The STORY BOOK OF THE FIELDS

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The Story-Book of the Fields

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CHAPTER I

Ice

We have all seen a pump, and know something about its construction. There is a long leaden pipe which goes down into the well, and above that a short, thick pipe in which the piston rises and falls. This large pipe is the cylinder.

One very frosty morning we find the cylinder cracked from top to bottom. There is a hole the length of your finger, and a lump of ice projecting through it. How could the cold break this hard iron pipe ? It was not the cold alone. There was something in the cylinder : there was water, and this water was changed into ice, which was imprisoned between the cylinder and the piston, unable to rise or fall. Now ice expands as it forms. It expands to such an extent that, if it happens to be imprisoned, it presses here, there and everywhere, and smashes the obstacle which prevents its expansion. So the cylinder is cracked because ice was formed inside it.

I can quote an experiment which will show the irresistible power of ice when it forms and expands in a closed space. What is stronger than a cannon? It is made of bronze, a metal almost as impregnable as iron. It weighs several tons and is more than a hand-breadth in thickness. A small bag of gunpowder and a cannon-ball which you could hardly lift are placed inside. The gunpowder is ignited, there is an explosion like a clap of thunder, and the iron cannon-ball is hurled for a league, and even farther. So you may judge of the resistance offered by this terrible machine.

Well, the power of the pressure of ice has been tried in a cannon. A cannon is filled with water; then its mouth is stopped with a solid plug of iron, screwed in so that it cannot give way. This cannon is exposed to the cold during a very severe winter's day. The water turns to ice, and soon the gun is cracked from end to end, the ice projecting through the crack. After this, how can we be surprised that the cylinder of a pump should be broken by the pressure of ice, when a cannon is rent as easily as a worn-out cloth? Moreover, this fracture, caused by the water freezing, is effected as quietly as possible. There is no explosion such as you might imagine, no fragments thrown out. Without any disturbance the metal is rent, and that is all. If you were astride on the gun you would have nothing to fear at the time of the rupture.

It is probable that you will not have the opportunity of seeing the bursting of a cannon by ice, but I can suggest another experiment. Take a bottle, fill it quite full of water, then cork it with a strong cork fastened by a string. Expose your bottle in the open air during a sharp frost. Sooner or later you will find it in pieces, broken by the pressure of the ice. Here again there is no danger. The fragments of the bottle are not thrown off. They adhere together, joined by the ice, or else they fall quietly to the ground.

In the new pump which has replaced the old one damaged by the cold, there is a tap quite at the bottom of the cylinder, and when a hard frost is expected the tap is turned to let the water escape. This is to prevent the ice from forming in the cylinder.

Also, as the tap may be forgotten, during severe cold it is well to cover the cylinder with rags or straw, to preserve it from contact with the air and so prevent it from becoming too cold.

CHAPTER II

The Origin of Soil

Soil, or arable ground, is the surface of the earth worked and stirred by our agricultural implements, and in which plants are able to develop their roots. In some places the rock is bare and completely barren; in others the soil is a few inches thick, and scanty grass will grow, while in others again it reaches a sufficient depth, and vegetation succeeds. But nowhere is this soil of unlimited thickness. At no very great depth the bare rock of the neighbouring mountains reappears. How then has this bed of earth been formed whence all food proceeds—for the plant, for the animal, and for man?

Mined every winter—and on high mountains the whole year long—by the ice which is formed in their smallest fissures, rocks of all kinds break into tiny fragments, separate into grains of sand, fall in dust and provide the powdered mineral matters which are carried away by the rain and deposited in the valleys. Broken stones, sand, mud and soil have, for the most part, no other origin. The ice by its power of expansion has detached them from the tops of the mountains, and the water has swept them away and carried them further. We can form an idea of the action of ice, how it crumbles the rocks to turn them into earth and to enrich the valleys, by examining the surface of a beaten road at the time of thaw.

This surface, which was firm under foot before the frost, is broken up by the thaw and here and there raised up in little crumbling clods. With the coming of the frost the moisture with which the soil was impregnated became ice which, increasing in volume and expanding, reduced the surface of the road to fragments. When the thaw sets in, these fragments, no longer held together by the ice, form mud first, and afterwards dust. It is in an exactly similar way that the soil has been formed by fragments of rocks of every kind, reduced to powder by ice.

But agricultural ground not only contains powdered mineral matters, it contains also a compost, provided independently by the decomposition of vegetable substances. To give you an idea of the causes which from the remotest times have fertilised the dust of the rock, we will limit ourselves to the following example.

Geography has taught you something about a volcano. It is a mountain, the summit of which is hollowed out into an immense excavation forming a funnel. At times in the vicinity of a volcano the earth quakes; formidable noises, like the rolling of thunder, or the reports of cannon, resound in the depth of the mountain. The crater throws up to the sky a tall column of smoke—dark in the daylight, fiery red at night. Suddenly the mountain is rent open, and from its crevices a river of fire, a flow of molten rocks, pours out. After a time the volcano quiets down and the source of the terrible stream dries up. The lava itself is arrested and leaves off flowing, and after a period which may last for years, is completely cooled. Now what will become of this enormous bed of black cavernous stone, like the hearth of a blacksmith's forge? What will this sheet of lava produce, covering a surface of several square miles?

This desolate, accursed surface seems destined never to be clothed in green. But that is a mistake. After centuries and centuries a strong growth of oaks, beeches and other great trees will have succeeded in establishing themselves. The air, the snow, the rain and, above all, the frost successively attack the hard surface of the lava, detach tiny morsels and gradually produce a little dust at its expense. On this dust there appear strange and vigorous growths—those white and yellow patches, those vegetable crusts called lichens, which live on the rock. The lichens adhere to the lava, wear it away still more, and die, leaving a small amount of compost consisting of their rotted remains. Now the mosses appear, which perish in their turn and augment the quantity of fertilising matter. Then the ferns come, needing more nourishment. After these a few tufts of grass; then some brambles and poor shrubs; so that every year the soil is increased by fresh fragments of the lava and of the compost left by the generations of plants which have rotted on the spot. Thus in the course of time a stream of lava is covered by a forest.

The arable ground which we cultivate has had a similar origin. The barren rocks, hard as they are, reduced to dust by the combined action of water, air and cold, have formed its mineral part, while the vegetable generations succeeding each other, beginning with the simplest, constitute the soil.

Note how in nature the least of creatures fulfils its part and, in proportion to its strength, contributes to the general harmony. The changes of weather, which crumble the hardest rock, are not enough to produce the arable ground ; besides these, vigorous plants are needed which can live on that ungrateful surface—those grasses, mosses and lichens, which wear away the stone. It is by means of these elementary plants, so poor in appearance and yet so robust, that the dust of the rocks is enriched with a compost and makes a soil fit to nourish other more delicate plants. It is not in cultivated plains that you will find these close carpets of moss and lichen bravely wearing away the rock ; it is at the tops of the mountains that you can see them at work, encrusted on the firm rock in order to convert it into arable ground. It is from these heights that the soil has gradually descended, swept on by the rain, and has come to fertilise the valleys. The same work is always going on. In mountainous regions the tiniest plants incessantly augment the quantity of arable ground. The threads of rain-water which furrow these regions take possession of it and carry it off to the plains. What a worthy subject of our reflection is this production of arable ground by these legions of inferior plants, the obscure labourers indefatigably stripping the rock! What immense results obtained by the simplest means!

CHAPTER III

The Stem

The stem is the common support of the different parts of the plant which, if it is only to last one year, is called *annual* or *herbaceous*. Such is the case of the potato, parsnip or parsley, and of all those plants which from their weak substance are called herbs. If destined to last for a greater or less number of years, being formed of strong wood, the growth is called *ligneous*, as in the case of trees.

Let us cut very neatly through some ligneous stem—for instance, the stem of an oak. We shall perceive three parts—in the centre the *pith*, very slightly developed; round the pith the *wood*; and lastly the *bark* outside. With a little attention you will recognise that the wood consists of concentric layers, outlined on the section of the stem by a series of circles, which have the pith for a common centre. These layers are called *ligneous zones*, or *annual layers*, because one of them is formed every year. During the warm weather a special fluid is produced by the whole tree; this is the *sap*, the liquid food of the plant. This liquid passes between the wood and the bark, and in its course gradually becomes on one side a layer of wood moulded on the exterior of that of the preceding year, and on the other a thin sheet of bark, in addition to that which is already formed.

Thus in every year, for the bark as well as the wood, a fresh growth takes place. But the added growth is deposited on the two sides in an opposite direction; on the outside for the wood, on the inside for the bark. The wood, clothed in successive years by a new ligneous layer, grows old at the centre and young again on the surface; the bark, being lined each year by a fresh sheet, grows old on the outside and young on the inside. The former buries its worn-out and dead layers in the interior of the trunk, the latter casts outside its old growths, which crack and fall away in rough scales. The wearing-out proceeds simultaneously on the surface and at the centre of the tree, but, at the limit of the wood and the bark, life is always at work with new growths.

Here are some experimental proofs of this annual formation of a ligneous layer. A strip of bark is removed from a tree and a thin sheet of metal is fixed on the bare wood. The bark is replaced and firmly fastened, so that the wound may heal. Ten years pass away and we return and remove the bark in the same place. The metal sheet can no longer be seen, and to find it we must dig into the thickness of the wood. Now, if we count the ligneous layers removed before we reach the sheet of metal, we shall find exactly ten, the same as the number of years which have expired.

We know of a number of observations of the same kind as the following one. Some foresters cut down a beech, with the date 1750 carved on its trunk. The same inscription was found in the interior of the wood, and to reach it they had to go through fifty-five layers showing nothing whatever. Now, by adding fifty-five to 1750, we get the very year in which the tree was cut down, 1805. The inscription carved on the trunk in 1750 had penetrated the bark and reached what was then the exterior layer of wood. Since then fifty-five years had passed and fresh layers, exactly the same in number, had covered the first.

So a tree is composed of a succession of ligneous sheaths covering each other. The stem or trunk contains them all, the branches more or fewer, according to their age. Each is produced by the growth of one year. The ligneous sheath of the present year occupies the exterior of the stem, immediately under the bark: those of past years occupy the interior and are nearer the centre, according to their date. The layers of future years will, one by one, be superposed on their elders, and the present surface layer will, in its turn, be imprisoned in the thickness of the trunk.

Of all these ligneous layers of different ages, the most necessary now is that of the surface. Its destruction would involve the death of the tree; for it is by its means that the nourishing juices of the earth reach the shoots, the leaves and the young twigs. In their turn, when they occupied the surface, the interior layers acted the same part with regard to the contemporary shoots; but now that these shoots have become branches, the lower layers only play a subordinate part, or are even absolutely useless. Those nearest to the surface are still capable of some work and assist the layer of the year by bringing the juices of the earth to the branches. As for those approaching the centre, they have lost their activity for ever. Their wood is hardened, dried up, encrusted with dead matter. In their old age these interior layers are useless for the work of vegetation. At most by the support of their strong wood they add to the solidity of the edifice. The activity of the tree thus decreases from the surface to the centre. On the surface there are youth, vigour and work ; in the centre, old age, decay and rest.

CHAPTER IV

Combustion

If we throw a shovelful of coal into a stove, the coal catches fire, reddens, throws out heat and is consumed. Nothing is left but a handful of ashes—insignificant compared with its original weight. What has become of the coal? It is not annihilated; for nothing in this world can be annihilated. Just try to annihilate a grain of sand. You may crush it, pulverise it, but you will never reduce it to nothing. And the cleverest men, with means at their disposal more various and powerful than ours, would be equally incapable. In spite of every effort the grain of sand will still exist, in some fashion or other. Nothing and chance, the two big words that we employ on every occasion, are really quite meaningless. Everything obeys laws; everything is indestructible.

The coal when consumed is not annihilated at all. It no longer exists in the stove in black visible lumps, but it exists in the air as an invisible substance. In order to make this clearer let us consider sugar. This is white, hard, and crackles when bitten. We will put a little of it in water. The sugar melts, is dispersed in the water, and at once is neither white, hard, nor does it crackle when bitten. It is even invisible to the keenest sight. But this invisible sugar exists all the same. One proof of this is that it has imparted the taste of sugar to the water. Besides, when the water has gone, being evaporated on a plate in the sun, the sugar remains and reappears as it was at first. This instance will prove that a substance without ceasing to be the same, may change from colour to colourless, from tangible to intangible, from visible to invisible.

Well, coal when burning acts in the same way. It is dissolved in the air and becomes invisible. That which is not really coal, being indissoluble, remains on the hearth and forms the ashes. All the coal disappears, dissolved in the air and seems to be annihilated because we can no longer see it. This dissolution is accompanied by heat and is called *combustion.*

What do we do if we want to encourage the fire? We turn the air on to the fuel with bellows. The fire revives and increases at every puff. The coal, at first dark red, becomes bright red and then glowing white. The air has brought new life to the heart of the fire. What do we do on the other hand to prevent the fuel from being consumed too quickly? We cover it with ashes and thus preserve it from contact with the air. Under the layer of ashes the coal remains red, but is not consumed. So the fire on the hearth is only kept up by the constant arrival of air. The quicker and more lavish the dissolution, the higher the degree to which the heat is raised.

The dissolution which is effected in our fires in a violent manner, with the production of great heat, is not the only way in which coal, or carbon, is consumed. A piece of wood exposed to the weather turns brown after a time, gradually falls to pieces and at last drops into dust. Now, this destruction of wood can be compared at every point with that which takes place in a stove. It is still combustion, but so slow that the heat thrown out is almost or completely imperceptible. The rotting wood gradually dissolves its carbon into the air, which carries it away in an invisible condition; and as a consequence of these incessant losses, the trunk of a tree ends by being reduced to some spadefuls of earth, just as the coal of our stoves is reduced to a few cinders. The same result occurs in all decomposition of animal or vegetable matter. Everything that rots is consumed, that is to say it is dissolved slowly into the air.

It is easy to explain why the heat which results from combustion caused by rotting is not generally perceptible. Let us suppose that a log will take a year to be consumed by rotting, and that a similar log will take one hour to burn in a fire. In both cases heat will be produced. Only, in the rotting wood, this heat will be produced very slowly and very little at a time, since it has to take a whole year : so it will be imperceptible. As to the wood burning on the hearth, the production of heat will be fierce and quick, seeing that it is only to last for one hour. Consequently this heat will be keenly perceptible. However, if the amount of rottenness is large, the heat produced may be perceived. In a manure heap the temperature is raised to a high degree ; in a damp haystack it may even cause fire.

Therefore, although the process is really the same, it is well to distinguish between quick and slow combustion, in order to recognise different degrees in the way of burning. An old rotten trunk of a tree, a haystack becoming heated, a log flaming on the hearth, all show so many different degrees in rapidity of combustion.

We can derive coal from apples, or meat, or anything which can rot. We will take bread first and place a piece on the red hearth. The bread smokes, turns black and, if we wait long enough, there will be nothing left but carbon. That this carbon comes from the bread is evident, and as we can only give what we have, the bread which gives the carbon must have had it originally, but concealed, hidden among other things which prevented us from seeing it. These other things are gone, driven away by the heat, and now the carbon, stripped of its surroundings, appears black and crackling as its real self. Similarly the apple which you put to bake in the oven, would end by turning into a lump of coal. Flesh, submitted to the prolonged action of fire, becomes coal, as shown by those cutlets forgotten in the pan. Enough! the result would always be the same. Everything which forms a part of the plant or the animal contains coal or carbon, and by decaying dissolves this carbon in the air.

CHAPTER V

CARBONIC ACID GAS

BY dissolving sugar or salt, water acquires a different taste—the taste of sugar or salt. Similarly, by dissolving carbon the air receives new properties and takes the name of *carbonic acid gas*. All subtle, and generally invisible, substances such as air, are called *gases*. Air is a gas, and after having dissolved carbon it remains a gas. As for the word carbonic, it comes from carbon, the scientific name for coal.

This gas, or air impregnated with carbon, is an invisible substance, the presence of which can only be detected by indirect methods. The following is the simplest of these methods : We dilute in water a small quantity of slack lime, the white paste obtained by masons when they pour water on to the limestone, in order to make their mortar. The resulting liquid is as white as milk and is called whitewash. By means of a funnel we filter it through filtering paper. A colourless and perfectly limpid liquid passes through the filter. This is water containing a small quantity of lime in solution. It is called lime-water. This is all the preparation necessary to enable us to detect the carbonic acid gas.

Now we must procure a large glass bottle with a wide mouth. An ordinary decanter will do, if the mouth is large enough. To begin with the bottle is full of air and contains nothing else. We pour in a little lime-water and shake it so that the lime-water may reach every part of the bottle. Nothing happens. The lime-water was clear at its entrance and remains clear. We conclude that the air has no effect on the lime-water.

Let us try again. We introduced into the bottle a lump of burning coal hanging by a wire. For a time this coal burns, then it turns paler, and ends by going out. We take it out. What has happened ? Evidently, from the fact of combustion, some carbon has been dissolved in the air of the bottle, which must now contain carbonic acid gas.

Let us again pour in a few drops of lime-water and shake it. Now the liquid, which was originally perfectly clear, is disturbed, turns very white and, when at rest, deposits flakes of a white substance. This milky disturbance and these white flakes did not appear when the air was pure; if they are formed now it must be because the contents of the bottle have changed their nature. The change is caused by the dissolution of the carbon in the air: in other words by the formation of carbonic acid gas. Henceforward we can recognise this gas by its property of disturbing and whitening lime-water, and forming a deposit of white, powderous matter. This matter contains lime and carbonic acid gas in combination, being neither the one nor the other, but a fresh substance called *carbonate of lime*, or *chalk*. The chalk that we use to write on the black-board is exactly the same thing—a combination of carbonic acid gas and lime. But it is not obtained by the method that we have used; that would be too long and too expensive. We find it ready made in the bosom of the earth, like clay, sand and so many other things.

