They are more especially pests of the agriculturalist, though tomatoes, strawberries, potatoes, and other vegetables are liable to suffer injury when grown in gardens or allotments. Three years and even more are believed to be spent in the larval stage and, owing to their resistant coats, these larvæ are notoriously difficult to destroy, no effective remedy having so far been discovered. Lures in the form of slices of potato, carrot, or beet buried an inch or more beneath the soil when Wireworms are prevalent, often attracts considerable numbers which can then be readily destroyed. The lures should be examined twice a week and the spots marked with pegs. In bad infestations crude powdered naphthaline dug well into the soil in the autumn or early spring is worthy of trial. Gas lime, lime, or salt are of very little use. In the case of a badly infested potato crop there is no remedy beyond digging it up. Infested soil should be well turned over, exposed, and broken up. Birds then have easy access to the Wireworms and material benefit is often derived by adopting this measure.

Chapter 15.

INJURIOUS INSECTS (Continued).

Crane Flies; the Pear Midge; the Celery Fly; the Cabbage Root Fly; the Onion Fly; the Narcissus Fly; the House Fly.

In this lecture we are concerned with the order Diptera which comprises the true Flies. These Insects can be recognised by the presence of a single pair of wings, the hinder pair being absent, and only represented by curious knobbed organs known as halteres or balancers. The larvæ of the Diptera are devoid of true limbs and are commonly known as maggots. A pupa stage is always present and, in a very large number of species, the skin of the larva is retained, forming a hardened case or puparium enclosing the true pupa. Although no adult Flies are directly injurious to vegetation, certain kinds such as Mosquitoes, Sand Flies, and Tsetse Flies are injurious to man. They pierce the skin in order to suck his blood and thereby act as carriers of the organisms of some of the most virulent diseases.

Some of the most familiar of the larger Flies are the "Daddy Long Legs," or Crane Flies (*Tipula oleracea* and allied species) (13). Although they are commonly pests of our meadows and cereal crops nevertheless they not infrequently injure turnips, peas, beans, cabbages, hops, dahlias, carnations and other garden plants. Their larvæ are commonly known as "leather jackets," and when fully grown they attain a length of 1½in. In colour they are dull grey or brown and are not unlike fragments of small dark twigs. They live exclusively beneath the soil and, although they devour a considerable amount of dead vegetable matter, their staple diet seems to consist mainly of the roots of various plants. They are specially common in damp parts of meadows, wherever there is rank herbage, especially grass. Leather Jackets feed mostly at night when they often come to the surface of the soil. When fully fed they turn to elongate pupæ, which force their way to the surface of the soil, where they may be often seen projecting for about half their length vertically out of the ground. The Crane Flies issue late in the spring and lay their black spindle-shaped eggs on or near the surface of the ground. These eggs give rise to the Leather Jackets which eventually transform into a second brood of Flies appearing in great numbers during August and September. The late brood of Crane Flies is always more abundant than the spring one, and their eggs develop into larvæ which remain beneath the soil all through the winter. They are often abundant in garden lawns in low-lying districts, and it is advisable in such cases to roll heavily and keep the grass closely cut. Rolling at the proper seasons crushes the pupæ and if done regularly after dark a large number of the larvæ would probably also be destroyed. When present in large numbers thorough turning of the soil in the autumn and winter renders the larvæ accessible to rooks, starlings, and other birds which prey upon them in large numbers. A good soil dressing is 1 to 2 cwts. of nitrate of soda to the acre, and although Leather Jackets are susceptible to its effects, they are by no means always eradicated. Gas lime is only doubtfully effective. Theobald advises the use of traps of partially buried turf as a device for enticing the Flies to lay their eggs, and also to attract the larvæ from the adjacent soil. To arrest local attacks in parts of lawns and beds ½ oz. of carbon bisulphide to each square yard injected by means of a Vermorel injector, or other suitable instrument, to a depth of about 6 inches is usually quite effective.

The Pear Midge (*Diplosis pyrivora*) (4) is one of the worst enemies of pear growers. All varieties appear to be attacked by this Insect, but it is not known to affect any other kind of fruit. The adult Midge is only about ⅛in. long and is blackish-grey or black in colour; the female can be distinguished from the male by the abdomen terminating in a long pointed egg-laying instrument or ovipositor. The Flies or Midges first appear during April just about the time when the pear blossoms commence to show their petals, and are to be found up to about the middle of May. The eggs are laid within the blossoms, and when the latter are unopened the petals are stated to be pierced by the ovipositor and the eggs deposited on the anthers. In opened flowers the pistil is pierced and the eggs inserted therein. The larvæ are very minute white or pale yellow maggots and only attain a length of about $\frac{1}{7}$ in. when fully grown. They feed within the developing fruitlets eating out their centres and leaving behind them a mass of decomposing tissues. As many as ten, twenty, or even thirty of these maggots may be found within a single fruitlet. The attacked fruits usually swell more rapidly than sound ones, and can be readily recognised on the tree by being often twice the size of the latter and more or less distorted. When mature the maggots leave the fruitlets either before or after the latter have fallen. In either case they crawl out from their shelter and exhibit curious jumping movements until they bury themselves in the ground beneath the trees. Here they spin delicate cocoons of a dirty creamish colour, and hibernate therein throughout the rest of the year until the following spring. Unfortunately there is no universal measure for dealing with this Insect. All infested fruitlets should be collected and destroyed before the larvæ leave them. In very bad infestations it is better to gather and destroy the whole crop. If an orchard be well stocked with poultry in the spring when the Flies appear and also in June when the maggots reach the earth, material benefit is very often attained. Removal of the surface soil containing the pupæ is scarcely a practicable measure. In America the application of Kainit is recommended. If well spread at the rate of half a ton to the acre around the trees it is stated to destroy the larvæ and pupæ in the soil. When the larvæ are leaving the fruitlets 5 cwt. to the acre is said to be sufficient to destroy them. In this country Kainit has been very little used, and reports as to its value are conflicting, nevertheless, it fully merits a fair trial.