The air in which carbon is dissolved will no longer maintain combustion. This may be easily shown. We will go back to our wide-mouthed bottle. If it is full of pure air and we introduce a bit of lighted candle hanging by a wire, this candle will go on burning as usual. But let us first place in the bottle a red-hot coal and wait a few minutes to give time for the carbon to be dissolved in the air; then withdraw the coal and replace it by a lighted candle. This will burn dim and go out. However carefully we introduce it we shall not be able to make it burn inside the bottle until the gaseous contents are renewed and replaced by pure air.

Air impregnated by dissolved carbon is deadly for man. If this formidable gas is breathed to any extent, the mind grows dull, numbness ensues, strength departs and, without timely help, death will follow. We have heard of unfortunate people who, voluntarily or accidentally, have been killed or, as it is called, asphyxiated, by a charcoal stove lighted in a close room. The air impregnated with dissolved carbon is the cause of this lamentable result. It produces first violent headache and general discomfort; then the loss of feeling, giddiness, nausea and extreme weakness. If this condition is prolonged life is in danger.

You will see to what danger carbon exposes us, when the products of combustion do not pass out by a chimney but are scattered in the room that we occupy—especially if the latter is small or very close. In such a room we should never trust a charcoal stove. Whether it is well alight or half out, covered with ashes or uncovered, this charcoal gives out a deadly gas, the more to be feared because it is neither seen nor felt, nor even suspected. Death may ensue before the danger is perceived. It is also very unwise to close the chimney of a bedroom fire, in order to keep up a gentle warmth in the night. As the chimney no longer gives an outlet to the products of combustion, the latter are dispersed in the room. If the room is small and without any opening to renew the air, a small chafing-dish will be enough to give a headache, or even to cause a serious accident.

CHAPTER VI

Hollow Trees—The Age of Trees

The ligneous zones are divided into two parts. The first is central, from which life has more or less withdrawn, the other exterior, which contains life in a greater or less degree. The former is of a dark colour ; the latter is whitish. The former is known as wood, or good wood ; the latter as sapwood. In the sapwood the wood is pale, soft and impregnated with juices : this is living wood. In the centre it is highly coloured, hard and dried up : this is wood all but dead.

Old age is far from perfection. Why, then, are these interior layers called *good*? They should be called imperfect. No doubt the hard wood is imperfect as regards the tree which it no longer feeds, but it is perfect for the service that we require. For our furniture we need wood with close structure, fine grain and rich colour. None of these qualities exist in the sapwood : they are only found in the centre. Ebony, so hard and so black; and mahogany, reddish and fine in texture, come from two foreign trees, the sapwood of which is soft and white. Sandalwood and logwood, which provide colouring matter for dyes, are covered with colourless sapwood. The wood, the hardness of which has been compared to iron, and which on that account is called iron-wood, is the wood of a tree the sapwood of which is in no way remarkable. We know the difference of hardness and colour between the wood and sapwood of the oak, the walnut, or the pear-tree. The sapwood can never be used as wood for dyeing or for cabinet-work. It has to be removed by the axe to lay bare the wood, in which the colouring matter and the close texture are only to be found.

The wood begins its career as sapwood, and this sapwood is destined to gradually become wood as it grows older and is covered by fresh layers. Colour and hardness proceed from the centre to the circumference, while new soft and white layers are formed on the outside. In some trees the transformation from sapwood into wood is very incomplete; the wood decaying without becoming hard. These are called white woods, among which are the poplar and the willow. The white woods are poor in quality, having no firmness and wearing out quickly.

When they have reached a great age some trees, especially those the wood of which does not become hard, often have a hollow trunk. Sooner or later the interior layers, consumed by decay, are mingled with the earth, and the trunk ends by becoming hollow, though this does not prevent it from bearing a vigorous crown of branches. There is nothing stranger, at first sight, than old willows, gnawed by the larvæ of insects, excavated by decay, disembowelled by years, and, in spite of so much destruction, covered by a vigorous growth. Within they are decaying corpses; outside they enjoy the fullness of life. This singularity is explained, if we reflect that the central layers are of no use to the fortune of the tree. As old relics of departed generations, they can be wasted by decay; the rest of the tree will not suffer as long as the exterior is preserved, for it is there only that the life abides. Being destroyed in its central portion by the attacks of time, and rejuvenated every year by new generations of shoots, the tree passes through centuries without danger of death—at once old and young, dead and alive.

Since a ligneous layer is formed every year, we need only count the number of these layers to arrive at the age of the tree. So, when a tree is cut across and we count one hundred and fifty layers, it means that the tree is one hundred and fifty years old. Let us look at the transom section of some young oak. From the pith to the bark there are six layers, so the oak is six years old. For any other tree the same calculation would hold good: so many layers, so many years.

You see, therefore, that it is very easy to ascertain the age of a tree that has been cut down, by merely counting the number of ligneous layers in the trunk. We can also do this while the tree remains standing, by comparing half the diameter of the trunk with the average diameter of an annual layer, which is found by cutting down and examining a large branch. It is interesting to find out the limit of age that may be reached by trees. The results furnished by such observations will by far surpass our expectation. We will confine ourselves to a small number of examples of this curious subject.

The cemetery of Allouville, in Normandy, is shaded by one of the oldest oaks in France. The dust of the dead, into which its roots project, appears to have imparted exceptional vigour. Its trunk measures ten yards in circumference at the level of the ground. A hermit's cell, surmounted by a small belfry, rises in the midst of the huge mass of branches. The base of the trunk, which is partly hollow, has since 1696 been arranged as a chapel, dedicated to Our Lady of Peace. The most exalted persons have considered it an honour to pray in this rustic sanctuary, and to meditate for a short time under the shade of the old tree, which has witnessed the opening and closing of so many graves. From its dimensions an age of nine hundred years is attributed to this oak. The acorn which gave birth to it must have germinated in the year 1000. Nowadays the ancient oak bears its enormous branches easily, and every spring is covered with vigorous foliage. Honoured by men, wasted by lightning, it follows the course of years with, perhaps, before it a future as long as its past.

After the oak of Allouville we will recall some others, also comrades of the dead; for it is in these abodes of rest, where the sacredness of the spot protects them from the assaults of man, that trees live to a great age. Two yew-trees situated in the cemetery of La Haie de Routot, in the Department of Eure, deserve special attention. In 1832 they still shaded with their dark foliage the whole of the burying-ground and part of the church, when an exceptionally violent wind blew down some of their branches. Yet, despite this mutilation, they both remain majestic in their old age. Their trunks, which are quite hollow, are each nine yards in circumference. Their age is supposed to be fourteen hundred years.

CHAPTER VII

RESPIRATION

FIRST among the most imperative needs to which we are subject are those of eating and drinking. There is, however, one need to which hunger and thirst, however insistent, must give way, a need ever recurring and never satisfied, felt incessantly whether awake or asleep, by night and by day, at every hour, at every moment. This is the need of air.

Air is so necessary to life that we cannot regulate our use of it, as we do that of food and drink, so as to protect ourselves from the fatal consequences which the slightest neglect would entail, It is without our knowledge, independently of our will, that the air penetrates into our bodies, to play its wonderful part. Above all we live on air, ordinary food being only of secondary importance. The need of food is only experienced at fairly long intervals ; the need of air is felt incessantly, always imperious and inexorable.

Let us try for a moment to prevent the air from entering our body by closing its passage through the nose and mouth. It is impossible to endure it, we are stifled and feel that we should certainly perish if this condition were at all prolonged. This will convince us of the necessity of air for life. All animals from the least to the greatest are in the same case ; above all, they live on air. Those that live in water—fishes and others—are no exception to the rule. They can only live in water into which air passes and is dissolved.

In physics we have a striking experiment with regard to this subject. An animal—a bird, for instance—is placed under a bell glass, and then the air is withdrawn by means of a special pump called an air pump. As the air disappears, being drawn out by the pump, the bird totters, struggles in terrible distress and falls down in a dying condition. If we are slow in restoring the air to the bell the poor little thing will certainly die : nothing can restore it to life. But if the air is restored in time its action will revive the bird. In the same way a lighted candle placed under the bell will be at once extinguished if the air is withdrawn. The candle must have air in order to burn.

We will now consider the reason why air is so absolutely necessary for the support of life. Men and animals have a proper temperature—a heat which does not result from exterior circumstances but from the mere fact of life. Our clothes preserve it and prevent it from dispersing, but they do not impart it. Moreover, this natural heat remains the same under a blazing sun or in the frost of winter, in the warmest and in the coldest climate ; it cannot be decreased without risk to our lives. How is this bodily heat preserved always and the same all over, and how can it be produced except by combustion ? As a matter of fact, permanent combustion is constantly going on within us ; respiration supplies it with air, and food with fuel. To live is to be consumed in the strictest sense of the word ; and to breathe is to burn. There is an old figure of speech—*the torch of life.* This figure expresses the reality. Air consumes the torch, air consumes the animal. It causes the torch to diffuse heat and light ; it causes the animal to produce heat and motion. Without air the torch will be extinguished, and without air the animal will die. In this respect the animal may be compared to a very perfect machine set in motion by heat. It feeds and breathes in order to produce heat and motion ; it eats the fuel in the form of food and burns it in its body by means of the air supplied by respiration.

That is why the need of food is felt more keenly in winter. The body becomes colder by contact with the cold air outside, so we must burn more fuel to keep the natural heat at the same level. A cold temperature excites the need of eating, and a high temperature reduces it. The hungry stomachs of the northern nations need strong meat, fat or lard ; the tribes of the Sahara are satisfied with three or four dates in the day, with a pinch of flour kneaded in the palm of the hand. Everything which diminishes the waste of heat also diminishes the need of food. Sleep, rest, warm garments all assist our food to keep up the natural heat, and to a certain extent they take its place. Popular common-sense repeats this in the saying, "*He who sleeps, dines.*"

The materials which the air burns within us are provided by the very substance of our body, that is to say, by the blood into which the digested food is transformed. We say of someone who puts extreme energy into his work that he is burning the candle at both ends. This is another popular saying which agrees perfectly with our most certain knowledge of the facts of life. There is not the least motion, not a limb stirs, without causing an expenditure of fuel in proportion to the force exerted, and this fuel is provided by the blood, which is itself maintained by food. To walk, to run, to become excited, to work, to take trouble, is literally to burn the blood. This is the reason why activity and hard work excite the need of eating, and why it is reduced by repose and idleness.

CHAPTER VIII

RESPIRATION (*continued*)

YOU must not imagine that vital combustion is carried on in the same way as in our fires, or that there is some kind of stove in our bodies. Although there is actual combustion there is no fire. Remember the wood turning to dust and slowly consumed in the air, and the stack of damp hay becoming heated till sometimes it catches fire. Vital combustion is quicker than that of decaying wood, and slower than that of wood that burns. Therefore it produces heat, but not enough to be dangerous, as a hot fire would be.

When passing through a fire and maintaining its combustion, the air changes its nature. It dissolves carbon and takes up carbonic acid gas, which passes out through the chimney, while pure air constantly comes in to take its place. Exactly the same thing happens in the combustion that supports life.

The chest acts like bellows which are alternately filled with air and emptied. These alternate motions are inspiration and *expiration*. In the former the pure air enters our bodies to burn the material for the blood and to produce heat ; in the latter the air, having fulfilled its task, is carried off, not in the same state as when it entered, but impregnated with carbon and unfit to breathe, like that which escapes from a lighted fire.

The burning fire and the breathing body both produce carbonic acid gas, by dissolving their carbon into the air. The breath from our chest is no different from the breath from the stove. This may be proved by an experiment. You saw that the presence of carbonic acid gas is detected by lime-water. If this water is disturbed, turns milky and deposits white flakes, it is a sure sign that the air is impregnated with carbon. Fill a glass with completely clear lime-water, then take some small tube—a reed, for instance, or a straw—and by means of this tube blow into the liquid. You will see that the lime-water will soon be disturbed, will resemble milk, and produce numerous white flakes. This is a clear proof that the air coming from the interior of the body is like that in the bottle in which a burning coal was held, and like that it contains carbonic acid gas.

When once it has been used for respiration, air, as we have seen, contains a harmful substance, carbonic acid gas. This air is henceforth unable to support life. An animal which had nothing else to breathe would soon perish. Nor is it able to maintain combustion. This is quite clear, according to the close resemblance between ordinary combustion and the facts of life. Where the animal can live, a lighted candle will burn; when the animal faints for lack of air, the candle goes out. To know whether air is fit to breathe we need only notice whether a lighted candle will burn or go out.

We will now collect our breath—that air that has been working within us. This is a very simple matter, as you will see. I take a bottle with a wide mouth, fill it full of water, cover the opening with the palm of my hand and turn it upside down in a large earthenware pan, also full of water. I hold the bottle with one hand, taking care that the mouth always remains under water. Then we blow under the bottle with a reed. The air issuing from the body disturbs the water and rises in large bubbles through the contents of our vessel, till it reaches the top. As the breath, or the air, is collected in the upper part of the bottle, the water being driven back escapes at the base and flows into the pan. When the vessel is filled with air we cover the opening again with the palm of the hand, and place the bottle on the table with the mouth at the top. The bottle is full of our breath. As we see it there is nothing to show that this air, which has already been used for respiration, differs in any way from the air which has not been so used. It is as transparent and invisible as usual. We might say that there has been no change. But let us test it and we shall see that this air is far from being the same.

With the help of a wire I let a piece of a lighted candle down into the bottle. As soon as the flame passes the mouth, it is immediately extinguished. It is extinguished as completely and quickly as if it were immersed in water. This extinction is not caused by any clumsy movement. I again immerse the candle as slowly and carefully as possible. No use ; as soon as it enters the bottle it goes out. If we introduce it into a similar bottle full of pure air the candle will go on burning. We know, therefore, that when air has once been breathed it is no longer able to support flame or to support life. Since a candle goes out any animal would perish, after a more or less prolonged stay.

From this you will understand how carefully we must attend to the renewal of air in our houses, and especially in our bedrooms. Let us throw open our windows and allow the pure outside air to pour in. We must keep far from our dwellings any cause of corruption which might affect the air—the chief support of life. In sheepfolds and stables where numbers of animals are kept, the free access of air is indispensable to health ; all the more because the atmosphere is vitiated both by the breath of the animals and by inevitable impurities. To sum up—Air is indispensable to every creature and everything that can affect its purity must be avoided with the greatest care.

CHAPTER IX

The Root

The stem is the part of the plant that grows upwards and needs air and light ; the root grows downwards and requires the earth and darkness. The extremities of its numerous subdivisions are in a constant state of growth, always young and soft, and therefore, well adapted for absorbing like a sponge the liquids with which the ground is saturated. It is to record this power of absorption that the extremities of the roots, which are constantly renewed, are called *spongioles*. The spongioles come at the end of the rootlets or final subdivisions of the root.

There are two principal types of the various forms of the root. Sometimes it consists of a single growth or tap, which produces branches as it penetrates deeper into the ground. This is called a tap root. Sometimes it is a bunch or sheaf of simple or branched members, which all beginning at the same level are all of equal importance. This is a *fasciculated* root.

Generally the development of the root corresponds with that of the stem. The oak, the elm, the sycamore, the beech, and all our large trees, have a strong, deep root to support their enormous branches and defend them from the gusts of the wind. But there are some humble plants, the roots of which are quite out of proportion to the rest of the plant—a tap root stronger than that of many other plants that are more highly developed in their visible portion. Such are the mallow, the radish, and the carrot. The lucerne supports its scanty tuft of foliage by a root which penetrates to a depth of two or three yards.

One agricultural operation of the greatest interest depends partly on the excessive development of certain roots. The plant is a laboratory where the filth of our stables and poultry-yards is converted into food. At the pleasure of the cultivator, a load of dung, by passing through some plant, is transformed into vegetables, fruit, or bread. This manure is a very precious substance, which nothing can replace, and which must be utilised to the last morsel; for all our food depends upon it. We will suppose that the ground, enriched by this manure, has produced a first harvest of wheat. But the wheat, with its short delicate roots, has only benefited by the fertilising qualities of the superficial layer, and has left those untouched which have been dissolved by the rain and transported to a lower depth. It is true that the plant has fulfilled its duty admirably ; it has made a clean sweep and converted into wheat all the manure contained by the soil within reach of its roots, so that if wheat were sown again there would be no harvest. The ground is exhausted on the surface, but there is still wealth below. Is there anything that can search the layers underneath and extract food from them ? It will be neither barley, oats, nor rye, the small fasciculated roots of which would find that the wheat had left them nothing in the top story of the ground. It will be lucerne, which will plunge its roots, as thick as a finger, to a depth of one, two, or three yards, bringing back the manure as forage which, with the help of the animal that feeds on it, will turn to flesh for food, milk, fleece, or at any rate, labour. This succession of two or three plants, deriving the greatest advantage from prepared ground, is called *rotation*.

The deep root which is so advantageous for utilising the lower layers of the soil may occasionally become a nuisance. If a tree has to be transplanted, the long tap root will cause the operation to be difficult and risky. There must be a deep excavation to remove it and also to replant it, and care must be taken not to injure the root; for it is the only one, and if it does not take the plant will die. It would be better for the tree to have fasciculated roots, not reaching to a great depth. It would then be easily removed, and if some roots were destroyed by the operation there would be enough of them left whole to ensure success in transplanting.

This result may be obtained; it is easy to deprive the tree of its tap root and to give it, not a regular bunch of equal roots but a much branched and shallow root, offering all the advantages of the fasciculated root—though not its form. In the nurseries where the young trees spend a few years before being transplanted, when they are two years old the principal root, which would become the tap root, is cut off by the spade, and the remaining stump branches out horizontally without increasing its depth. Sometimes there is a layer of tiles in the soil of the nursery. The tap root of the shrub lengthens until it reaches this barrier, but it must then arrest its downward progress and branch out laterally.

The root with which we have been concerned is primordial and original; every plant possesses it as it leaves the seed—and it appears as soon as germination begins. But many plants have other roots which are developed at different points on the stem and replace the original root if it should die, or come to its assistance if it persists. These play an important part in certain horticultural operations, especially in propagation by cuttings and *layering*.

Besides these two operations which are intended to multiply the plant, the production of adventitious roots is promoted, with the object of fixing the plant more firmly in the ground, or of obtaining a more abundant harvest. The most effective way of doing this is to heap up the ground at the base of the stem. This is called buttressing. The buried portion is soon covered with roots. Maize, for instance, if left to itself, has too weak a root to resist the wind and the rain, which would lay it flat. The agriculturist buttresses the maize, in order to make it steadier, and bundles of adventitious roots are formed in the earth heaped at the base of the stem, which afford strong support to the plant.

The stalk of wheat bears shoots on its lower part, which may either perish, to the detriment of the harvest, or may be developed and increase the number of ears. If the wheat is sown in autumn, a cold and rainy season, the growth is slow, the stalk remains short and the different shoots remain very near each other, almost at the level of the ground. Favoured by the vicinity of the damp ground, these shoots give out adventitious roots, which feed them directly and provide them with the abundant nourishment that the ordinary root, from its own resources, could not have supplied. Thus stimulated they each develop a stalk which will afterwards provide an ear. But if the wheat is sown in spring, the rapid growth in a mild temperature carries the shoots too high for them to be able to take root, and the stem remains single. In the former case from each grain of wheat sown a bundle of stalks is grown, producing the same number of ears; in the latter the harvest is reduced to its simplest expression; a single seed produces a single stem and a single ear. This development of the lower shoots is of great importance, and in order to promote it they must produce adventitious roots from contact with the ground.

CHAPTER X

The Soil

Four substances, combined in varying proportions, form the soil or arable land: these are *sand* or *silex*, *clay*, *chalk* and *humus*. Each of these materials by itself would produce a very poor soil quite unfit for cultivation; but in combination with each other they fulfil the conditions that are required for fertility. Generally, arable land contains all four, with one or the other predominating. The soil takes its name from its chief component. The terms siliceous soil, clay, calcareous and humiferous soils, are used to designate arable ground in which silex, clay, chalk or humus respectively predominate.

Sand consists of very small fragments of a very hard rock, which is sometimes opaque and sometimes as transparent as glass, and always easily recognised by its property of emitting a spark when struck with steel.

Flints and white pebbles belong to this class of stone, which is called *silex* or *quartz*. Sandy lands have little consistency, are very pervious to water and are easily heated by the action of the sun, which exposes them to frequent drought.

The name of granite is given to a rock which is chiefly composed of silex and which forms whole mountain chains. The soil formed by the tiny fragments of this rock is called *granitic* soil. It is not favourable to cultivation, though chestnuts flourish in it, as well as certain wild plants which affect this ground. Chief among these are the heaths and the red foxglove. The heaths, with their pretty little pink flowers, will cover the poorest sandy soil with an endless carpet. The foxglove is a plant with large leaves, with flowers red on the outside and spotted with white and purple within, arranged on a long and splendid spike reaching almost to the height of a man. The flowers are shaped like long bells, or fingers of gloves; hence their name of foxgloves.

The soil formed by the matter cast up by volcanoes is also siliceous and is called *volcanic* soil. It is often extremely fertile.

Valleys traversed by great rivers have a sandy soil with a mixture of clay, which is the most productive and most easily cultivated. Its fertility is increased if it is inundated by floods; for the river leaves behind a fertile mud formed of clay and organic matters carried by the water.

Heath land is a soil composed of fine sand and humus supplied by the decay of heaths and other plants. It is also used for the cultivation of garden flowers.

Clay is an earth which when kneaded with water turns into a firm and flexible paste, which can be moulded into any shape. When perfectly pure it is white. This is *kaolin*, a very rare substance used for the manufacture of porcelain. *Plastic clay* is oily to the touch and forms a pliable paste when mixed with water. It becomes very hard when baked in the fire and is used for pottery. Other clays produce a paste which is not pliable and which readily absorbs fats. These are used in manufactures to remove from cloths the oil used in weaving them. *Ochres* are clays coloured red or yellow by rust, which are used in rough painting. *Marls* are composed of clay and chalk in varying proportions. These marls disintegrate, or fall into powder, under the influence of air and damp. They are used in agriculture for improving the ground.

Clay soil is entirely different from sand. It is converted by water into a sticky paste, which adheres firmly to the plough. When once wetted it is cold and dries very slowly. By the spade it is divided into compact clods, which refuse to crumble when exposed to the air, and are unfit for sowing. The cultivator must use every effort to draw off the water and to break up the earth with the plough before and during the frost. It is improved by sand, ashes or lime. Wheat does better in a clay soil than in any other ground.

Clay lands may be known by their vegetation. The wild plants that distinguish them are the coltsfoot and the dwarf elder. The coltsfoot is so called because of the shape of its leaves, the outline of which recalls the print of a horse's foot. They are white underneath and the flowers are yellow like small marigolds. They appear before the leaves in early spring. The dwarf elder is a kind of herbaceous elder, rising to half the height of a man. It has small white flowers which are succeeded by reddish violet berries.

CHAPTER XI

Shoots

If we take a branch of lilac or any other shrub, in the angle called the *axil* formed by each leaf with the branch that bears it, we find a small rounded body, clothed with brown scales. This is a *shoot* or, as it is sometimes called, an *eye*.

Shoots are found at fixed points: there is one at the axil of each leaf and one at the extremity of the branch. Those which are placed at the axils of the leaves are *axillary shoots;* the one at the end of the branch is a *terminal shoot.* They are not all equally vigorous, the stronger ones being at the upper end of the branch, and the weaker ones below. Those sheltered in the axil of the lower leaves are so small that some attention is needed to detect them, and without care these weakly shoots will often waste away without developing. In a branch of lilac it is easy to notice the difference in size between one shoot and the next.

Whether terminal or axillary, shoots are divided into two classes. As they develop some grow long and are covered only with leaves: these are called leaf shoots and finally become branches. Others remain short and only produce flowers, or flowers and leaves in conjunction. These are flower shoots or buds. It is very easy to distinguish them on our fruit trees; the leaf shoots being long and pointed, while the flower shoots are rounded and larger.

All through the summer the shoots are growing in the axils of the leaves, and acquiring strength to endure the winter. The cold weather comes and the leaves fall, but the shoots keep their place, firmly fixed in a fold of the bark, just above the scar left by the fall of the leaf. To resist the onslaught of cold and damp, which would be fatal, a winter garment is indispensable. This will consist on the inside of down and on the outside of a strong case of polished scales. If we examine the shoot of the chestnut we shall find inside a kind of down swathing the little tender leaves, and outside a solid armour of scales arranged as regularly as the tiles of a roof, and closely encircling it. Moreover, to prevent the damp from penetrating each scale is tarred with a resinous gum, which is now like dried varnish, but which will turn soft in the spring so as to allow the shoot to expand. Then the scales, no longer glued together but quite sticky, separate and the first leaves unfold lined with a russet down. Almost all shoots at the time of their effort in spring show in different degrees this stickiness, which results from the melting of their resinous coat. We may notice particularly those of the ash, the alder and especially the poplar, which allow an abundant yellow, bitter gum to ooze out when pressed by the fingers. This gum is diligently collected by bees who use it to make their *propolis*, the cement with which they plaster the fissures and walls of the hive before constructing the combs. Despite its modest appearance the shoot is a masterpiece ; its polish repels the damp, its scales protect it from the air ; while its lining of down prevents any access of cold.

The scales are the essential portions of the shoot's winter coat. These are only small leaves hardened and tough and modified to form a means of defence. The subsequent leaves which form the heart of the shoot are of the ordinary shape. They are all small, pale and delicate, and arranged with wonderful method so as to occupy the least possible space and all to be contained in their narrow cradle, notwithstanding their great number. We are surprised to find how much a shoot contains in its scaly case, in a space so small that we could hardly make it hold a hempseed : there are leaves by the dozen and whole bunches of flowers. The bunch contained in a lilac shoot has more than a hundred flowers. If the different parts of a shoot were removed one by one and the combination once taken to pieces, would any fingers have the skill to reconstruct it ? It is above all the leaves that lend themselves to a thousand arrangements so as to occupy as little space as possible. All are in their place in the tiny dwelling : none are torn or bruised. Within the shoot they take the shape of cornets, they roll over one edge or both ; they are folded lengthways or along their breadth ; they form a ball, crumple, or are creased like a fan.

CHAPTER XII

Soil (*continued*)

Chalk is the rock from which lime is obtained. It is composed of carbonic gas and lime. In order to obtain the lime the chalk is exposed to great heat in furnaces by lime burners. The carbonic gas is disengaged and dispersed in the air and the lime is left. Common building stone and ashlar are chalk. In arable ground chalk is often present in larger or smaller lumps, but more often it is very fine dust which cannot be distinguished from other substances, especially clay. River and spring water almost always contains a small proportion of chalk in solution. This provides the stony layer which gradually accumulates inside water bottles and dims the transparency of the glass. Some water contains enough to deposit a mineral crust on the objects over which it flows, such as mosses and aquatic plants and to fill up their arteries. The clearest water, in which absolutely nothing can be seen, holds chalk in solution, invisible as sugar dissolved in water, so that when we drink a glass of water, at the same time we drink a small quantity of stone. Our bodies, to provide for their growth and strength, require a considerable amount of stony matter, which goes to form the solid framework of the bones. These materials, which are absolutely necessary, cannot originate from ourselves but must be derived from our food and drink. Water provides chalk for us and also for plants which all contain a greater or less proportion of this mineral substance.

Calcareous soils are whitish because they are chiefly composed of chalk. If the proportion of chalk is overwhelming they will be barren, but fairly productive when this is combined with clay and specially favourable to the vine, sainfoin, lucerne and clover.

The characteristic plants of the chalk are the box, the compact and fine-grained wood of which is so highly esteemed by turners, and the dogberry.

Wood, leaves or plants which are exposed for long to the air and damp undergo a slow combustion or rot. The result of this decomposition is a brown substance called *humus*. The inside of old hollow willows is converted into humus, and also the leaves that fall from the trees and rot on the ground. The vegetable generations of to-day are nourished by the humus formed by the remains of their predecessors; and they, in their turn, will become the soil which will give birth to their successors. It is thus that plant life is supported in portions of the earth that are not cultivated by man. Humus is the natural manure and where it is formed uninterruptedly the plant life remains vigorous, transmitting the same substance from one generation to the next, alternately plant and soil. But the hay from the meadow is taken to the hay-loft and the harvest of the cornfield is stored in the barn; so that the ground is deprived of the humus which would be naturally formed by the corruption of the hay or wheat. We must therefore restore to the ground in some way the soil that has been removed, or it will gradually become poorer and finally barren. This is done by supplying it with manure; for the dung of animals is a kind of humus, produced by the work of digestion instead of by natural corruption.

Humus fulfils a double office. In the first place it makes the earth lighter, so that it is more easily penetrated by air and water. Also, by the slow combustion carried on within it, it constantly gives out a small amount of carbonic gas which is absorbed by the roots. Cultivation can only prosper if the ground contains a sufficient amount of humus. Wheat requires a proportion of almost 80 per cent., while rye and oats are satisfied with 20 per cent. In poor, sandy ground, occasionally the whole crop is turned over and buried so as to be altogether converted into humus. A meadow or a field of clover is sometimes treated in this way. When it is proposed to improve land by this means the plants that are first cultivated in order to be buried afterwards must be such as derive the greater part of their constituents from the atmosphere as the ground is unable to support them. Among the plants which satisfy this condition are buckwheat, clover, lupine, beans, vetches, lucerne and sainfoin.

Humiferous soils have for their principal component the brown matter produced by the decomposition of leaves and other vegetable remains. The chief of these is *turf*. Turf is a blackish, spongy substance, formed in damp flat ground by an accumulation of vegetable remains and especially of mosses.

Turf is used as a fuel. If such soil is to be used it must first be cleansed by drying and lightened by weeding and by the addition of sand and marl. Lime must be supplied to promote and complete the decomposition of vegetable matter. Turf lands may be recognised by the *sphagnum*, a great moss which grows with its root under water, and the cotton grass, bearing tufts as soft to the touch and as white as the finest silk.

CHAPTER XIII

Adventitious Shoots

The shoots which appear in the spring grow strong in the summer: in the winter they remain stationary and pass the time in profound sleep. In the spring they wake up again and lengthen into branches, or open into flowers. It is evident that these dormant shoots, which have to endure the heat of summer and the chill of winter, must be clothed in such a way as not to be scorched by the sun or injured by the cold. They are all, therefore, covered with an envelope of scales, and among such are those of the lilac, chestnut, pear, apple, cherry, poplar and, in a word, almost all our native trees.

But though the tree may wait and devote a whole year to developing its shoots, protected by their case of scales, there are a number of plants whose time is limited, as they only live for one year and are therefore called *annuals*. Such are the potato, carrot, pumpkin and many others which must develop their shoots in haste—in a few months or a few days. As these have not to live through the winter they are never covered with protective scales ; but as soon as they appear they lengthen, unfold their leaves and become branches, taking their share in the common work. Soon in the axil of their leaves other shoots appear which act in the same way, at once developing into branches which produce other shoots in their turn. This goes on until the winter puts a stop to this series of branches and kills the whole plant. Annuals therefore branch quickly, producing in one year successive generations of branches, more or fewer according to their species and their degree of strength. Their shoots, which have to develop speedily, are always bare. Long-lived plants on the contrary, such as trees, branch slowly : they have only one generation of branches in each year and their shoots, which have to live through the winter, are covered with scales.

Certain plants produce both kinds of shoot, such as the peach-tree and the vine. At the end of winter we find the vine with scaly shoots lined with down, and the branches of the peach also bearing scaly shoots coated with varnish. Both are dormant shoots, having rested through the winter in their case of down and scales. In the spring, obeying the common law, they lengthen into branches, while in the axil of their leaves other shoots appear which have no protective envelope, and develop at once. The vine and the peach thus produce two generations in one year: the one provided with scaly shoots that have lived through the winter, and the other by naked shoots which were only formed in spring. The branches produced by the latter give birth to scaly shoots, which sleep through the winter and reproduce the same series of facts in the following year.

The axillary and terminal shoots belong to the regular course of events, appearing on every plant that lives for several years. But when the plant is in danger, or that accidentally the regular shoots are lacking or insufficient, others will appear here and there, even on the root itself, to revive the sick plant and restore it to prosperity. These accidental shoots are to the aerial portion of the plant what the adventitious roots are to that which is underground, and the peril of the moment calls them into existence at the threatened point. The edges of the wound left by the amputation of a branch, the parts of the stem choked by bandages, or the bark where it has been injured by blows, are the spots where they prefer to appear. They are called adventitious shoots, and their structure does not differ from that of those that are normal.

The adventitious shoots are used so as to obtain valuable results. If young trees are planted with a convenient space left between each one and its neighbour, each plant will grow up with a single stem, and the plantation will become a forest. But it may be desirable to replace this single stem by a group of several, and to effect this the trees are cut down to the level of the ground. Adventitious shoots will appear on the edge of the great wound caused by the amputation, and will lengthen into so many stems. Each plant, which would have produced one tree, is converted into a stock with numerous branches, all of the same age and strength. When the branches have attained the required size they are cut down afresh and more shoots are produced as the wounds are multiplied. Thus a stock which is constantly amputated and restored by adventitious shoots produces more wood than could be obtained from a tree allowed to grow freely.

Untouched by the axe, the poplar rises as a majestic obelisk of foliage. The willow, which is such an unpleasing object by the side of our ditches, with its ugly capital bristling with divergent rods, is in its natural condition an exceptionally beautiful tree with flexible branches and delicate foliage. As ornamental trees they have nothing to gain by man's interference with their way of growth. But alas! the useful and the beautiful do not always coincide, and if we wish these trees to produce plenty of brushwood and faggots, the decapitation, periodically repeated, changes them into pollards, seamed with scars and disfigured by wounds, but resisting the mutilation by adventitious shoots, replacing in greater abundance the branches of which they have been deprived.

Before we finish with these adventitious shoots which multiply when the plant is poorest, and resist destruction until it is completely exhausted, we will recall the weeds which it is so hard to expel from our gardens if we limit our efforts to raking the ground. We have exerted ourselves in tidying our walks, and everything has disappeared; the ground is clear—at any rate we think so. It is a mistake: in a few days the weeds have reappeared more flourishing than ever, and the reason for this is evident. By raking we have cut down all the stalks, and the wounds have produced adventitious shoots, so that instead of destroying the weeds we have multiplied them. The only way to clear the ground is to pull them up. That makes an end of everything.