The Celery Fly (*Acidia heraclei*) (17) is a pretty brownish Insect with mottled ornamental wings. It may appear at the end of April but is commonest in June and there are several broods in the year. The eggs are laid on the leaves of celery and also parsnips. The larvæ are white or greenish maggots which mine the leaves of those plants. There may be several larvæ in a leaf and by their devouring the middle layers of tissues transparent patches result, covered only by the upper and lower epidermis. After a while these patches become brown and the functions of the leaves are very greatly reduced. The larvæ turn into yellow or yellow-brown pupæ shaped somewhat like minute barrels, and are found sometimes in the leaves but mostly in the soil. The Insect winters in the pupa buried a few inches beneath the ground. This fact is of value with regard to preventive measures and deep trenching in winter between the original rows and burying the soil therein containing the pupæ will destroy many of the Flies which would otherwise emerge. The mixing of gas lime with the soil adds to the effectiveness of this measure. Screening the young plants with cheap muslin when first put out protects them from the Flies until they are well established, and less liable to suffer severely from the Insect. Picking off and burning the mined leaves will destroy the larvæ, but in bad attacks the depletion of the foliage by this method would be too great. All infected celery tops should be burnt and not cast aside on refuse heaps. Theobald recommends spraying with nicotine; a useful formula is ½ oz. of 98 per cent. nicotine, and ¼ lb. of soft soap to 10 gallons of water. Various preparations of nicotine are obtainable and so long as the above proportions are maintained it matters very little which is used (15). It is best to spray in the evening and when the foliage is not too dry, the spray is said to soak through the epidermis and kill a large number of the larvæ.

The Cabbage Root Fly (*Chortophila brassicae*) (7) is one of the worst pests of cabbage and cauliflowers, and may also attack radishes, turnips, swedes and stocks. Growth of the affected plant is checked, the leaves flag and discolour, the roots are largely destroyed, and the plants die. The Fly is an ashy-grey Insect not unlike the House Fly in general appearance and measures about ¼in. long. The winter is passed through in the pupa stage and the first brood of Flies appear in April or the beginning of May and there are most probably three generations in a year. The eggs are visible to the naked eye, and are laid close to, or on the plant, usually just below the surface of the soil. The larvæ are typical Fly maggots, white or pale yellowish, and about ¼in. in length when mature.

They commence injury by gnawing the outer layers of the young roots, afterwards making tunnels inside the main root; they may also invade the lower part of the stem. The pupæ are about $\frac{1}{5}$ in. long, oval in form, a light or dark brown and are found in the soil close to the plants. As regards preventive measures early plants have the best chance of success as they become well set before the bulk of the Flies appear. Earthing the soil around growing plants is valuable as it causes the development of fresh rootlets, which serve to replace those already destroyed by the maggots. A cupful of paraffin well mixed with each bucketful of sand, sprinkled round the plants once a week until good growth is made, is to be recommended and it acts as a deterrent, driving the Flies elsewhere. Dusting the young plants with soot is said to be effective and is well worth trial. In America tarred felt paper discs, slipped round the stems of the young plants and pressed flat on the ground are strongly recommended. They are said to afford efficient protection to young plants against the Flies laying eggs thereon. Experiments are being conducted under my direction to test the value of these discs, and if they prove satisfactory, their low cost and the simplicity of the method will argue strongly in their favour. When the crop is infested much benefit is derived by pulling up and burning all infected plants as soon as noticed. Furthermore, all cabbage stumps should be uprooted straight away and not left to decay; by these means large numbers of larvæ are destroyed which would otherwise escape into the soil to pupate. In very severe infestations I would strongly advise discontinuing growing cabbages for one year, and replacing with peas and beans or other distantly related crops. Unless some such course be taken bad infestations may continue for several years in succession, owing to the large number of pupæ the soil contains during the winter, after the season is over. Such pupæ are very hard to get rid of as soil dressings such as lime or gas lime are of very little value. Digging over the soil exposes considerable numbers of pupæ to the attacks of insectivorous birds, while over large areas deep ploughing might possibly effectively bury a large proportion of them.