CHAPTER XIV

Plants and the Atmosphere

The carbonic gas produced by the breath of the human race annually is equal to that produced by the consumption of eighty-five millions of tons of coal. This amount of coal would form a mountain one mile in circumference at the base, and between four and five hundred yards in height. This is the amount of fuel required to maintain the natural heat of man. We eat this mountain of carbon among us in our food, and at the end of the year, having dispersed it in the air in puffs of carbonic gas, we proceed at once to attack another. Think how many mountains of carbon the human race has breathed into the atmosphere since the beginning of the world.

We must also reckon the animals, both of land and sea, which must use up a goodly mountain of fuel; for they are far more numerous than ourselves, occupying the whole of the globe—continents and oceans. All this carbon to support life! And all this passes into the air as a poisonous gas, of which a few breaths would kill you at once.

And this is not all. Fermenting matters, such as the juice of the vintage, or the dough of bread, and substances which are consumed by rotting, such as manure, produce carbonic acid gas. With a very moderate amount of manure an acre of cultivated ground will give out daily one hundred cubic yards of carbonic acid gas.

The wood, charcoal and coal which we consume in our houses, and in the great industrial furnaces, also supply the air with noxious gas. Only think of the amount of carbonic acid gas poured into the atmosphere by a furnace where the coal is thrown in by cart-loads. Think of the volcanoes, those gigantic natural chimneys, which in one eruption emit amounts of gas compared to which those which we have mentioned are of no account. It is quite evident that the atmosphere is constantly receiving torrents of carbonic acid gas which defy all computation. And yet animals have nothing to fear, now or in the future; for the atmosphere while constantly poisoned is also constantly purified.

And who is the providential cleanser

responsible for the purity of the air? It is the plant which, by feeding on carbonic gas, prevents us from perishing, and with it prepares the bread by which we live. This fatal gas, which is produced by all decaying matter, is the special food of the plant. The blade of grass develops its life from the spoils of death.

The leaf is riddled by an infinite number of very small holes, encircled by two lips that give them the appearance of a half-open mouth. These are called *stomata*. More than a million of them may be counted on one leaf of the lime, for they are so small that they cannot be seen without a microscope. It is by means of these openings that the plant inhales, not the pure air that we inhale, but the poisonous gas which is fatal to the animal but wholesome for itself. By its millions of stomata it breathes in the carbonic acid gas contained in the atmosphere: it draws it into the substance of its leaves, and there, in the sunlight, a wonderful process is effected. Stimulated by the light, the leaves analyse the fatal gas and strip it of its carbon. They restore the consumed carbon, they undo the work of combustion and separate the carbon from the air with which it is combined—in a word, they decompose the carbonic acid gas.

You must not think that it is an easy thing to restore to their primitive condition two substances which have been combined by fire, and to bring back something, which has been burnt, to its original state. Scientific men would need all the ingenious methods and all the powerful drugs at their command to deprive the carbonic gas of its carbon. This work, which would require all the resources of the man of science, is easily accomplished by the leaves without effort, instantaneously, but always on condition of having the assistance of the sun.

But if the sunlight is lacking the plant has no effect on the carbonic gas, which is its chief food. Then it languishes and starves. It stretches upward as if to seek the light of which it has been deprived, its leaves and stalk turn pale and lose their green colour, and at last it dies. This sickly condition, caused by privation of light, is called *etiolation*. It is promoted in horticulture in order to obtain more tender garden stuff, and to diminish or get rid of the strong and unpleasant flavour of some vegetables. The lettuce is tied round with a reed, so that the heart, deprived of the sunlight, may become tender and white. Celery and cardoons, the flavour of which would be unendurable without this treatment of darkness, are partly buried. If we cover the grass with a tile, or hide a plant under a flower-pot, after a few days without light we shall find their leaves sickly and yellow.

On the contrary, when the plant receives the rays of the sun directly, the carbonic acid gas is decomposed at once ; the carbon and the air separate, and each resumes its original qualities. When deprived of its carbon the air becomes that which it was before entering into combination with it : it is pure air, able to support fire and life. In this state it is restored to the atmosphere by the stomata, and serves again for combustion and respiration. As a fatal gas it entered the leaf, as a life-giving gas it leaves it. It will return some day with a fresh load of carbon, will deposit it in the plant and then, purified at once, will resume its aerial journey. The swarm comes and goes from the hive to the fields and from the fields to the hive, light and eager for booty ; or else loaded with honey and returning to the combs with burdened flight. Thus the air reaches the leaves with a load of carbon, taken from the body of an animal, from a lighted cinder, or from putrefying matter; it gives this up to the plant and starts again for a fresh harvest.

It is in this way that the atmosphere remains healthy, in spite of the immense torrents of carbonic gas that are uninterruptedly poured into it. The plant feeds on the fatal gas. Under the influence of the sunlight it decomposes it into carbon, which it retains for its own substance, and into air for breathing, which it restores to the atmosphere. Wood, sugar, starch, flour, gum, resin, oil, and everything else provided by plants, come from carbon combined with other substances. Thus the animal and the plant provide mutual support; the animal produces carbonic gas which feeds the plant, and the plant turns this noxious gas into breathable air and food. In a double way our life depends on the plants, for they purify the atmosphere and provide our food.

CHAPTER XV

Bulbs and Suckers

When they have attained a certain degree of strength the shoots of some plants leave the parent stalk: they emigrate, are detached from the stalk and take root in the ground to derive their food thence. Now it is evident that a shoot which is intended to develop independently, by its own strength, cannot be organised in the same way as one which is never to leave its nursing branch. To suffice for its first need, as long as the roots which are to feed it have not entered the ground, it must have a store of provisions. Every shoot that emigrates carries its food with it.

A pretty little lily from the mountains is cultivated in our gardens; it has orange flowers and is called the *bulbiferous lily.* The shoots which are to live through the winter and develop in the following spring are situated at the axil of the leaves. They are covered with succulent, thick, tender, fleshy scales, fit both to feed and protect them, which make them quite plump. Towards the end of the summer they leave the parent plant ; at the least wind they fall off and are scattered on the ground, henceforth left to their own resources. If the season is damp many of them, while still situated in the axil of the leaves, send out one or two little roots, which hang in the air as if trying to reach the ground. At the beginning of October, all the shoots will have fallen, and then the parent stalk dies. The wind and the autumn rains soon cover them with dead leaves and soil. Beneath this shelter they are swollen through the winter by the juices of their scales, and gradually plunge their roots into the ground, so that in the spring each one is displaying its first green leaf, in order to continue its evolution and so become a plant similar to the original lily.

The shoots with fleshy scales, intended to develop alone, independently of the parent stalk, are called *suckers*. No agricultural plant would provide us with so striking an example of the migration of shoots as the bulbiferous lily, but we have in our kitchen gardens the garlic, which behaves in almost the same way. Take a whole head of garlic. Outside we shall find, to begin with, white dry coverings. Remove these and underneath we shall find large shoots, which are easily separated from each other. Then there are more white coverings, followed by more shoots, so that the whole head is a bundle of intercalated shoots and coverings.

These coverings are the dried remains of former leaves, white in their underground portion, still in existence, and green in their aerial part which is now lacking. Shoots were formed in the axil of these leaves, following the general rule ; only as they were intended to develop independently they have stored food in the substance of their scales, which is the cause of their unusual size. If we split one of them lengthways we shall find beneath the tough sheath an enormous fleshy mass, forming almost the whole of the shoot. This is the store of food. With such a provision the shoot is quite independent. Indeed, for propagating garlic gardeners do not make use of the seed, which would be a lengthy process. They make use of the shoots, planting separately the suckers of which the heads are composed. Each of these, after being fed by its store of provision, produces roots and leaves and becomes a complete head of garlic.

From the sucker to the bulb, from the garlic to the onion, there is but a short step. If we cut through an onion from top to bottom, we shall find that it consists of a succession of fleshy scales firmly fixed one into the other. In the centre of these succulent scales, which are only leaves transformed into a supply of food, there are other leaves of the normal shape and green colour. So an onion is also a shoot fitted for an independent existence by means of the conversion of its exterior leaves into fleshy scales.

We must all have noticed that the onion when hanging on the wall for use in the kitchen is awakened by the heat of the room in winter, and from the heart of its brown scales sends out a fine green growth which appears to protest against the severity of the season and recall the joyous time of spring. As it develops the fleshy scales wrinkle, turn soft and flabby and finally rot in order to supply it with food. Sooner or later, when the provision is exhausted, the growth will die unless it is planted. This is a striking example of a shoot developing independently by means of its store of food. The leek is also a bulb of a very slender shape. Like the onion it is formed by a series of leaves fitted one over the other. The lily, tulip and hyacinth are among the ornamental plants which grow from bulbs.

CHAPTER XVI

Potash and Phosphorus

If we burn any plant the first effect of the heat is to show the carbon of which it was composed, in combination with other substances. As the combustion continues the carbon is absorbed in the air as carbonic acid gas, and an earthy matter remains which we call ash. There are then two substances, carbon and ash, which form part of every plant, without exception. The plant has not produced them independently: it did not derive them from nothing; for nothing can come from nothing. Therefore, it must have received them from some source. We know the origin of the carbon. The greater part of it comes from the atmosphere, whence the leaves draw the carbonic acid gas, decomposing it in the sunlight, retaining the carbon and rejecting the purified air. Thus the vegetation of the whole world finds its chief food in the atmosphere—a store which is inexhaustible and always equally abundant, because the breath of animals, corruption and combustion pour into it incessantly as much carbonic gas as all the plants can consume. In order to maintain the fertility of his fields the agriculturist need not trouble himself about carbon. The crops will find in the air the carbonic gas that they need without his intervention. There remains the ash, a mixture of several substances, the most important of which we will now consider.

If we boil a few handfuls of ashes with water in a pot for a short time and then allow the mixture to cool, the ashes will fall to the bottom and the liquid will become clear. We shall find that this liquid has a peculiar smell like that from the wash-tub in the laundry, and also a sharp, almost a burning taste. This smell of the wash-tub and this sharp taste were not present in the water originally, but proceed from the ashes which have given up certain substances to the water.

It follows from this that in the ashes there are at least two substances of different nature. The most abundant of these does not melt in water, and collects at the bottom in an earthy layer, while the other, which is only a very small portion of the whole, is easily dissolved in water, to which it imparts its properties, especially the smell and the sharp taste.

If we wish to isolate the latter we shall find no difficulty. We need only put the clear liquid in a vessel on the fire and heat it until none of the water is left. A very small quantity of a whitish substance will remain, looking something like pounded salt. In spite of its appearance it is not kitchen salt—far from it : we should discover this quickly from its taste, which is unendurable. It is called *potash*. This is the one among all the components of the ashes that is most necessary to vegetation. Every tree, shrub and plant, to the least blade of grass, contains a certain amount of it, more or less according to its species, and must therefore find it in the ground if it is to prosper. But in plants potash does not exist in the same condition as we find it after the action of fire and the reduction to ashes. In them it is combined with other substances, which deprive it of its burning and sharp taste. In the same way the carbon, when combined with other matters, is no longer black and hard.

What else is there in the ashes ? We may learn from a short story. In 1669 there lived in Hamburg, a town in Germany, an old scientist who was seeking for the means of converting metals of little value into gold. With worn-out iron, old rusty nails and discarded saucepans, he was hoping to make gold. But he did not succeed, nor could he succeed, because the thing is impossible. No metal can ever be changed into another. But after all, one evening he did see something shining in his phials. It was not gold but something far more useful. It was *phosphorus*, which now gives us fire. We need not laugh at Brandt; for by his search for the impossible he made a most important discovery. It is to him that we owe the match—that precious source of light and fire, so easily and so quickly used.

If we examine a match we shall find that there are two substances on the inflammable end; sulphur next the wood and something else over the sulphur. This other substance is phosphorus, coloured blue, red or brown, according to the fancy of the manufacturer. Phosphorus itself is yellowish, and transparent as wax. Its name signifies *light-bearer*. When it is rubbed lightly with the fingers in the dark it gives out a white light, and at the same time a smell of garlic is noticed, which is the smell of phosphorus. This substance is highly inflammable. If it is heated ever so little, or rubbed against anything hard, it takes fire. Hence its use in the manufacture of matches.

Phosphorus is a horribly poisonous substance. By dissolving a small quantity of phosphorus in grease, a poison is obtained, which is used for killing rats and mice. Some crusts of bread are spread with this composition and put down in the places frequented by these animals. Any of them who taste it die at once. You will understand that we have to be very careful with matches on account of their poisonous property, as their contact with food might entail the most serious consequences.

CHAPTER XVII

TUBERS—STARCH

THERE are some shoots which are destined to an independent existence, which do not store up food or thicken their scales before separating from the parent plant, but the branch itself is responsible for their support. When the branch is to be the future food of the shoots that it bears, instead of coming into the air, where it would be covered with leaves and flowers, it remains underground, with only the remains of scales instead of leaves. It grows corpulent and so shapeless that it is no longer called a branch, and receives the name of *tuber*. As soon as the provision is sufficient the tuber is detached from the parent plant, and henceforth the shoots that it bears find in it abundant food for an independent existence. A tuber is an underground branch, swollen with alimentary matter, with poor scales instead of leaves and covered with shoots that it has to feed.

Let us now consider a potato. What do we see on its surface? Certain depressions or eyes, which are so many shoots; for these eyes will develop into branches if the potato is placed in favourable conditions. On old potatoes, in the after season, we see them becoming growths, which only need a little sunshine to turn green and develop into stalks.

This property is made use of in propagating the plant. For this purpose we do not sow seeds, which would not result in a harvest for some years, but tubers, which produce abundantly in the same season. Or, better still, the potato is divided into quarters, when each portion that is buried provides a fresh plant—supposing of course that it contains at least one eye: otherwise it will decay without producing anything.

Moreover, there are very small scales on the eyes, which are leaves adapted to an underground existence—leaves in the same degree as the tough scales of an ordinary shoot. The potato then is a branch, since it possesses leaves and shoots. By earthing up the plant, that is by heaping up the earth about it, the young branches thus buried are converted into potatoes; and in dark and rainy seasons we occasionally see some of the ordinary branches thickening in the open air, swelling up and becoming more or less perfect potatoes.

Many other plants produce similar underground branches. Among these is the Jerusalem artichoke, the tubers of which have their shoots arranged in pairs, just like the leaves and shoots on the stem.

The potato feeds its shoots with a floury substance called *starch ;* the same substance which makes it so valuable a food for ourselves. We profit by the provision made by the plant for its offspring. Starch is composed of innumerable tiny grains, contained in the very small cavities with which the flesh of the tuber is completely riddled. These cavities are called *cells.* They are very small receptacles formed of a fine membrane and completely closed. They are filled with grains of starch and pressed closely together, making up the fleshy substance of the potato. But these cells are so minute that we could see nothing of them in the potato, however closely we inspected it : a microscope would be needed for their discovery. They are so fine that in a fragment of potato the size of a pin's head there is room for dozens and dozens of them. In a potato of average size there would be many millions.

To separate the starch from the potato, it is only necessary to tear open the cells and to set the grains free. The potato is reduced to pulp with a grater. The pulp is placed on a cloth over a large glass, and sprinkled with water. The grains are carried through the fabric by the water, while the remains of the cells, which are not fine enough to pass, are left behind.

Now we shall have a glass of water, with a number of satiny white points falling like snow and collecting at the bottom. When the deposit is complete and the water is thrown away, a powdery, splendid, white substance remains, which cracks in the fingers like fine sand, and which is the starch of the potato. The grains that compose it are so fine that it would take from one hundred and fifty to two hundred of them to equal the size of a pin's head. But these tiny grains are very complicated; for each of them is composed of a great number of leaflets fitted one over the other. If we boil the starch in a little water, the leaflets will open out and separate, and the whole will turn into a sticky jelly, exceeding in volume by far the starch that has been used.

CHAPTER XVIII

USES OF STARCH

STARCH is the alimentary provision of plants. Wherever there are shoots which are to develop independently, wherever there is a germ, there is also a quantity of starch which serves as an abundant store. It is found in tubers, suckers, bulbs, grains, and fleshy roots. As these shoots and germs develop through the process of vegetation, the starch becomes a kind of sugar, which is soluble in water, and is able to penetrate the young plant and serve for its food.

By certain processes man is able to effect this same change of starch into a sweet substance. The most simple of these is the employment of heat, which always takes part in the preparation of floury foods. For instance, a raw potato is uneatable; but boiled in water, or baked under the ashes, it is excellent. What, then, has happened? Part of the starch has been converted into sugar by the heat, and the tuber has become a sweet, floury paste. The same thing applies to the chestnut. When raw it is not good for much, although it is sometimes eaten; but when baked it deserves all praise and is another instance of the conversion of starch into sugar by means of heat. Beans and peas, as hard as bullets when dry and without any pleasant taste, are distinctly sweet as soon as the boiling water has affected their starch. And all our floury foods undergo the same change.

In order to convert starch into sugar, industry makes use of a more powerful means than heat alone. It is boiled in water, with the addition of a small quantity of sulphuric acid or oil of vitriol, and under the influence of this powerful liquid the starch becomes a sweet syrup. Of course, as soon as it is formed the syrup is purified from the oil of vitriol which has helped to produce it.

The sugar obtained in this way is a soft, sticky substance, almost as sweet as honey, but very different from ordinary sugar. It is called *glucose*, and confectioners make great use of it. When we eat a sugar-plum, it is generally starch and glucose. Many of the pastrycook's or confectioner's dainties, which seem to be sweetened with ordinary sugar, really owe their sweet taste to glucose, which is much cheaper. The potato plays many parts besides that of a table vegetable.