The Onion Fly (*Hylemia cepetorum*) (17) is closely related to the Cabbage Fly and is a common pest wherever onions are grown; it is a greyish Insect very like the

Cabbage Fly. The Flies are common in April and May laying their eggs on the necks of onions or on the leaves just above the soil surface. After about a week, the eggs hatch into larvæ which become fully grown in three to four weeks, and are then about ⅓in. long. They turn to brown pupæ in the soil, though a few may remain in the bulbs, and the Flies commence to appear about fourteen days later. There are several broods in the year though the exact number has not been determined; the winter is passed as pupæ which give rise to the early Flies of the next year. In the earliest indications of an attack the first leaves become yellow and then whitish, followed by other leaves behaving in a similar manner. Very young plants are usually nearly eaten through just above the forming bulbs, and the larvæ migrate through the soil to attack fresh plants. As the onions increase in size each may shelter a number of maggots which devour the interior and render it rotten. As regards remedial measures insecticides are useless against the maggots on account of their burrowing habits. All infected onions should be pulled up and burnt. Earthing up the young plants is valuable as it protects the forming bulbs. Early sowing is also to be recommended in order to get the plants well started before the Flies appear; or the seeds may be sown under glass February and planted out in April. Trenching and burying the soil containing the winter pupæ as in the case of the Celery Fly, should not be neglected. Various substances are also advised in order to deter the females from laying their eggs, and one or other of the following methods are useful. Watering, or better still, spraying the bases of the plants with an emulsion consist- of two to three pints of paraffin and 1 lb. of soft soap dissolved in one gallon of boiling water. To this pour seven to eight gallons of soft water. Add the paraffin while the soap solution is hot and churn the mixture *very thoroughly* by syringing it back into itself so that no free paraffin remains on the surface. A mixture of one bushel of soot to two of finely powdered lime is also recommended. In America they advise a mixture of carbolic acid and lime. Three pints are slaked with a gallon of water and a tablespoonful of crude carbolic is added afterwards. This should be well watered round the bases of the plants.

Growers of bulbs often lose many plants from the

Narcissus Fly (*Merodon equestris*) (14), which is a large hairy Insect marked very like a small Bumble Bee. It appears in spring and early summer up to July, flying in the sunshine over the beds. The eggs are laid on or near the leaf bases or on the necks of the bulbs if the latter are exposed. Narcissi and Hyacinths are the bulbs chiefly attacked. The method by which the young larvæ enter the bulbs is doubtful; they either penetrate between the scales of the neck or crawl outside to the base of the bulb and then gnaw their way within, or possibly both methods may occur. When fully grown the larvæ measure $\frac{3}{4}$in. long and in this stage they pass the winter, usually turning to the pupa in the spring, either in the soil or sometimes in the bulbs. The life-history is said to occupy two years, but this is probably erroneous. The presence of these larvæ can be usually detected by gently pressing the bulbs, the infected ones being less hard, but it is often impossible to be quite sure without cutting open the bulb. Before planting, or just after lifting, all infected bulbs should be burnt, and any bulbs, concerning which there is the least suspicion, should be steeped for an hour in water at 110 deg. F.; if this temperature be not exceeded no harm should accrue to the bulbs, while any maggots present are said to die afterwards as the result. Possibly a lower temperature is effective and growers are advised to determine this point for themselves. Any bulbs that fail to appear or undergo very little growth in spring should be dug up and destroyed as soon as possible.

The House Fly (*Musca domestica*) (16) although quite harmless to vegetation is of great importance economically. Its eggs are usually laid in fermenting accumulations of horse manure, but may be also deposited in decaying vegetable refuse, ash-pit contents and other substances. The female Fly lays upwards of 120 to 150 eggs at a time, and each is capable of laying five to six such batches. The length of the complete life cycle depends very largely upon temperature, and during hot weather it may only occupy three weeks from the time the eggs are laid up to the time when the resultant Flies emerge. Certain of the late autumn Flies survive the winter and give rise to the maggots in the following spring; the Flies appear in their greatest profusion during August and September. The House Fly is injurious to man in acting as a carrier of disease germs, and it is specially concerned with the spread of infantile or summer diarrhœa and typhoid fever. It is, therefore, of prime importance to give the Insect no opportunities for breeding and thereby providing a check upon its abundance. All accumulations of manure and refuse should be removed *at least* once a fortnight, or more often if possible. The adoption of closed ash-bins excludes the access of the Flies to their contents, and are most effective in this respect. Accumulations of farm manure provide nutriment for enormous numbers of House Fly maggots. Experiments on a large scale are being conducted both in this country and America for the purpose of rendering manure heaps repellant to the Flies and their maggots and, at the same time, still retaining their valuable fertilising properties. When troublesome in houses the House Fly can be readily poisoned by using one teaspoonful of formalin added to a teacupful of water poured into a soup plate. The mixture should be sweetened with a little sugar or should contain about 25 per cent. of milk. If placed at night large numbers of the Flies will partake of it in the early morning and are poisoned thereby. The mixture also has the advantage of being too weak to be harmful to human beings or domestic animals.

Chapter 16.

INJURIOUS ANIMALS (Continued).

Aphides and their life-histories; preventive and remedial measures. The Apple Sucker. Scale Insects. Greenhouse Pests and Fumigation Methods.