And this is not all; for starch sugar is exactly the same as that of ripe grapes. With potato flour, water, and a few drops of oil of vitriol, the manufacturer, with his enormous boilers, obtains the same sweet substance that the grape produces in its berries in the sunlight. Now grape sugar becomes alcohol by fermentation, and starch sugar must experience a similar change. In northern countries, where the climate does not admit of the culture of the vine, alcoholic drinks are prepared with starch converted into sugar. Because of their origin these drinks are called potato brandy, but all seeds and roots that abound in starch may be used for a like purpose.

Beer results from a similar conversion. Barley is made to germinate by keeping it rather damp in a gentle heat. During the process of germination the starch is converted to glucose in order to feed the new growth. When the little plant begins to break through, the grain is dried and reduced to flour. When this is diluted in water it provides a sweet liquid which, by fermenting, acquires alcohol and finally becomes beer.

CHAPTER XIX

PHOSPHATES AND NITROGEN

PHOSPHORUS, that terrible poison, is found abundantly in the bodies of all animals, especially in the bones from which all that is now used is derived. It exists in meat, in milk and in cheese, in plants—above all, in cereals—so that it is contained in flour and bread. But we need feel no alarm ; we shall not die poisoned like the rats that eat the phosphorated crusts.

When two or more substances are combined, they lose their original properties, and the combination possesses other properties altogether different from these. Thus carbon, when combined with the air that we breathe, becomes an invisible, subtle and unbreathable gas ; and lime, which has a burning taste, in combination with carbonic acid gas, becomes chalk, which is quite tasteless. And substances of which the least amount is fatal may, when combined with others, become harmless and even form part of our food. This is the case with phosphorus. We will try to discover what it is that is combined with phosphorus, so that it is no longer poisonous and forms part of our meat and flour.

When phosphorus is burnt a thick white smoke is produced, as you may see by burning a few matches. This white smoke, under the influence of the least damp, turns into a liquid with an extremely sharp taste, which is called *phosphoric acid*. Since this substance results from the combustion of the phosphorus, in the same way as carbonic acid gas does from the combustion of carbon, it ought to contain, and does contain, the air that is required by all burning matter. This phosphoric acid is no longer inflammable, however much it is heated ; for, being itself the result of combustion, it cannot be burnt again. But although there is no risk of burning by phosphoric acid, it is nevertheless dangerous on account of its extreme sharpness, by which it easily eats away flesh. This formidable substance, when associated with lime, loses all its noxious qualities and becomes white and perfectly tasteless, losing its poison altogether. It is then called *phosphate of lime.* This combination of burnt phosphorus and lime forms the greater part of the mineral substance of bones. If we put a bone on the fire the grease and juices with which it is saturated will burn, and the bone will remain light, friable, and perfectly white. This bone which has been burnt in the fire consists almost entirely of phosphate of lime. Containing the most inflammable of substances—phosphorus—it is itself absolutely uninflammable; while partly composed of a deadly poison, it is perfectly harmless; and while holding in combination matter with a horribly sharp taste, it is itself quite tasteless. It is in this combination, as an inoffensive phosphate, that phosphorus exists in meat, milk, the grain of cereals, flour and bread.

A cow will provide about fifteen gallons of milk in a week, containing one pound of phosphate. This phosphate comes from the hay, which derived it from the ground. But as the ground only holds a moderate quantity, of which it is constantly deprived by the hay, in time it will be exhausted, and the milk will become less plentiful and inferior. Two and a half pounds of bones (which contain about the same amount of phosphate as the fifteen gallons of milk), reduced to powder and spread over the pasture, will compensate for the weekly loss in phosphate drawn from the ground by the cow's production of milk. Such is the advantage derived from the use of powdered bones on exhausted pastures.

Phosphoric acid, in combination with other substances, is found in all agricultural produce, so that the phosphate contained in bones has a remarkable effect on our harvests. A harvest has been doubled, as if by enchantment, by the use of powdered bones. One pound of this powder will contain the phosphoric acid needed for the production of one hundred pounds of wheat. In spite of their powerful effect, the use of bones in agriculture must always be limited, because there are not enough of them, and because they are largely used for other purposes. Fortunately, in some places phosphate of lime is found in the form of stones called *nodules* or *coprolites*. These precious stones are carefully collected and reduced to powder in a mill, and so that the substance shall be more soluble in the dampness of the soil, and consequently more effective for the nutrition of plants, it is sprinkled with a highly corrosive liquid, called sulphuric acid, or oil of vitriol. In this way the *superphosphate of lime* is obtained, which is provided for agriculture by the manufacturer as a most effective manure, especially for cereals.

Some time ago we were asking what could be contained in the ashes of a burnt plant, and we found potash. Since every plant must have phosphate, if it is to flourish, we must find this in its ashes, since it is indestructible by heat. After the combustion of any plant, of a truss of hay, or a handful of grain, scientific experiment will always find the combination of phosphorus. It will also be found in the ashes of lime, in the rust of iron, in the silex of pebbles, and many other substances.

In order to complete this difficult but important subject of the nutrition of plants, something must be said about *ammonia.* Ammonia is an invisible gas, extremely soluble in water. In combination with other substances ammonia loses its overpowering smell, and forms different compounds, which are among the most effective manures. These compounds provide one of the components of plants, called *nitrogen.* When isolated, nitrogen is a gas without smell or colour. In this condition it forms four-fifths of the common air that we breathe. The other fifth consists of a second gas called *oxygen*, also without colour or smell. Oxygen only is able to support respiration and combustion. It is that alone which acts upon us so as to consume the material of our blood and to produce natural heat. That alone in combustion dissolves carbon, phosphorus, sulphur and other substances, producing a compound which we call carbonic acid gas, when it is derived from carbon, or phosphoric acid if it comes from phosphorus. In a word, all the properties that we have hitherto considered as belonging to the air, really are properties of oxygen. As for nitrogen, it plays no part in the atmosphere, except to modify the excessive energy of oxygen.

Nitrogen is necessary for all plants. It is needed by the wheat to form the grain in its ear ; by the pea, the bean and the lentil, to fill their pods ; by the grass of the pasture and by the hay of the meadow, to prepare the food which the sheep will convert to meat, and the cow to milk. We ourselves need phosphorus, since it enters into the composition of our bones ; still more do we need carbon, which is the chief fuel for the support of vital heat. But we could not eat the carbon as the charcoal-burner produces it in the forest, or the phosphorus as it exists in the match. The former would be a horrible mouthful, and the latter a fatal poison. They must be prepared in a suitable manner, as we find them in bread, in milk, in meat, fruit and vegetables. In a like way the plants require nitrogen, not as it exists in the air but in combination with other substances, of which the most important are the compounds of ammonia.

To sum up. In the nutrition of plants there are four prominent substances. First of all there is carbonic acid gas, which provides the carbon—the most abundant of all, but about which we need not concern ourselves, because the plants take it from the atmosphere, to which it is constantly supplied. There are also potash, phosphoric acid and nitrogen, which the roots extract from the ground in combination with other matters. These are the substances which are removed with the harvest, and which must be restored to the earth if it is to remain fertile. This is the office of manure, without which the soil would be exhausted and would cease to produce.

CHAPTER XX

The Ascent of the Sap

We will now inquire how the plant is fed by the substances, the most important of which we have been studying. The substance of any plant is not compact and uniform, without intervening spaces. On the contrary, if we examine it with the microscope we shall see an infinite number of very small cavities called *cells*. They are receptacles without any opening, sometimes round or oval, more often of no regular shape, and angular by reason of their mutual pressure. Their walls are composed of a very fine membrane. In the pith of the elder, which is riddled like a sponge, there are cells large enough to be seen without a microscope. Other cavities are long, pointed at both ends and swelling out in the middle, like a spindle. These are called *fibres*. Others are channels of uniformly equal thickness, and long enough to extend from the roots to the highest leaves.

These are called *vessels*. If we examine attentively the transverse section of a dry branch of a vine, we shall see a number of openings into which it might be possible to introduce a horsehair. These are the openings of so many interrupted vessels. Everything in the plant, absolutely everything—the root, the stem, wood, bark, leaves, flowers, fruit, seeds—everything is formed by a collection of cells, fibres and vessels.

Having said this, we will examine the root of the plant. In its younger portions, at the extremity of its most delicate branches, it is composed of new cells, which are tender and well adapted for absorbing the dampness of the ground. These extremities are called *spongioles*, and fill up just as sponges would. When this is accomplished, we find channels prepared to carry the fluid to the top of the plant ; and these are the vessels which may be compared to the pipes that carry the water of our fountains. But while in the fountain the water flows by reason of its own weight, passing from the higher to the lower portion, this is not the case with the fluid absorbed by the roots, which travels from the bottom to the top. What, then, is the force that causes it to rise ?

This force resides in the shoots, or rather in the leaves. Every leaf is the seat of vigorous evaporation, the object of which is to eject from the plant the large amount of water which has been needed to dissolve in the ground the precious nutritive substances that have been absorbed, and to transport them to the foliage. This evaporation gives rise to a vacuum in the cells that have ejected the water, which is at once filled up from the neighbouring cells, which in their turn receive the contents of the inferior layers. A similar process goes on from cell to cell, from fibre to fibre, from vessel to vessel, at points farther and farther from the evaporating surface, until it reaches the extremities of the radicles, which by their constant absorption replace the fluid that is lost. It resembles the action of our pumps, where the piston leaves a vacuum behind it, immediately filled by the water in the pipe, which receives it from the well. This fluid that rises in every plant, being absorbed by the spongioles of the radicles, and set in motion by the evaporation of the leaves, is called *rising sap* or *raw sap*. It is said to be rising because it proceeds from the bottom to the top, from the roots to the branches;

it is raw because it has not yet had the preparation that is to turn it into the liquid food of the plant. Hence we learn that the rising sap is transported first of all to those parts where the shoots are numerous and the foliage abundant, and prefers the extremities of the branches, where evaporation is most active.

We know that the exterior wood is the youngest: it consists of cells, fibres and vessels, the cavities of which are unconfined, and whose walls are permeable. The interior wood is older: its cells, fibres and vessels are encrusted, obstructed, worn out and useless. So the fluid makes its way where circulation is possible, and no longer penetrates where it is unable to pass. The ascent of the sap occurs in the superficial and recently formed layers. If a tree is cut down at the season of the activity of the sap, the outside layers will be damp, while the inner wood is perfectly dry. In herbaceous plants the ascent takes place throughout the stem. This ascent stops in the winter because of the absence of leaves, and acquires remarkable activity at the return of spring. If fruit trees have their branches lopped at this season, they are said to *bleed*, for the ascending fluid pours out through the openings of the severed vessels. This bleeding is seen abundantly in the vine.

Now what should we expect to find in this fluid pouring either from the vine or from a fruit tree? Many things, no doubt; for this fluid is the principal substance from which all that the plant contains is to be derived. Well, we should be mistaken: the rising sap is scarcely anything but pure water. It is with great difficulty that science has succeeded in determining some substances in solution, because their amount is so small. The most frequent among these substances are compounds of potash and lime and of carbonic acid gas, traces of phosphates and of nitrogenous or ammoniacal compounds. The fluid from which the plant is to derive its food is a very thin broth, composed of an enormous quantity of water and a very small amount of matter in solution. But these scanty materials are the only portion utilised by the plant, and the water that collected them from the ground, and then transported them from the roots to the leaves; the water which makes up almost the whole of the rising sap, leaves the plant as soon as the journey is accomplished, and returns as vapour to the atmosphere, whence it originally descended as rain.

CHAPTER XXI

Lime

To make the mortar which is used in building construction, masons make use of lime. Stones, which look as if they were burnt, are placed in a kind of basin surrounded by sand, and water is poured over them. In a short time the heap grows hot and burning, cracks and falls into dust, while absorbing the water, which disappears, being taken up by the material, or evaporated by the heat. More water is added till the whole is reduced to a paste, which is mixed with sand, and the result is mortar.

Lime is derived from a very common substance called *chalk* or, in scientific phraseology, *carbonate of lime*. The process is very simple. It consists in heating the stone in kilns constructed in the open air, in the vicinity of the places providing the fuel and the chalk, in order to avoid the expense of transport for a substance which must remain cheap. The lime kiln is about eighteen feet in height and is lined with bricks able to endure the fire. There is an opening at the base through which the lime can be withdrawn when it is sufficiently baked. In order to fill the kiln a rough arch is built with large pieces of chalk above the hearth on which the fuel is to burn, and over this arch smaller pieces are heaped up until the building is full. The fuel is either wood, brushwood, turf or coal. When the baking is completed the work stops, and the lime is removed by breaking down the arch that supports the whole. The whole heap collapses and falls to the opening at the base, where it is extracted.

Another method, which is the oldest and is still used in many places, consists in arranging the fuel and the chalk in alternate layers in the kiln. The whole rests on a layer of wood, which is lighted first, and when the fire has spread through the mass, the opening at the top is covered with sods of grass so that the baking may be slower and more regular.

Nothing can be more simple than the production of lime. We will now consider the effect on the chalk from the heat of the furnace, and how it turns into lime by passing through the fire. Chalk contains two different substances : lime in the first place, and also a gas, carbonic acid gas, which is as invisible and impalpable as air itself. The name carbonate of lime, which is given to chalk, denotes this combination exactly. As it is extracted from the ground the chalk holds the two components in close association, forming one substance, and not possessing the properties which they have when separated. Heat destroys this association and the lime remains in the kiln, while the carbonic acid gas is dispersed in the atmosphere with the smoke of the fuel. Having lost the gas, the lime, the properties of which are no longer concealed by the presence of another matter, remains as it is needed by the mason for his mortar.

So the action of the fire consists in decomposing the chalk and expelling the carbonic acid gas which is associated with it ; and the process in the kiln is only the separation of the gas and the lime. We will now consider the mortar. When it is sprinkled with water the lime becomes very hot, cracks and falls into fine dust like flour. The heat evolved arises from the violence with which the two substances combine. Before absorbing the water the lime is called *quick-lime*; afterwards, when reduced to powder, it has the name of *slaked lime*. This slaked lime is made into a paste with water, well mixed and kneaded with sand. It is now mortar. This is the mortar that is inserted between layers of stone to bind them together and to strengthen the building.

There is another observation which will explain the part played by the mortar. If we examine the water that has covered the slaked lime for some days we shall see a thin transparent skin, like ice, floating on the surface. This small solid crust is a substance similar to that from which the lime was extracted; it is chalk, or carbonate of lime. You have been told that two things are required for the formation of such a substance, viz., lime and carbonic acid gas. The lime is provided by the water, which must hold it in solution, as it covers a thick layer of the material, while the carbonic acid gas comes from the air, where it is always present in a small proportion. So the lime is able to absorb slowly the small amount of carbonic acid gas in the atmosphere and to resume its former condition as chalk.

A similar process takes place in the mortar. The lime takes back from the atmosphere the gas which was lost through the heat of the kiln, and gradually becomes chalk. It is mixed with sand in order to separate it and thus to enable it more easily to absorb the air that is required for its conversion into chalk. When the mortar is completely restored to the condition of chalk, the courses of a building are so firmly connected that it is sometimes easier to break the stones than to remove them.

Fat lime or pure lime, in contact with water, becomes very hot, increases considerably in volume and forms a strong adhesive mortar. *Greystone lime* does not heat readily, cracks slowly and scarcely increases in volume. The former is derived from almost pure chalk ; and may be mixed with much sand, when it provides abundant mortar : the latter comes from chalk containing various foreign matters, takes up less sand and produces less mortar. Both harden in the air by absorbing carbonic acid gas which converts them into chalk.

There is a third variety of lime, *hydraulic lime,* which possesses the valuable property of hardening under water. It comes from chalk that contains a certain portion of clay. Hydraulic mortar is used for the masonry of bridges, canals, cisterns, foundations, cellars and all buildings carried out under water or in damp ground.

CHAPTER XXII

The Descent of the Sap

The rising sap in a fluid made up of a large amount of water and a very small proportion of nutritive substances in solution, which are absorbed from the ground by the roots and conveyed to the leaves by the sap-wood. It is not as yet a fluid capable of feeding the plant, and assumes this character after reaching the leaves by a double process. In the first place, being dispersed among the leaves, which collectively provide a great surface for evaporation, it gives out its excess of water as steam and concentrates its serviceable materials. Then, under the influence of the sunlight and through the action of the green matter in the leaves, it experiences changes which completely alter its nature.

Among these processes one of the best known is the decomposition of the carbonic acid gas, absorbed from the air by the leaves and from the ground by the roots. We have seen that this gas, the chief food of the plant, is made up of carbon combined with oxygen —that component of the air which is fit for breathing. Under the influence of the sunlight the leaves decompose this gas; the oxygen is set free, becoming fit for the breath of animals and for combustion, while the carbon remains in the plant, and in conjunction with the materials supplied by the rising sap, becomes the nourishing fluid, the descending sap, from which the whole substance of the plant is to be formed. This fluid is neither wood, nor bark, nor leaf, nor flower, nor fruit, but forms part of each one of these. The blood of an animal is neither flesh, nor bone, nor fleece—yet bone, flesh and fleece are formed from its substance. The falling sap is also a fluid adapted for everything; it is the material of the fruit and the wood, the leaves and the flowers, the bark and the shoots. It is the blood of the plant and everything in the plant finds therein a provision for growth and food. What a wonderful and incomprehensible process has been needed for this purpose! What activity and what transformations beyond the reach of human science are going on in the crowded ranks of the cells of the apparently quiet leaves! Fluids distend the cells, ooze from one to another, transpire, circulate and exchange their matter in solution; vapour is emitted, gases come and go; the sunlight divides some substances and unites others, and the raw components of the ascending sap are formed into the material of life.