The present lecture is devoted to a consideration of certain injurious Hemiptera. Members of this order of Insects are characterised by the presence of a jointed rostrum or beak, enclosing two pairs of stylets used for piercing the tissues of plants and imbibing sap therefrom. Nearly always four wings are present, the young resemble the adults in general form, and a pupa stage is almost always absent. The family of the Aphididae is of great importance, including as it does the "Green Fly" or "Plant Lice." Aphides may draw the sap from all parts of plants, even the roots, and the injuries they cause are often great. They bear near the end of the body a pair of tubes, which secrete a substance commonly termed "honey dew." This accumulates on the leaves, blocking up their stomata, and also provides nutriment upon which various Fungi develop. Aphides undergo a remarkable life cycle. In the autumn we usually find the fertilised winged females. The eggs laid by them develop the following spring into wingless females. These latter breed with great rapidity by parthenogenesis —i.e., without the agency of the males, none being present. Eggs are not laid but living young are brought forth, and this goes on for several generations until the summer. Winged females then appear but there are still no males, and living young continue to be produced. After a variable number of generations of this kind, winged males and winged females become evident, and the eggs laid by the latter give rise to a similar cycle in the following spring. Some Aphides are restricted to a particular species of plant, while others have alternate hosts. Thus the Hop Aphis winters on damson and flies to hops in the spring. The Elm Aphis goes to the roots of *Ribes*, the Mealy Plum Aphis to rushes and aquatic grasses, and the Bean Aphis to mangolds, poppies, dock, etc. Some of the most destructive Aphides are the Bean Aphis (*Aphis rumicis*), Currant Aphides (*Rhopalosiphon ribis* Linn. and *Myzus ribis* Linn.), Hop and Damson Aphis (*Phorodon humuli*), Apple Aphides (*Aphis pomi* De Geer., *Aphis sorbi* Kalt., and *Aphis fitchii* Sand.), Plum Aphis (*Aphis pruni* Réaum.), Cabbage Aphis (*Aphis brassicae* Linn.), Turnip Aphis (*Aphis rapae* Curt.), Rose Aphides (species of *Siphonophora*), Woolly Aphis (*Schizoneura lanigera*), and others. In dealing with these pests it is important to remember that when using insecticides contact insecticides only are of use. Insecticides frequently do not destroy the eggs and, notwithstanding spraying, fresh broods appear from the unaffected eggs. When the leaves of the host plant are curled insecticides are of little value, as they do not reach the Aphides within. Frequently the undersides of leaves alone shelter the Aphides, and spraying must be adjusted so as to reach them. The earlier measures are applied after the appearance of Aphides, the better the chances are of success, before the latter become numerous.

The Bean Aphis (17) is usually black and very conspicuous; it especially attacks broad beans. It appears when the beans commence to bloom and attacks the heads. It breeds rapidly, covering the plants with a black sticky mass which gradually extends downwards over the stems and leaves. A simple and effective measure is to pick off the infested tops as soon as any Aphides are seen thereon, and drop them straight away into a pail of lime. In bad infestations spring spraying with a knapsack sprayer is necessary. Two applications are desirable and are usually successful. The Cabbage Aphis (17) may also infest swedes and turnips. It usually appears about May, but evidences of injury are not generally noticeable until June, when the leaves begin to show blister-like areas on the upper surface, while the Aphides are to be found in the corresponding hollows on the undersides of the leaves. The leaves become yellow and discoloured, and in late summer the plants may swarm with the Insects. In the early stages of attack benefit is derived by cutting off the blistered or yellowish leaves and destroying them. Later on dusting with soot is worthy of a trial, and spraying is practicable on a small scale in garden plots. All methods of cultivation tending to produce vigorous growth are serviceable, and copious watering in dry weather, which favours Aphid multiplication, is of great value. *Aphis pomi* and *A. sorbi* (4) which attack the apple, puncture the leaves and cause them to curl and become discoloured, while *A. fitchii* attacks the blossoms and buds, but does not usually cause leaf curling. For all three species it is important to spray about the middle of April, when the eggs have hatched and the young are most vulnerable. The Rose Aphides are familiar to every gardener, and there are three species commonly met with. *Siphonophora dirhoda* Wlk. is stated to migrate to grasses, Polygonum and wheat, *S. rosae* Reau. to teazles, while *S. rosarum* Wlk. appears to have no alternate host. If only the latter species be present one or two early sprayings are sufficient, but with the other two species additional applications are sometimes necessary owing to fresh infections from their other plant hosts. Paraffin should never be used on rose trees, and only ½lb. of soft soap should be mixed to 10 gallons of water in the quassia wash referred to further on. When only affecting a few twigs here and there, Rose Aphides can be readily killed by momentary immersion in a vessel of water just too hot to keep the hand in, without injury to the plant (10). Of the Currant Aphides (4), *R. ribis* produces reddish blister-like galls on the surface of the leaves, while *M. ribis* causes the leaves to curl up especially those on the terminal shoots. Both species as they become numerous are difficult to deal with, as they are protected in the hollows of the blisters on the undersides of the leaves, or within the curled up leaves. One of the effects of their presence is the frequent falling of the fruit before maturity. Both species deposit their eggs under the broken rind or upon it, chiefly on twigs of the previous year's growth. Both currants and gooseberries are attacked, and *M. ribis* especially frequents black currants. Early spraying in April is the best measure, and care must be exercised in order that the fluid reaches the undersides of the leaves.

The Plum Aphis (4) appears before the buds open, and the parent form may be found in March. They are dull fat purple Insects, while the young are olive green at first, becoming purple later on. The latter attack the young unfolding leaves and soon cause them to curl, not only those of plum and damson, but also allied fruit trees. Spraying should take place as soon as the Aphides are noticed and before the buds are open, if possible, as the Insects are then most readily destroyed. Further spraying late in September and in October helps to kill off the egg-laying females.

The Woolly Aphis, or American Blight (4) is a universal pest of apple in this country. By constant sucking of the sap it lessens the vitality of the trees; their punctures in the bark and young wood cause abnormal growths of soft tissue which form characteristic rounded swellings. Later on these swellings split and from them arise large rugose deformities often ascribed to "canker." These wounds further predispose the trees to the attacks of fungus enemies. Under ground this Insect further causes gall-like swellings on the roots. As a result of Wooly Aphis attacks, young trees may die, stunted trees often result, and the fruit is deficient and of poor quality. The parent wingless Aphides are reddish or purplish-brown, and are invested with a white wooly substance. Living young are produced and become similarly invested with this white material, forming conspicuous objects on the branches of the trees. The wingless egg-laying females and winged males occur in autumn. Each female is very small and lays a single egg near the foot of the tree, and the egg hatches the following spring. Winged parthenogenetic females appear to be rare and are seldom met with. In the winter the Insect lives in the adult state on the bark, or in the roots below ground, and also in the egg stage. The possibility of resistent varieties of apple is worthy of attention, especially as in Australia the roots of apples grafted on to the Northern Spy and Majetin (an English apple) are said to be proof against this Insect. Spraying with soft soap and quassia is an efficient summer treatment, but the solution must not be spared, and force is necessary or the wooly covering of the Aphide will not be wetted. The only way of getting rid of the root forms is by injecting bisulphide of carbon. For an average-sized tree four 1 oz. injections into the soil 2 feet away from the trunk are sufficient. The fluid must not reach any of the larger roots and, moreover, it is very poisonous and highly inflammable. If summer spraying is not sufficient, a winter wash, as detailed in Leaflet 34 of the Board of Agriculture, is advisable. Banding the tree trunks in early spring is said to give encouraging results, and several cases have been reported of large numbers of Aphides migrating from the roots, being trapped on these bands as they were ascending the trunks. "Tree tanglefoot" is best for this purpose.

As regards preventive and remedial measures (4, 15) against Aphides there are three seasons of application. (a) In autumn to kill off the egg-laying females. The leaves are then of much less value, and it matters very little if they are injured. Thorough spraying with a mixture of 1 pint paraffin and 1½lbs. soft soap added to 10 galls. of soft water, which should be made up in the manner suggested in the previous lecture for dealing with the Onion Fly. In the case of Currant Aphides heavy pruning is valuable, as the eggs are present in large numbers on the shoots. All prunings should be taken away and burnt. (b) Winter measures: these consist of using sprays, which have the effect of sealing up the eggs with a coating through which the young Insect is unable to make its way. A good mixture recommended by Theobald consists of 1 cwt. of fresh lime, which should be gradually slaked, and mixed with 100 galls. of water in which 30lbs. of salt have been dissolved. The addition of 5lbs. of water glass is stated to be an advantage, though not essential. Failure in obtaining satisfactory results are usually to be traced to want of care in starting with freshly-burnt lime, or in slaking this. It is best used as a late winter wash, as its effects wear off owing to weather action if it remains on the trees all through the winter. This wash is useful in sealing up the eggs of the Apple and Plum Aphides, and may also be used for the same purpose against the Currant Aphides if pruning has not been done. (c) Spring spraying, which should be done as early as possible. A useful mixture for most Aphides is made up by boiling for 2 hours 1lb. of quassia chips (which must be quite fresh) in just sufficient water to keep liquid. This solution should be strained, and then well mixed with 10 galls. of warm water, in which 1lb. of soft soap has been previously dissolved. Washes containing paraffin are liable to injure the delicate spring foliage, and if adopted should be used in weak strength. When the leaves commence to curl it is waste of most insecticides to use them; nicotine and soft soap compounds are the only ones which offer any prospect of partial success. Summer spraying is not to be recommended except in the case of the Woolv Aphis.