The perfected sap descends from the leaves to the twigs, from the twigs to the branches, from the branches to the stem and thence to the roots—being distributed in every direction during its course. It circulates between the wood and the bark. At the time when it is most abundant, in spring, it forms a thin layer of sticky matter between the wood and the bark, so that the latter is easily stripped from the branch.

It is perfectly easy to note its downward progress. If a ring of bark is removed from a trunk the nourishing fluid will ooze out and collect on the upper edge of the wound; but nothing of the kind is seen on the lower one. When thus arrested by the interruption of its regular path, the sap accumulates above the bare ring and results in an abundant growth of wood and bark, which is shown in a thick circular swelling, while the trunk below the ring retains its original dimensions.

A tight bandage, by compressing and obstructing the path of the nourishing fluid, will produce a similar swelling above the stoppage. We have seen a shrub fastened too tightly to the post that was to support it, choked by its own growth if not released in time. The stem is gradually swollen above the fastening, which is finally overgrown and concealed by the bark. If the whole of the trunk is not confined, if there is anywhere a fragment of bark which will afford a passage, the nourishing juice will adopt this path and evade the obstacle continuing its progress to the roots. In this case the tree will still grow. But if the barrier is absolutely insuperable, as in the case of a strong bandage, or the complete removal of a ring of bark, the sap cannot descend to feed the roots ; and when these perish the death of the tree will soon follow.

There is one lesson to be learned from these remarks on the course of the liquid food in plants. If we fasten a plant to the post that is to support it, we must take care not to make the bandage too tight, or else to loosen it in good time, as otherwise we may run the risk of a fatal stoppage in the trunk.

CHAPTER XXIII

The Pruning of Trees

A tree exists in the first place for its own preservation, and only in the second place for the preservation of the species, effected by the seeds. This is natural, for its own existence is a necessary preliminary to the production of posterity. The tree then lives in the first place for its own existence, and does this by producing shoots which turn into branches covered with leaves. It is by means of the leaves that the fundamental process in the life of plants is carried on; it is in their substance, in the sunlight, that the descending sap is prepared, the liquid food, the blood of the plant. The propagation of the species comes in the second place. It is left to the flowering shoots, or to those which flower and produce fruit, in the centre of which are the seeds.

Thus, if left to its own devices, a strong tree in favourable conditions first uses all its sap for shoots ; it produces strong branches and abundant foliage without any signs of flowering. Later on, when the branches are strong and the impulse of growth begins to slacken, flowering shoots appear, but these are generally few in number, because the abundant production of fruit is the cause of rapid waste. Abundant blossom only comes at the end of life. A tree never flowers better than when it is about to die, as if, anticipating its end, it was trying to leave a numerous posterity. A strong tree produces little or no blossom, but a dying tree flowers abundantly. But it is for the interest of man that the tree should flower and bear fruit as quickly and as abundantly as possible : we do not require the branches that it would produce without our interference, but the loads of fruit evoked by our care. *Pruning*, or the art of managing fruit trees so as to obtain abundant fruit, is the result of this struggle between the natural tendencies of the tree and our own needs.

If we examine the general principles which are to guide us in the practice of this art, the first question that occurs concerns the form that the branches are to assume. This form, far from being a matter of indifference, is of the greatest importance ; for the distribution of the sap and the sunlight, the chief factors in the life of the plant, is closely connected with it. If the tree is allowed to develop freely and assume its natural form, the sap coming from the roots, in its natural impulse, will tend to reach the highest parts, which will grow vigorously, while the lower portions will waste and perish for lack of sufficient food. If the branches do not receive sufficient light, those in the centre, deprived of the life-giving rays of the sun, will remain sickly, puny and more or less etiolated. On the other hand, the tree must derive all the benefit from the situation allotted to it in the garden so that there may be no wasted or unproductive space.

The form is determined by these conditions. In the first place it must be symmetrical, so that there may be an equal distribution of food, and that some of the branches may not overflow with sap, while others have none at all. In the second place it must allow the sunlight to penetrate to every part in order to ripen the fruit and to carry out the important process of the preparation of the sap in the leaves. In practice three forms have been selected with the object of attaining these results; pruning as *espalier*, as *pyramid*, or as *cup*. When pruned as espalier the tree extends its branches, symmetrically arranged, to the right and left against a wall. The wall serves as a support and a shelter against the wind; while it supplies additional heat and light to the foliage and fruit by reflecting the beams of the sun. In the pyramidal form the branches of the tree decrease in length regularly from the base to the top, being sufficiently far apart not to shut off the light from the centre. The whole forms a sugar-loaf, or cone, to the heart of which the sunlight and the air have free access. This is the form most in accordance with the natural tendency. The tree in the cup shape has a certain number of equally strong branches arranged in a circle round an empty central space, which thus receives its share of sunlight without any impediment.

CHAPTER XXIV

Plaster

Though less important than lime, plaster is much used in building, especially for ceilings, for chimneypieces and for joining bricks. It is a white powder which is made into a paste with water, being mixed in small quantities as it is needed. The worker take a few handfuls of the powder, which he dilutes in a little water in his bucket, with the help of his trowel. He takes the paste, spreads it on his hand, uses it at once and then prepares some more. Plaster cannot be mixed beforehand, because it hardens very quickly, turns solid and is then of no use. For it to be soft enough it must be used as soon as it is prepared.

Plaster is made of a stone called gypsum, which is always of the same nature, but which varies considerably in appearance according to the degree of its purity. Sometimes it is a shapeless, whitish substance, more or less granulated; sometimes delicately fibrous, with undulating reflections; or again transparent as glass and separating into very thin sheets, exhibiting here and there the splendid colours of the rainbow. This beautiful transparent gypsum was used by the ancients for window panes.

The impure gypsum, or shapeless stone, is used for common plaster, while the purer kinds provide the finer sort that is intended for moulding. The plaster stone is very common, forming whole hills or mountains in certain places. In order to prepare it for use a moderate amount of heat is required. For this purpose a number of small arches are built up with lumps of gypsum and other smaller pieces are piled over these. The whole mass is baked by burning wood and brushwood underneath.

Gypsum consists of lime similar to that contained in chalk, but it is combined with sulphuric acid, which cannot be expelled by heat. It also contains water which forms one-fifth of the whole weight of the stone. It is only the water that is removed by the heat, and as soon as it is rid of that, the gypsum becomes plaster.

But this has a great tendency to absorb

the water of which it has been deprived by baking, and thus to resume its original condition as stone. It is on this property that the use of plaster depends. When mixed in the bucket the powder quickly absorbs the water restored to it, and hardens into a substance as firm as the gypsum before it was baked. In the case of lime the change is slow, but for plaster it is very quick.

When baked the plaster is crushed under vertical millstones and then passed through a sieve. The powder must be kept in a very dry place, for it absorbs the damp very readily, and will then no longer harden when mixed with water. It can be easily understood that after being more or less saturated, the plaster cannot readily absorb the water which is needed for its conversion into a solid substance. It cannot combine with the water when it is required for use. Damp plaster is quite useless.

Statues, busts, medallions and other ornamental objects are prepared from plaster by moulding. This plaster is made with the purest gypsum, with those beautiful transparent sheets which have been already mentioned. It is baked in ovens like those used by bakers, and kept from contact with the fuel so as not to spoil its whiteness. The powder, which resembles fine flour, is diluted in water and reduced to a clear solution, which is poured into the moulds. As soon as the plaster has hardened, the mould, consisting of several pieces, is removed, and the object which has been moulded is extracted.

CHAPTER XXV

PRUNING (*continued*)

WHEN the desired form has been obtained it has to be retained, although the tree will rebel and attempt to regain the natural arrangement of its branches. Suppose, for instance, that a pear tree, pruned as an espalier, has spoilt its symmetrical plan by developing more on one side than the other. How can we restore the equality of the two portions—how weaken the too vigorous side and strengthen the feeble one? There are several ways in which this may be effected.

We cut off the branches on the strong side with the shears, only leaving them with a small number of shoots, that is, we prune them very short. On the weak side, on the contrary, we shall leave the branches untouched, or prune them very slightly, leaving the greater number of their buds. What will be the result of this treatment? Since abundant foliage, the workshop where the descending sap is prepared and the pump which attracts and draws up the sap from the roots, is the prime cause of a strong growth, the weak portion, with its numerous shoots lengthening into leafy growths, will grow, while the strong part with its few shoots is enfeebled. Thus the two processes tend to the same result, the restoration of the desired equality.

The herbaceous extremity of the young branches on the over-strong side is cut through with the fingers and thumb nail. This operation is called nipping. The sap that would have been expended in lengthening these branches is diverted from its course and turns to the weaker growths, which it animates and revives. If the weaker side needs nipping to arrest any growth that would interfere with its symmetry, this is put off as late as possible : on the strong side it is effected at an early date. Thus the sap diverted from the strong side to the sickly one has a whole season to restore equality.

Instead of cutting with the thumb nail and nipping the young shoots, they may be wholly removed while still herbaceous. This removal is effected at an early date on the strong side, only leaving those shoots which are indispensable ; but if required on the weaker side it is postponed as long as possible. This will have more effect than the nipping on the impulse imparted to the weak portion. The greater the number of branches that are suppressed the fewer will be the number of guests for the sap, the excess of which will help the branches that need strengthening.

The cause that diverts the sap from the pruned or nipped portion to the part that is intact, is evidently the greater or less suppression of the foliage. It is the leaves, by the constant evaporation proceeding on their surface, that cause the ascent of the fluid drawn from the ground by the roots. The more numerous they are at any point the more abundantly the sap flows towards it ; the fewer there are the less sap is received. If we diminish the number of leaves in any part by nipping or any other method, we also diminish the supply of sap, which will turn in other directions, to parts with more leaves, which will attract it by evaporation. It will be seen that we may adopt a middle course between the nipping which partly suppresses the foliage of a young plant, and the removal of the shoot, which stops it altogether. This consists in removing a certain number of leaves from the over-strong shoots. They must be removed neatly, not tearing them, but cutting the stalk and leaving the base in its place.

The most direct path for the progress of the sap from the roots to the foliage follows the vertical line from the bottom to the top. Anything that disturbs this direction interferes with the ascensional force. Thus in branches with abrupt angles or sharp curves the impulse of the sap is slackened, as the speed of a stream is impeded by the unevenness of its bed. Also, in a branch forced to bend towards the ground the sap can only progress with difficulty, since its course towards the end of the branch is effected in a direction contrary to that which is natural. The application of this principle is easily seen. If we wish to moderate an over-strong branch we shall bend it towards the ground, while if we have to strengthen one that is weak we shall draw it up in a vertical direction.

We may also make use of the exhausting effect of fruit. The more fruit that a branch bears the weaker it becomes; for the expenditure of sap in fruit leaves less for the production of the foliage which is its strength. So we shall leave as much fruit as possible on the stronger side and suppress it on the other.

CHAPTER XXVI

Production of Fruit

If we prune a tree very vigorously on one side and very little on the other, we divert the sap, which leaves the former side, turning towards the other which has more shoots and therefore more leaves. We have seen how this principle is used to moderate a growth that is too strong and to animate one that is too feeble, thus restoring the equilibrium of the two. But what will happen if the whole tree is pruned at once?

We will first consider what takes place in a single branch. If it is slightly pruned it retains the majority of its shoots, all of which it must feed with the sap that it receives, while if vigorously pruned it will only keep a few shoots, which, having the same amount to share amongst them, will receive a more liberal portion because they are less numerous. What might have been the food of twelve is now the portion of two or three. Each one develops more strongly because of this superabundance of food. If the whole of the tree is vigorously pruned, the whole of the sap absorbed by the roots, having no tendency to turn in one direction rather than another, is distributed equally throughout, and the few shoots that are left by the pruning take on a growth proportionate to the food of which they are able to dispose. Vigorous pruning thus applied to the whole tree has the effect of strengthening it and of restoring its youth by substituting new branches for those which are worn out. So when a tree is exhausted by abundant production of fruit it is vigorously pruned for a year in order to restore its strength.

We will now consider the contrary course to be followed supposing that we want the tree to blossom and bear fruit. We shall be guided by two principles. In the first place, when the tree is most vigorous it sends out long branches and thick foliage, but no flowers—or few. It is only in a weaker condition that it flowers abundantly. Secondly, the shoot that should have become wood turns into a flower bud. The flower is really a branch, which instead of growing and producing leaves, has, through lack of strength, remained short and contracted and has exchanged its leaves for flowering organs—for sepals, petals, stamens and pistils. So the usual process is to weaken the tree and the shoots.

In order to weaken the shoots the branches which are to grow long will be only slightly pruned. The numerous shoots will each receive a smaller amount of sap, and some of them, especially at the base of the branches, will be too weak to carry on the struggle and will turn to flower buds, although they would have grown into wood if their rivals had been removed.

In order to diminish the vigour of the tree the herbaceous extremity of the young branches is pinched off or nipped with the nail; or sometimes these branches are twisted into a curve which impedes the circulation of the sap. Another method is to break off the woody branches of the preceding year, either partly or altogether, leaving the ends hanging. If the tree is not too vigorous, any one of these methods will cause it to bear fruit.

If the growth is very strong more energetic means will be required. The branches are all bent down to the ground and fixed in that position. This abnormal direction is opposed to the ascensional course of the sap and, therefore, affords a scantier supply to the shoots. This poverty promotes the production of fruit. When the result has been obtained the branches are restored to their natural position, or else the tree would be exhausted.

Sometimes the pruning is postponed till the summer when the young shoots are already a few inches long. The sap which has been spent on the production of these shoots, which are now removed by pruning, is a serious loss to the tree, which is no longer able to feed the lower shoots on the branches and turns them into flower buds.

If none of these methods will induce the tree to bear fruit there are others more violent to which we should only resort in the last extremity. Towards the end of winter, before the sap begins to rise, a ring is cut round the base of the trunk, very narrrow, but deep enough to penetrate the exterior layers of the wood. We know that the sap rises through these exterior layers, which are the youngest and the most easily permeated by fluids ; so that if we partially arrest its course a less abundant supply will reach the shoots, and the tree, being weakened, will begin to produce fruit.

Sometimes the roots, the original sources of the sap, are approached. The principal roots are laid bare in the spring and exposed to the fresh air and the heat of the sun for the whole summer. Being deprived of the coolness and the dark required for their function, they supply less food to the tree and this poverty results in the appearance of flower buds. A more effective method, but one which unless used with discretion will ruin the tree, is to lay bare, mutilate and cut off some of the roots and then to replace the earth. This will evidently diminish the supply of sap. Or if a tree is small enough it may be transplanted in the autumn, retaining all its roots, when the disturbance effected by this change will cause it to flower in the following year.

CHAPTER XXVII

The Use of Lime in Agriculture.

In order to be fertile, besides the organic matters contained in humus and manure, the ground must hold chalk, sand and clay. It may happen that the ground in its natural condition does not contain enough of these, or that it may be altogether deficient in one or other of them. In this case the nature of the ground must be corrected by the supply of that which is lacking. So land which is too sandy is improved by chalk and clay; while that which is too strong and contains too much clay, is improved by sand, and still more by chalk. The mineral substances which are added to the ground to correct its nature also help in the nutrition of plants, and may therefore be looked upon as mineral manures.

One of the most valuable of these is lime, which is not only indispensable for land that contains no chalk, but is also required for the nutrition of all our cultivated vegetables. It acts in various ways. In the first place it attacks vegetable substances vigorously, decomposes them, and converts them into humus. A heap of leaves that would take a long time to rot, if mingled with lime soon becomes a mass of humus. Hence it is of great use in fields that contain many weeds, or in those that have been recently cleared, or wherever there are old trunks, heaps of leaves, fragments of wood or heath to be removed. It will speedily convert all these herbaceous or woody substances into humus, enriching the ground to the great advantage of future harvests.

In the second place, lime will correct and neutralise the acid nature of some soils. This property is shown in the following experiment. If we mix a little lime with strong vinegar we shall find that the smell and acid taste will soon disappear. Where-ever there are rotting plants, leaves, mosses, reeds, or old trunks of trees, substances with a bitter taste are produced, otherwise called acids, the presence of which is injurious to all cultivation. This is specially the case in marshy ground, where the excessive acidity suits the tough growth of reeds and sedges that are of no use to us ; but such acidity is quite unsuitable for the various plants that we cultivate. Lime, which corrects the acidity, does wonders in marshy ground and damp meadows. The need of lime is shown by the growth of ferns, heath, sedges, reeds, mosses, or sphagnum.

In the third place, as soon as it is in the ground, the lime again returns to its original condition of chalk, but in the form of very fine powder. This reversion to the condition of chalk is effected by combination with the carbonic acid gas, which proceeds from the atmosphere or from the substances rotting in the ground. In this new form lime plays an important part, by supplying the chalk to land where it is deficient, and by causing the clay to be more easily penetrated by air and water.

The distribution of lime to the ground takes place at the end of summer when the land is dry. Heaps consisting of four or five gallons of quicklime are placed at intervals of five yards, and covered with a little earth. In a short time, through the dampness of the air, the lime is reduced to a fine powder. It is then spread evenly with the shovel, and buried by slight ploughing.