Another family of Hemiptera, viz., the Psyllidae, or "Jumpers," includes the well-known Apple Sucker (*Psylla mali*) (4), which is a not distant relation of the Froghoppers, or "Cuckoo Spit" Insects. The adult Apple Suckers are small, greenish-yellow, four-winged Insects about ⅛in. long. They are to be found flying and leaping about apple leaves from May until the autumn. They lay their eggs from late September until early in November, usually on the bark of one-year shoots below buds or around leaf scars. The eggs are orange, darkening to orange-red, and hatch in April. The young larvæ are very minute, flattened, dirty-yellow Insects with red eyes, and they secrete a waxy substance from the hind end of the body. As soon as the buds open they congregate within, while the older larvæ and nymphs are to be found on the undersides of the leaves. Damage is caused by the larvæ and nymphs piercing the young leaves, which become brown as if frost-bitten, and wither. In this way floral and leaf buds are destroyed wholesale. The adults cause a relatively small amount of injury. Undoubtedly the most vulnerable period in the life-history of the Insect is when the young larvæ emerge from the egg; for various reasons, however, spraying at this time presents difficulties. Owing to the waxy substance which the larvæ exude, sprays should contain a wax solvent which, however, is liable to damage the developing leaves. Furthermore, the larvæ very soon enter the buds, and then spraying is of little value. The larvæ emerge from the eggs during several weeks, and the time appears to vary in different kinds of apple; for this reason several sprayings are necessary. The best period for dealing with this species is apparently February and March, 2-3 weeks before the buds open. A wash of lime and salt recommended by Theobald appears to be an effective measure. It should be used on dry days, and is made by taking 1-1½ cwts. of best quality lime, slaking it gradually, and mixing it with 100 galls. of water in which 30-40lbs. of salt have been dissolved. The mixture should then be strained through sacking or other material before being used. Lime washes are useful in other ways and beneficial to the trees. This mixture coats the eggs and prevents them from hatching, and also seals up the buds protecting them from any larvæ that may be hatched. In the autumn, spraying with paraffin is also valuable—it should be done as soon as the fruit have been gathered. so as to kill the females before the eggs have been laid. Paraffin 4pts., soft soap $1\frac{1}{2}$lbs., and water 10 galls., forms a suitable mixture, but a stronger proportion of paraffin can be used at this time of the year if desirable. Heavy spraying is necessary, not only on the leaves but also on the clouds of Apple Suckers which are disturbed and take to the wing.

The family of the Coccidæ, or Scale Insects (4), include some highly injurious members. The females are degenerate, and spend their life hidden beneath a scale-like covering formed by the cast skins of the larvæ, cuticular secretions, and other means. The males live under smaller but similar scales, and when mature issue as minute winged Insects. The Mussel Scale (*Lepidosaphes ulmi = Mytilaspis pomorum*) is the commonest and best known species, and is an abundant pest of apple trees. During the spring and summer it sucks the sap, and passes the winter in the eggs which are hidden beneath the parent female's scaley covering which still remains. One or other of the Woburn washes (4, 15) have given good results in destroying the eggs of this Insect. They can be used any time during the winter, and the 10b formula given by Pickering and Theobald (15) is as good as any. The Brown Scale (*Lecanium persicæ*) often attacks currants and gooseberry, and the Woolly Currant Scale (*Pulvinaria vitis*) both currants and vines. For use against these two Scale Insects the wash 10b referred to above, is generally recommended and should be well sprayed over the bushes during January. With regard to Scale Insects on vines different treatment is necessary, and the same applies to Mealy Bug and to the Greenhouse White Fly. The latter belongs to an allied family of the Hemiptera, viz., the Aleurodidæ, and is a minute moth-like white Insect with four wings. Its larvæ are green and resemble young Scale Insects, and are destructive to tomatoes and other greenhouse plants. For

Insects in greenhouses which attack the leaves of plants, and do not live in the soil, fumigation with hydrocyanic acid gas is the best general remedy. It is made up as follows:—2 ozs. cyanide of potassium, 4 ozs. sulphuric acid, and 8 ozs. of water. Estimate cubic space of greenhouse and use this preparation for each 1,000 cubic feet of space, doubling the quantity for 2,000 cubic feet, and so on. First close up all windows and doors and any holes should be securely filled up. One window should alone be left open for purpose of introducing the mixture, which is extremely poisonous to man and all forms of animal life, but does not injure plants. Use at *dusk* when the plants are *dry*, and the temperature of the greenhouse should *not exceed 60 F.*—the best temperature is 50 F. Do not use when there is a bright light (daylight). Pour the water into a jar first, and then add the acid slowly. Wrap the cyanide in a piece of blotting-paper and drop into the jar with a suitable instrument from outside through the window of the greenhouse. Then close the window and leave for at least 1 hour. Afterwards open all doors and windows from the outside, but do not enter the greenhouse until another hour has elapsed. Cost about 6d.

Chapter 17.

BENEFICIAL ANIMALS, &c.

Birds. The Testacella Slug. Earthworms. Centipedes. Beneficial Insects. The Isle of Wight Bee Disease. Literature bearing upon Economic Zoology.

Beneficial animals are on the whole less widely known than injurious species and, unlike the latter, they should be encouraged so far as may be possible and under no circumstances be destroyed. BIRDS (1, 2) occupy a very high place as benefactors of the farmer and horticulturalist. There are a number of kinds which cause little harm, and are in many cases, directly beneficial. Among these may be cited the Fieldfare, Hedge Sparrow, Wrens, Long-tailed and Coal Tits, Wagtails, Pipits, Swallow, Martins, Swift Cuckoo, Plover, and many others. Tits, for instance, are particularly partial to Scale Insects, as well as Aphides and other Insects. The Willow Wren devours large numbers of various Insects, and Newstead records one whose crop was filled with larvæ of the Winter Moth, another with Aphides, and three other individuals contained large numbers of Fly Maggots. Pipits, the Cuckoo, and Swift are also prominent devourers of Insect life. Occasionally, however, one or other species may be observed devouring fruit, the Mistle Thrush, for instance. but I believe in such cases the small amount of harm they cause is negligable compared with the benefit they confer. In this country much could be done along Continental lines towards encouraging beneficial Birds, especially by means of nesting-boxes, which help to ensure their presence in desired areas (19). The Department of Economic Zoology in this University has achieved some good results in the larch plantations of the Manchester Corporation catchment area around Lake Thirlmere. Here the Larch Saw-fly is most destructive, and by fastening on the trees large numbers of nesting-boxes suitable for Tits, which prey on the larvæ of this Insect, direct benefit has resulted.

Among MOLLUSCS the carnivorous Slug *Testacella* alone is valuable. It is a dirty white or yellowish form with a small shell situated at the hinder end of the body. In injurious Slugs the remains of the shell is always very far forwards and in close relation to the respiratory pore. It is local in this district, but has occurred in several localities. *Testacella* feeds upon other Slugs, Worms, and dead animal matter, and causes no harm to vegetation.,

EARTHWORMS are true segmented worms and differ from Eelworms. In the course of burrowing Earthworms let in moisture and air, the subsoil becomes loosened, and direct benefit therefrom is derived. Large quantities of earth are swallowed by them, which they pass out of their bodies in the form of "worm casts," commonly seen on lawns and flower-beds. In this manner fresh soil is constantly being brought to the surface, and at the same time Earthworms draw numerous leaves and other kinds of vegetation into their burrows which they consume in appreciable quantities. Humus is partly due to the activities of Earthworms—the bringing of soil to the surface and the burying of vegetable material is an important factor in the humus formation, which adds to the general fertility of the land. Darwin calculated that as much as ten tons of soil per annum passes through the bodies of Earthworms and is brought by them to the surface, over each acre of good land.

MILLIPEDES (7) belong to the class of Myriapoda which are more closely related to the Insecta than to any other group. Like the Insects, Myriapods are provided with a single pair of feelers or antennæ, but they always possess more than six pairs of legs, usually a large number, and never acquire wings. The two main groups of the Myriapods are the Centipedes or Chilopoda and the Millipedes or Diplopoda. The former, which are beneficial rather than injurious, have a somewhat flattened body and a single pair of legs to each segment. So far as known they feed upon small worms, slugs, insect larvæ, etc., and also upon dead animal matter. The Millipedes may be readily recognised by the possession of two pairs of legs to each body segment. They occasionally cause injury to potatoes and other root crops, and are often known as "false wireworms."

Among INSECTS (10) many kinds are beneficial and may be divided into two groups. (1) Predaceous Insects which attack other Insects directly and devour them, and immediate benefit is derived from their action. Among these may be mentioned Ground Beetles, Lady-Birds and their larvæ, the larvæ of Hoverer Flies, Wasps, Robber Flies, and others. (2) Parasitic Insects which deposit their eggs in the bodies of other Insects or in their immediate neighbourhood. They pass the greater part of their life within their hosts, whose death they sooner or later bring about. Parasitic Insects amount to tens of thousands of species and constitute Nature's most effective method of control over the excessive multiplication of Insect life. They are almost exclusively confined to the orders Hymenoptera and Diptera. One or two of the most important families of beneficial Insects may be briefly mentioned.

GROUND BEETLES, or Carabidæ, form a very extensive family, comprising a large number of British species. They can be recognised by their hard convex bodies, long thin legs and slender feelers, and their very active running habits. The majority are beneficial, devouring other Insects, Molluscs, and dead animal matter. Some few, however, are known to be injurious, but it is a safe rule never to destroy these Insects when seen, with the exception of those frequenting strawberry beds, which usually pertain to a harmful species. The larvæ of Ground Beetles have very similar feeding habits to the adults. They are elongate fleshy creatures, with a definite hard, brown head and first segment, three pairs of legs and two horn-like processes, either long or short, at the hinder end of the body. They frequent the soil, can run freely, and their pupæ are found buried some inches below the surface. LADY BIRDS are beetles belonging to the family of the Coccinellidæ. We have a number of species in this country, and one of the commonest and best known is the Seven-Spot Lady Bird

(*Coccinella septempunctata*). Both as larvæ and adults Lady Birds devour great numbers of Aphides and Scale Insects, and for this reason they should never be destroyed. The females deposit their eggs as a rule on Aphid infested plants so that their larvæ may not have far to wander for their food supply. The Beetles are all very similar in shape and are mostly black and red, or black and yellow in colour. They hibernate during the winter beneath bark of trees, under rubbish and in outhouses, etc. In the following spring they lay their cream-coloured eggs closely packed together in groups. The larvæ are black or leaden-coloured, marked as a rule with yellow or orange. They crawl freely about the plants and consume great numbers of Aphides and other Insects. The pupæ are attached to the upper or undersides of the leaves and are broad black objects marked with cream-colour or yellow. The adult Lady Birds appear early in summer and are common objects of the field and garden throughout the season. It is noteworthy that the destructive Scale Insect *Icerya purchasi* which devastated the orange groves of California has been almost entirely destroyed and checked by the importation into America of an Australian Lady Bird *Novius cardinalis.* The Scale Insect has thus remained permanently controlled, and the *Novius* Beetle is now a regular resident in California. The orange Scale Insect has been controlled by a similar measure in Florida, New Zealand, Portugal, Cape Colony, Formosa, Egypt, France, and other countries. HOVERER FLIES belong to the family of the Syrphidæ. They are often brilliantly coloured, being black with yellow bands, and have the appearance of small Wasps. They hover in the air, remaining stationary, except for their vibrating wings, over one spot for several minutes and then, darting away suddenly, hover again over a fresh spot. They only fly in sunshine, and rest on leaves and flowers in dull and wet weather; they feed mainly upon nectar. Most species of Hoverer Flies lay their eggs among colonies of Aphides, and their maggot-like larvæ on emerging feed voraciously upon the latter. When fully fed the pupæ are to be found enclosed in membraneous puparium on the leaves and stems of plants close to where the larvæ lived. The greater number of the members of this family are, therefore, beneficial Insects.