The lime must never be buried with the seed; for in contact with it the young shoots would be burned. Nor must the lime be mixed with the manure before use; for in that case there would be an abundant exhalation of ammonia, which is one of the most powerful agents in vegetation, and which would thus be utterly wasted. Lime and manure must always be used separately.

Marshy, clayey or granite soils are those in which lime produces the greatest effect. The important results produced by the distribution of lime, have given rise in many countries to its manufacture by rapid and powerful methods, solely with reference to its use in agriculture. In Mayenne, a district of France where a great extent of barren clay soil has been converted into rich meadows and cornfields of exceptional fertility, the lime is manufactured in huge kilns, twelve yards high, resting against the cliff that provides the chalk, and sometimes the fuel also.

All animal remains provide excellent manure. Such are old woollen rags, fragments of leather, scrapings of horn, the dried blood from slaughter-houses, or flesh unfit for human food. All these matters are rich in nitrogen and phosphates and form a valuable addition to the manure of the farm. Lime enables us to use any flesh in the best possible way.

The carcasses of animals, which through ignorant carelessness are left to the greedy appetites of dogs, magpies, and crows, should be cut up and buried in a mixture of quicklime and earth, which will soon decompose the flesh. In a few months we should have a trench full of powerful manure, instead of an unpleasant and useless carcass. The bones, which are not affected by the lime, should be burned to make them more friable, and then reduced to powder. These powdered bones, mixed with the manure provided by the decomposition of the flesh, will afford an abundant supply of phosphorus to the cereals and pasture. Horses and mules that have been killed, and all the larger animals that die a natural death, should be used in this way.

CHAPTER XXVIII

Cultivated Plants

There are three methods of propagation practised in cultivation: these are layering, by cuttings and by grafting. In order to appreciate the value of these operations we must recall the origin of our plants in common use.

Perhaps you may imagine that the pear tree has always exerted itself in producing large fruit with melting flesh with a view to our food; that the potato has swollen its great tubers with floury matter for our pleasure; or that the cabbage formed its compact head of beautiful leaves of its own accord for our gratification. You may think that the wheat, the pumpkin, the carrot, the vine, the beetroot, and so many others, have taken a keen interest in man and have always worked for him independently. You believe that the fruit of the vine is now similar to that from which Noah drew the juice that intoxicated him; that wheat, since it first appeared on the earth, has never failed to produce an annual harvest; that the beetroot and the pumpkin were of the noble size, which gives them their value, from the beginning of the world. In a word it appears to you that the plants that we use for food were originally found in the same condition as we have them at present. It is a mistake; the wild plant is generally of little use as food, and only becomes valuable through our care. It is our part, by work and cultivation, to profit by its properties by improving them.

In its native country, on the mountains of Chili and Peru, the potato that grows wild is a miserable tuber the size of a nut. Man receives the poor little savage into his garden, plants it in good ground, nurses and waters it, and the potato gradually improves. It gains in size and nutritive qualities and at last becomes a floury tuber the size of our two fists.

On oceanic cliffs, exposed to every wind, a cabbage grows wild, with a long stalk, a few raw green leaves, a sharp taste and a strong smell. It may possibly conceal valuable properties despite this unprepossessing appearance. Such an idea must have occurred to the man who, in remote ages, first admitted the cliff cabbage to his garden. The idea was justified—the wild cabbage has been improved by the incessant care of man; the stalk became stronger, the leaves increased in number, and, white and tender, were fitted into a close head, and the cabbage that we have to-day is the final result of this splendid transformation. We see the starting point of the precious plant on the rocks of the shore, and the goal in our gardens. But where are the intermediate forms that in the course of centuries gradually brought the species to its present condition? These forms were so many steps forward. It was necessary to preserve them to prevent them from falling back, to multiply them, and to keep on attempting further improvement. Who could reckon the expenditure of labour that has produced the cabbage?

You may know the wild pear tree. It is an ugly bush, bristling with fierce thorns. The pear is a detestable fruit that contracts the throat and sets the teeth on edge, very small, bitter, hard and apparently stuffed with gravel. The man must have been gifted with rare inspiration who first had faith in the cross-grained shrub, and foresaw, in the distant future, the mellow pear that we eat to-day.

In the same way, from the grape of the original vine, the berries of which were no larger than those of the elder, man, by the sweat of his brow, has acquired the juicy fruit of the vine as we know it to-day. He has obtained wheat from some poor seed now unknown, and his vegetables and fruit trees from a few wretched shrubs and uninviting herbs. Earth treats us as a harsh stepmother in order to compel us to work, which is the supreme law of our existence. It provides plenteous food for the young birds, but to us it only offers the berry of the bramble or the sloe in the hedge. We need not complain, for it is the struggle with want that creates our superiority.

It is for us by intelligence and labour to provide for ourselves ; to act on the noble motto—" Help thyself, and heaven will help thee."

Man has always sought to discover among the innumerable species of plants those that are capable of improvement. The greater number have remained useless ; but others, predestinated and created specially for the sake of man, have yielded to our care and, by cultivation, have acquired properties of the greatest importance, since they provide our food. But the improvement obtained is not so radical that we can rely on its permanence if our care is relaxed. The plant has always a tendency to return to its original condition. If the gardener leaves the cabbage to itself, without manure, water, or cultivation ; if he allows the seeds to germinate by chance wherever the wind carries them, the cabbage will soon lose its close head of white leaves, and resume the loose green leaves of its wild ancestors. The vine, deprived of the care of man, will revert to the wild vine of the hedge, a whole bunch of which is not equal to one berry of the cultivated grape ; the pear tree on the edge of the wood will resume its long thorns and nasty little fruit ; the plum tree and the cherry will contract their fruit to kernels covered by a sour skin—in a word, our orchards will lose their wealth and all their value to us.

This return to the wild state will take place despite all our care if we attempt to reproduce the plant from seed. We may sow the pips taken from a very good pear, and most of the trees grown from these seeds will only produce poor or very bad pears. Only a few will yield the parent pear. If we sow again with the pips of the second generation the pears will degenerate further. And if we proceed with such sowing, always using the seeds of the last generation, the fruit will become smaller and smaller, bitter and hard, till it has become once more the poor pear of the hedges. One more example. What flower can be compared to the rose, with its fine growth, its sweet scent and bright colour ? If we sow the seeds of this splendid plant its offspring will be the poor bushes, the simple wild roses of our hedges. There is nothing surprising in this ; the noble flower started as a wild rose, and in the seed it resumes the features of its race.

Among certain plants, however, the improvements resulting from cultivation are more stable and persist despite the experience of the seed, but only on the express condition that care shall never be lacking. All, if left to themselves and propagated by seed, will revert to their original condition after a certain number of generations, during which the characters impressed upon them by the intercession of man are gradually lost.

CHAPTER XXIX

Means of Propagation

How then can we propagate our fruit trees and decorative plants so that we need not fear to see them degenerate, since if sown they will, sooner or later, revert to the original wild type? They must be propagated by shoots and not by seeds. We must transfer the shoots or branches from one plant to another, which is grafting, or else directly to the ground, as in layering. These are invaluable methods which allow us to fix in the plant the perfection obtained by long years of work, and to profit by the improvements already effected by our forerunners, instead of inaugurating a development for which a human life would be insufficient.

The layer, the cutting, and the graft faithfully reproduce all the characters of the plant from which they are taken. Such as were the fruit, flowers and foliage of the plant from which the shoots have been transferred; such will be the fruit, flowers and leaves provided by them. Nothing will be added to the characters that it is desired to propagate, but nothing will be lacking. If there are double blooms on the plant from which the layer, slip, or graft is taken, so there will be double blooms on the plants produced by them; if there is a special shade of colour it will be matched by exactly the same colour, and if the fruit is large, sweet and perfumed, that produced from the graft, slip or layer will be exactly the same. The slightest peculiarity that, for some unknown reason, appears on a plant raised from seed, sometimes on a single branch, such as the incised outline of the leaves or the varied colour of the flowers, is reproduced with minute fidelity, if the graft, slip or layer is taken from the affected branch. In this way horticulture is daily enriched by double flowers, or new shades of colour, by fruit remarkable for its size, its late or early maturity, its mellow flesh, or stronger scent. If it were not for the slip and the graft these accidental occurrences produced by no evident cause would disappear at the death of the favoured plant, and we should always be seeking for improvements, which would be lost almost as soon as they were found, because of the lack of means for fixing them and making them permanent.

If history had preserved the record, what long and difficult trials must have been carried out, in order to derive our cultivated plants from a few useless wildlings! Think of all the happy inspirations that have been needed in order to select from the vegetable world the species capable of being modified for good; of the patient attempts to subject them to our cultivation; of the labour in improving them from year to year, and of the trouble in preventing them from degenerating and in handing them on to us in their perfect condition—think of all this and you will recognise that the smallest fruit or vegetable represents more than the work of the man who raised it in his garden. It may represent the accumulated labour of a hundred generations which were needed to create the table vegetable from the poor wild plant. We are living on the fruit and vegetables created by our ancestors; on the labour, the strength and the thought of the past. If the strength of our arms and our thought can provide for the life of future generations, our mission will have been worthily fulfilled.

It was not by chance that the ideas of layering, taking cuttings and grafting occurred to man, but by thoughtful observation of natural processes going on around him. He who first noticed attentively the way in which the strawberry plant grows and multiplies, received the first lesson in layering. We will consider this curious growth for ourselves. Certain long thin branches start from the parent plant of the strawberry and crawl along the ground. These are called runners. When they have reached a certain distance the extremity develops into a small plant, which takes root in the ground and soon becomes independent. The new strawberry plant, as soon as it is strong enough, sends out long branches which follow the same course—crawling over the ground, ending in a bunch of leaves and taking root. After a number of such growths the parent plant will be surrounded by young offshoots, settled in different places, according to the season and the nature of the ground. At first these offshoots are connected with the parent plant by the runners. There is a common life as the sap flows from the old plant to the young. But sooner or later the relation is broken off ; the runners, having become useless, dry up, and each growth, properly rooted, becomes a separate plant. We find here, apart from human industry, all the incidents of layering : the artificial operation finds its equivalent, and no doubt its model, in the natural process. A long branch bends towards the ground and is then detached from the parent stock by the destruction of the runner. In the same way the gardener buries a long branch in the ground, waits for it to produce adventitious roots, and then separates it with his shears, and this is layering.

CHAPTER XXX

The Use of Plaster in Agriculture

Plaster is by no means of the same importance in agriculture as lime, but it has an excellent effect on clover, sainfoin and lucerne. It is used in spring by dusting the young leaves when they are still damp with the morning dew. Misty and calm weather is most suitable for this operation. Plaster also has a good effect on colza, flax, buckwheat and tobacco, but it is useless for cereals.

The intelligent husbandman has a further use for plaster. In every heap of manure there is slow combustion and fermentation, producing ammoniacal exhalations, which are dispersed in the air and absolutely wasted. These exhalations should be retained in the manure as far as possible; for it is the compounds of ammonia that supply nitrogen to the plants. To prevent this loss plaster is scattered over the top of the manure; or sometimes, as the heap is formed, each layer is dusted with plaster. The plaster absorbs the ammoniacal vapour, parting with some of its sulphuric acid and forming a compound —sulphate of ammonia—which cannot be reduced to vapour. The plaster is said to fix the ammonia; that is, to prevent it from dispersing.

With regard to the fertilising effect of plaster on lucerne, the following experiment is related. Franklin, one of the greatest men in the United States of America, knowing the powerful effect of plaster, tried to spread its use among his fellow-citizens; but they, faithful to their old customs, would not listen to him. In order to convince them Franklin sowed plaster in a field of lucerne, beside the most frequented road in Philadelphia, spreading it over the plants so as to trace out letters and words. The lucerne grew everywhere, but much taller, greener and thicker in the parts that had been plastered, so that the passers-by could read in the lucerne these words in gigantic letters—"*This was plastered.*" The ingenious experiment was quite successful, and plaster was immediately used in agriculture.

CHAPTER XXXI

Layering

Some plants, such as the carnation, throw out straight, flexible shoots from the base of their stem, by means of which new plants may be provided. These branches are fastened to the ground by bending them into an elbow, which is buried and fixed with a hook. The end is made to stand up and is kept in position by a support. The buried elbow sooner or later produces adventitious roots, and until that occurs the parent stock feeds the branches. As soon as there are a sufficient number of these roots the branches are cut and each root, transplanted separately, becomes an independent plant. This operation is called layering.

We will take an instance of the method, the principle of which has been explained. Suppose that in a vineyard certain stocks have failed and must be replaced. For this purpose layering will be the most convenient method, and will also give the quickest return. Near the space to be filled a plant is selected with a vigorous, long and conveniently situated shoot. The ground occupied by the dead stock is thoroughly dug over and the whole plant with its roots is removed, as the rotting of these might be injurious to the new-comer. When the ground has been dug over a trench is arranged about a foot in depth and the branch is deposited in it, care being taken to bend it without breaking or splitting. The buried portion is covered with a layer of earth and the trench is filled up with manure. The end of the branch is drawn up out of the ground, fastened to a post as a support, and cut back till it only retains two shoots. All the shoots on the portion between the parent stock and the point where the branch enters the ground are removed, since they would divert some of the sap. The best time for practising this operation is the beginning of winter, because the lengthy stay of the branch underground while all plant life is at rest, allows it to grow more vigorously when the sap returns in the spring.

What will be the fate of the branch partially buried in this way? If it had remained in the open air it would have produced its fruit. Why should it not still do this in the condition in which it has been placed by the vine-dresser, which in no way affects its connection with the parent stock? It is still in uninterrupted communication with the plant that feeds it and receives its share of the rising sap absorbed by its roots. The shoots that it has retained will develop leaves, which, in the sunlight, will transform this raw fluid into nourishing sap. There is no reason why it should not yield the same result that it would have done if it had remained unburied. And, indeed, the layer does bear fruit the same year, producing a few bunches if it is well cared for. However, under the influence of the cool ground and the stimulant of the manure, in time the adventitious roots appear on the buried portion, become numerous and strong, and the day arrives when they are able to feed the young plant without the assistance of the parent. It is in the third year that the root becomes strong enough for independent existence. Then comes the weaning—the nursling is deprived of its nurse by the knife separating the parent stock from the layer now that the latter is able to provide for itself.

The vine, with its long shoots so near the ground, is well adapted for burying the branches that are to take root, but with most trees or shrubs the conditions are very different. Their branches are neither long nor flexible enough, nor are they sufficiently near the ground to be placed in the trench. This difficulty may be overcome in the simplest fashion. We know that a stem, cut down to the level of the ground will develop at the edges of the wound numerous adventitious shoots that will grow into branches. These will be exactly the growths that we need ; for they are long and flexible and start from the level of the ground. Each of them, treated as a layer, buried in a trench where it is fastened by a hook, with its extremity maintained in a vertical position by means of a support, will take root sooner or later, according to its species, and may then be transplanted as an independent plant. This method goes by the name of arching, as the buried branch is bent into the form of an arch.

The following method dispenses with the arching, which cannot be practised if the wood is too brittle. The trunk that is to provide the layers is cut down in the spring, and the young growths appear on the edges of the wound. When they are long enough but are still in the herbaceous condition, which is most favourable to the development of adventitious roots, the parent stock is buttressed and permeable soft earth is heaped up round the trunk and the base of its offshoots. The heap of earth takes the shape of a truncated cone, with an excavated hollow at the top to receive the occasional watering which will keep it suitably cool. In this healthy environment the young shoots will soon produce adventitious roots and in the following year there will be a number of rooted plants which may be separated by the knife. The original stock may be used again for the same purpose. This is called layering by circumposition.

If we do not wish to cut down the parent plant in order to obtain offshoots for layering, and the branch that we want to take root is too high to be laid on the ground, the following expedient may be adopted. A pot split lengthways or a leaden cornet is fastened to a shrub, and the branch to be layered is placed in the pot or the cornet longitudinally. The pot is then filled with soil or moss which is kept damp by frequent watering. Adventitious roots sooner or later appear in this moist medium. When these are suitably developed a gradual weaning begins ; a slight cut is made below the pot and deepened from day to day. The object of this is gradually to accustom the layer to do without the parent stem and to find its own living. At last the separation is complete. This gradual weaning is also advantageous for layers that are buried in the ground and ensures the success of the operation.

If the wood is tender the adventitious roots start easily from the buried portion, and the method that has been described will ensure the success of the layering. But close woods are less ready to take root and might remain for a considerable time in the earth without doing so. In that case art must intervene, based on the plant's mode of life. We will recall the effect of a tight ligature on a stem. The descending sap collects above this line, as it can no longer continue its course between the wood and the bark confined by the string. It accumulates and forms an excrescence, into which the plant pours the excess of the arrested matter. If this is buried in moist ground adventitious roots will soon appear and facilitate the downward course of the sap.

A small stream of water, uncontrolled, flows on without making any attempt to overcome obstacles; but if we arrest its course the accumulated water will be able to force its way through the barrier. This also happens with the sap. As long as it can travel unimpeded in its natural course it will not turn out of its way in spite of the moisture of the surrounding earth, and unless the weakness of the wood and bark offers very favourable conditions it will not waste its energy in producing roots. But if the natural course of the sap is arrested it will develop adventitious roots in order to continue its interrupted progress. The same result is achieved by removing a ring of bark from the buried part. The arrested sap forms an excrescence above the cut in the bark, from which roots are produced.

Now for the application of these theoretical principles. If the wood is close and refuses to submit to the methods of simple layering, the branch that is to be layered is strangled with a wire and tightly compressed without breaking the bark. The wire must be placed above a shoot and about the middle of the buried part. This method of layering is called wiring.