ICHNEUMON FLIES and their allies are parasitic Insects belonging to the order Hymenoptera, and are related to the Bees and Wasps. They can be recognised by the presence of four transparent wings, and by the possession in the female of a long needle-like ovipositor or egg-laying instrument. Almost every species of Insect is preyed upon by some other species of Ichneumon Fly or its ally. By means of their ovipositor these Insects pierce the skin of other Insects and lay their eggs within the body of the latter. The host Insects are not killed by this operation, but continue feeding. The larvæ of the parasite hatch out in due course and gradually devour the blood and tissues of the host, avoiding, however, the vital organs until the very last. The parasite turns to the pupæ either within or outside the host Insect, and just about the same time the latter dies. Some Insects are greatly destroyed by parasites and thus kept in check naturally—the common Hawthorn Scale and the Gypsy Moth are familiar examples. In America, however, the Gypsy Moth has got introduced artificially, and has now spread with alarming rapidity and causes millions of dollars damage annually. Unfortunately the natural enemies of this Moth were not imported, and the U.S. Department of Agriculture recognise that the only way of ridding the country of this Insect is by importing its natural enemies or parasites from Europe. This work is now steadily going ahead on a very large scale, but it is too early to know the final result. In Italy mulberry cultivation has been threatened by a Scale Insect. *Diaspis pentagona*. In 1891 the pest assumed such serious proportions that the Italian Government passed a legislative measure compelling mulberry cultivators to use all available means for coping with it. This, however, proved of little efficacy, and it was not until Professor Berlese, of Florence, introduced great numbers of a minute parasite from America into Italy that much headway was made. From all later reports it appears that this parasite has acclimatised itself to Italy and is proving of great value in destroying the Mulberry Scale.

Of all beneficial Insects the Hive Bee is the most useful species. It is desirable here to make some reference to the Isle of Wight Disease (18), which is causing much mortality among apiaries all over the country. The epidemic is due to a minute Protozoan organism (*Nosema* *apis)*, and the disease is spread by the distribution of its spores among unaffected bees. The disease is primarily one of the digestive system, and affected Bees are, as a rule, unable to fly more than a few yards without alighting. As the disease progresses the Bees can only fly a few feet from the hive, and then drop and crawl aimlessly over the ground. They may often be seen crawling up grass stems or up the supports of the hive. Diseased Bees frequently lose their power of flight, their abdomens become greatly distended, and often the wings are "out of joint," the hind wings protruding upwards and outside the anterior pair. In bad attacks large numbers of diseased Bees are to be found clustered together within the hive, or on the alighting board and ground. Sometimes the symptoms resemble those of "Bee paralysis" or of "dysentry," but nevertheless the disease is quite distinct from either of these complaints. The spores of the disease are spread in various ways; thus water near the hives becomes infected with Bee excrement, containing the spores, which are liable to be imbibed by the next Bee which visits the same spot. Honey, pollen and wax also become infected with the spores in a similar manner, and are very fertile sources for spreading the disease. Infection from one hive or apiary to another can be effected by the sale of diseased swarms, by the robbing of a diseased colony by healthy Bees, and by swarms occupying hives which were formerly infected. Bad weather also encourages the spread of the complaint, as the bees do not then take cleansing flights. There is evidence to indicate that partial immunity of stocks happens. Such stocks, however, might be hard to recognise, and at the same time would act as sources of infection for susceptable colonies. As regards measures against the disease, healthy stocks should be removed from the neighbourhood of diseased hives. Clean water should be readily accessible, changed daily and protected from contamination. The usual drinking places should, if possible, be done away with. All dead Bees should be burnt and diseased colonies, including the queens, destroyed. The ground around the hives should be dug over and treated with quicklime. Infected hives and all utensils should be charred inside and out with a painter's lamp. In place of charring a very thorough application of formalin or carbolic acid may be used, and the hives afterwards properly aired in strong sunlight. No cure for the disease has so far been discovered. The problem of hereditary infection is of great importance, but I am not aware that any evidence thereon is yet forthcoming. If the queen is capable of transmitting the *Nosema* parasite to the eggs, the young brood would thus be born infected, and the disease be passed from one generation to another, as happens in the case of the *Nosema* which causes Pebrine in silkworms. Investigations along these lines are greatly needed.

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(Nos. 9 and 10 are good elementary works on Insects; No. 4 is the best book of reference on fruit pests, while No. 15 is an elementary outline of the same subject; Nos. 7 and 13 are reports on various species of injurious Insects and other animals; No. 17 is a general book on pests of fruit and vegetables and, although out of date, contains useful information; Nos. 1 and 2 deal with the economic status of Birds, and No. 19 with the encouragement and protection of the beneficial species. The remainder of the references deal for the most part with special subjects referred to in these lectures.)

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