Or else, still in the middle of the portion underground and just below a shoot, the bark is cut through all round the branch without injuring the wood ; a second incision is made about half an inch below this and the bark between the two is removed in one piece. This is called ringing.

Thirdly, and still in the middle of the part lying in the trench, an oblique incision is made which penetrates the wood to the pith. In this way a small tongue is lifted up half as thick as the branch, which is kept apart by placing a small stone in the opening. This is called tonguing. By means of the portion left whole the branch remains in connection with the parent plant and receives its share of raw sap, and from the incised and raised portion it develops adventitious roots, because the course of the rising sap is arrested.

In order to bring into contact with the moist earth a greater number of wounds able to produce adventitious roots, the uplifted piece may be split in two and the two portions kept apart by a small stone. This method of double incision is used for trees which offer the greatest resistance to layering.

All these methods, and others derived from them, have the effect of promoting the development of adventitious roots by arresting the progress of the sap at some point underground.

CHAPTER XXXII

Cuttings

A cutting is a branch separated from the parent plant and placed in conditions suitable for the development of adventitious roots. The branch is placed in the ground in a moist position where the temperature is mild and the evaporation will be slow. For delicate cuttings the shelter of a glass bell is often necessary so as to keep the surrounding air sufficiently damp and to prevent the branch from drying up before it has acquired the roots to compensate for its loss. As an additional precaution, if there are many leaves on the branch most of the lower ones are removed, in order to diminish the evaporating surface without affecting the vitality of the plant, which is strongest at the top. In many cases this precaution is not required, and for the vine, willow, or poplar, it suffices to place the cutting in the ground.

Plants with soft wood full of juice are

most easily propagated by cuttings. Such is the willow, the wood of which is very soft. With plants the wood of which is close and hard, the application of this method would be very difficult or even impossible. It would inevitably fail if applied to the oak, olive, or box, and many other plants with a close texture. Moreover, propagation by cutting is less certain than by layering. The layer remains in connection with the parent plant until it has developed roots, while the cutting, parted abruptly, has to get through the difficult time without roots, unaided.

Among fruit-bearing plants there are only the vine, the currant, the quince and some varieties of plums and apples that can be propagated by cuttings. Of forest trees, the willow and the poplar will easily take root in this way. A number of decorative species, herbaceous plants or shrubs, such as the rose, the jasmine, or honeysuckle, are easily multiplied by this method, which is the common expedient of the florist.

We will consider the simplest case—that which requires the least precaution. Some moist ground near water has to be planted with willows or poplars. At the end of winter strong branches are cut, as thick as a big walking stick, or a wrist, or even thicker, and from one to four yards long. The lower branches are removed, the middle ones are partly cut away and the upper ones are left untouched. Lastly, the lower end is pointed with the hatchet so that it may enter the ground more easily. The cutting is now complete and it is only necessary to plunge the pointed end deeply in the ground and then to leave it alone. Without further care, if the ground is suitably moist, adventitious roots will appear, and each of these roughly cut posts will become a poplar or a willow.

But other plants do not possess this tendency to take root, which allows us to obtain a tree from a post driven in by a club, and delicate precautions are needed if their cuttings are to succeed. For instance, there is the vine, the cuttings of which are the new branches of the year. These are made into a sheaf and their lower extremities are soaked in water for a week or more. Why this long immersion of the part that is to be put underground? It is because the outer layer of the bark is dry and tough, hardly to be pierced by tender roots, especially if the ground is dry. This layer is softened by a prolonged stay under water, and when taken out of the bath the whole of the portion that is to be buried is slightly scraped, while the part that is to remain in the open air is left intact. Thus the outer skin of the bark, which has been softened by the water, has been removed, and the obstacle which would hinder the issue of the roots has been weakened, while the inner layers, which are the region of the plant's life work, are left. The small wounds that result from the scraping, by arresting the sap, promote the production of roots. When thus prepared the cuttings are placed in the ground. Vertical holes are made with a long wooden or iron dibble in very light ground, so that the young roots may enter it without difficulty, and a cutting is placed in each of these holes at a depth of half a yard. Fine earth, well heaped up, so that it may be equally in contact with the cutting on all sides, completes the filling up of the hole.

When the plant offers resistance to layering, the production of adventitious roots is promoted by means of the excrescence formed by the descending sap, either above a wire or above the place where a ring of bark has been removed. The same device may be used for cuttings. A wire is fastened tightly round the branch which is to be used as a cutting in the following year, or else a ring of bark is removed. An excrescence is formed in the autumn. The branch is then detached and buried during the winter so that the excrescence may swell and become softer. In spring it is taken up again and cut back to only four or five shoots. It is then planted as an ordinary cutting, when roots will be developed from the excrescence formed by the accumulation of the sap.

The advantage given by the excrescence may be gained without any exertion on our part. If we pull a twig towards the ground to break it off from the branch that supports it, there will be a rent in the angle, and a shield, or part of the base of the twig, will be detached with it. This shield, when touched up with the knife to give it a clear section, will provide all the advantages of the excrescence. By its abrupt change of direction it arrests and accumulates the descending sap, and is thus more fit for the production of adventitious roots than any other point.

Instead of separating the branch by tearing off its base, the older branch may be cut through by the shears, above and below this base, so that the cutting retains a fragment of the branch in the shape of a small crozier.

With this fragment a kind of natural excrescence, success is more certain than in any other way.

Finally, we will say something of shoots used for cuttings, a kind of sowing in which shoots are used instead of seeds. This, the most delicate of all methods, is only practised in exceptional cases. Suppose that we have only a small number of branches, or perhaps only one taken from some very rare variety of vine. We shall wish to obtain the greatest possible number of cuttings from this one branch. With this object the branch is divided into fragments about two inches long, each of which has a shoot in the middle. These fragments are cut lengthwise into two equal parts. The one that bears the shoot is retained and the other is thrown away. The fragments thus prepared are laid horizontally, with the shoot on top, in excellent soil, the shoot only being left uncovered. For such sowing to have any chance of success it will be understood that special conditions are necessary, which could not be realised if the operation were performed in open ground. The delicate cuttings are placed in an earthenware pot or pan and covered with a bell glass, which secures a moist atmosphere and gentle warmth. As soon as the roots appear the cuttings are transplanted to separate pots, where they remain until they are strong enough to be planted in the open ground.

CHAPTER XXXIII

Draining

At the bottom of a flower-pot there is a hole. A fragment of earthenware is placed over this hole, and if the plant is delicate this is covered with a layer of small stones. When these preparations are completed the pot is filled with earth. What is the use of the hole, the fragment, and the layer of stones? Let us find the answer to this question.

Water is absolutely necessary to plants, for it is by this means that the different nutritive substances contained in the earth are dissolved, so that they may be absorbed by the roots. For this purpose the earth entered by these roots must always contain suitable moisture, provided either by rain or by watering. But air is no less indispensable. It purifies the ground and by slow combustion of the soil gives out a small but constant supply of carbonic acid gas, which is the food of vegetable life. Deprived of its life-giving influence the plant will languish and decay, so that if vegetation is to flourish the earth must hold both air and water. But if there is no hole in the flower-pot, or if this hole is obstructed, the water will not run out, there will be no room for the air, and without this the roots will decay. On the contrary, if after saturating the earth the water flows out freely by the hole at the bottom, the damp earth will be like a sponge, penetrated by the air throughout, and the plant will flourish. This is the reason for the fragment of earthenware, which prevents the hole as the bottom from being filled up, and for the layer of small stones, which allows the air to circulate freely.

These reasons apply to cultivation on a large scale as well as to that of a flower in a pot. After the water has moistened the ground it must flow away, or else the roots will decay for lack of air. This is why clay soil, which retains the water after being saturated, is bad for cultivation ; while light soil, composed of sand and clay, which allows the water to flow away freely, is good. For the same reason a sandy subsoil is favourable to vegetation, while a clay subsoil is bad for it. With a sandy subsoil the conditions are the same as with a flower-pot open at the bottom; while with a clay subsoil they resemble those of a pot without any opening. In the former case the superabundant water flows away and the air comes in; in the latter it must remain and the air cannot reach the roots.

Now we will consider marshy ground. On account of the stagnant water, either on the surface or at a slight depth below, nothing can grow except a few hardy plants, such as reeds, destined by nature to live in such situations. Small trenches are dug at a depth which cannot be reached by the roots; a layer of stones is placed at the bottom of these and they are then filled up with the earth that has been excavated. These trenches, hidden underground, slope downwards, and at their lowest point end in a main channel. The water with which the ground is saturated collects in these trenches, flows through the bed of stones and falls into the main channel, which carries it to some stream at a distance. Now our marshy ground resembles the flower-pot with its hole at the bottom, its fragment of earthenware and its layer of gravel; the air can penetrate into it and cause it to become fertile. This operation is called draining.

When practised in this way draining is a simple matter; but it presents a serious difficulty. Sooner or later the layer of stones will be filled up by the earth transported by the water. For this reason the stones are sometimes replaced by faggots of branches which are not so easily obstructed; but a better result is obtained by channels of earthenware at the bottom of the trenches. Sometimes these channels are composed of tiles similar to those used for roofs, resting on flat tiles called sleepers. Or again, complete pipes of earthenware are used, loosely fitted to one another, so that the water may enter the channel through the joints.

The advantages of draining are not limited to drawing off the water from ground that is too damp and to promoting the access of air to the roots of plants. It also keeps up a constant moisture in the ground owing to the water that remains in the drains. When the base of a heap of sand is immersed in water the moisture may be seen to rise gradually until it reaches the top. In the same way in dry seasons the water in the channels will penetrate upwards till it reaches the roots, so that the water which is at certain times useless or even harmful is held in reserve and gradually distributed at the right moment.

Another advantage is to prevent the chilling of the ground caused by excessive evaporation. While being reduced to vapour the water chills the objects at the expense of which the evaporation takes place. On having a bath we feel cold because the moisture on our body is evaporated. In the same way water that is constantly evaporated from the surface of damp ground chills it and turns it into cold earth ; but if the water is carried away by draining the evaporation stops and there is no further chill. A high temperature is always favourable to vegetation.

Draining is so advantageous that it is not only practised on damp ground, which, without it would be altogether unproductive, but also on ordinary arable ground. Whenever the ground contains too much clay, or even if the soil is good but the subsoil is clay, the rain water cannot escape and the earth will be damp and cold. In course of time, however, the ground dries up, but the earth which has not been disintegrated by the action of air, forms into compact lumps, so that the roots are alternately first drowned and then imprisoned in hard earth and baked by the sun. Draining supplies a remedy for these disadvantages and, therefore, all heavy ground which retains the rainwater for a long time before absorbing it receives much benefit from this treatment.

CHAPTER XXXIV

Grafting

Grafting is the process of transplanting a shoot or a branch from its own branch to another branch, from its own tree to another tree. The plant which is to be the nourishing support is called the stock, and the shoot or branch transplanted is the graft.

There is one condition that is absolutely necessary if this change of support is to succeed; the transplanted shoot must find on its new branch food adapted to its requirements—sap similar to its own. This means that the two plants, the stock and the one that provides the graft, must belong to the same species, or at any rate to two that are very closely allied; for the similarity of the sap and its products can only result from similar organisations. It would be a waste of time to try to graft the lilac on the rose, or the rose on the willow; for these three species have nothing in common, either in leaves, flowers or fruit. An absolute difference in nutrition must inevitably result from this difference in structure; the rose shoot would starve on a branch of lilac, and the lilac shoot on the rose. But we can easily graft the lilac on the lilac, the rose on the rose, or the vine on the vine. We can even go further. The peach tree may be made to support the shoot of an apricot, or the plum-tree that of a cherry, and vice versa; for between these pairs of plants there is a close resemblance that can be easily recognised. For grafting to succeed the greatest similarity between the two plants is required.

The ancients were far from having clear ideas as to this absolute necessity of similar organisation. They speak of roses grafted on holly, with the object of obtaining green roses; of vines grafted on the walnut, so as to produce grapes with huge berries as large as walnuts. Even in our own time the question has been seriously discussed of grafting the vine on a mulberry tree, to give fresh life to the plants, the roots of which have been attacked by a louse that lives underground. Such grafts, or any others between quite dissimilar plants, have never existed save in the imagination of those who have dreamed of them.

We have already seen that, grown from seed, our fruit-trees do not generally reproduce the quality of the fruit from which the seed was derived. By an invisible tendency to return to its original condition, the fruit gradually, in successive generations, loses the improvements that it has acquired by cultivation. Thus the pear, after repeated sowing, would gradually become smaller, harder and more sour, until it reverted to the wretched pear of the hedgerow. But this disadvantage in sowing is compensated for by a valuable quality. The tree produced from seed resumes to a certain extent the hardiness of the wild type. It is immeasurably stronger, healthier and longer-lived than the perfected tree, the vigour of which is impaired by the very abundance of its fruit. The one has the strength, the other the fine fruit. The two qualities cannot progress simultaneously. For as one increases the other must diminish. These strong plants, produced from seed, are just those required for grafting. Being used as stocks they will provide their own quality of strength, while the graft that is added is responsible for the excellence of the fruit.

So the seeds of apples and pears are sown, and the kernels of apricots and peaches, and on the trees thus obtained, branches are grafted, taken from pear-trees, apple-trees, apricot and peach-trees, the fruit of which is known to be of superior quality. Thus on the same tree the root and stem of the hardy, almost wild, kind is allied to the foliage and flowers of that which is weaker but more perfect. Any variety of pear-tree can receive the graft of any pear-tree, or any peach-tree can receive a graft from any other ; and the same thing is true for all fruit-trees. This is called grafting on a free stock. Any wild pear-tree, cherry or plum-tree growing in the hedges or woods may be used as a stock. The splendid rose of our gardens is made to grow on the common wild rose of the hedge, whose modest flowers have only five petals, pale pink and almost scentless. Sometimes different, but closely allied, species are used. Thus the pear-tree may be grafted on the quince, the fruit of which resembles a large pear ; the apricot may be grafted on the plum, the peach on the plum, or on the almond, which resembles the peach by its foliage, its early flowering and the structure of its fruit.

We will notice, as a curiosity, the association of several kinds of fruit on the same plant. By means of grafting the same tree may bear almonds, apricots, peaches, plums and cherries simultaneously, because any of these five species may be grafted on any other of them. Another may bear at the same time pears, quinces, medlars, and service berries. These results are very curious, though not of any practical interest. It would be unnecessary to mention them except for the fact that they afford valuable information. They show that if by grafting shoots from another plant are added to a tree, its growth is not affected by the newcomers. Whether children of the tree, or strangers, the shoots develop and bear flowers or fruit according to their own nature, without copying in any way the habits of their neighbours. Among the curiosities that have been obtained by means of such an artificial association, based on the independence of the shoots, we may mention a pear-tree on which every variety of cultivated pear had been collected by grafting. Whether sour or sweet, dry or juicy, large or small, green or brightly coloured, round or long, hard or mellow—all these pears ripened on the same tree and were reproduced year after year unaltered, true to the racial character, not of the supporting tree, but of the different shoots grafted on to the common stock.

The association of similar plants will not insure the success of the operation. There must be abundant contact between the graft and the stock in their most vital parts, which are the most capable of uniting. This contact must take place in the interior layers of the bark, and in the new substances situated between this and the wood ; for it is in this region that the life of the plant is most active. The mature sap descends between the bark and the wood, where new cells and new fibres are organised, forming a sheet of bark on one side and a layer of wood on the other. It is only in this part that the union between the graft and stock can be effected.

CHAPTER XXXV

GRAFTING (*continued*)

THERE are three principal methods of grafting; these are side-grafting, grafting of branches, and grafting of shoots. There are numerous sub-divisions according to the shape of the cuts and the treatment of the parts brought into contact that cannot be mentioned here. Our discussion must be limited to that which is essential.

Side-grafting resembles layering, except for the fact that the plant that is to be used as the stock takes the place of the earth. In layering, the formation of adventitious roots is promoted by burying in the earth a branch that is still connected with the stem that feeds it. When, under the influence of the earth, a sufficient number of roots have been developed, the branch is gradually weaned by successive incisions, and finally separated from the parent plant. In side-grafting the object is to oblige some branch or twig to take root, not in the earth but in a neighbouring plant, while still connected with the original stock.

Suppose that there are two trees standing close together, and that we wish to graft a branch of one of them on to the other. Incisions are made lengthways in the parts that are to be brought into contact of the same size and penetrating to the pith. These parts are brought together, care being taken that the young and active substances, the internal layers of the bark, and the channels of the mature sap, should exactly coincide. The whole arrangement is held in place by means of bandages, and the two wounds are left to the slow action of life. Being fed by its own stem, from which it is not yet parted, the branch that is to be transplanted mingles its sap with that of the stock. On either side fresh substances are organised which scar over the wounds and join together, till sooner or later the branch is incorporated with the foreign stem. The graft must now be weaned, or gradually deprived of the food provided by its own stem. This is accomplished, as in simple layering, by means of successive incisions effected below the join. When it is thought that the grafted branch is deriving all its nourishment from the new stock, it is completely separated from the parent plant. This, which is the most elementary mode of grafting, is sometimes realised accidentally and independently. If in a hedge there are two branches in close and prolonged contact, this point of contact, worn and cut by friction, will end in becoming a join. Probably natural occurrences of this kind first inspired the idea of grafting.

Side-grafting is advantageously employed when a gap in the form of a fruit tree has to be filled up. Regular distribution and symmetrical branching are desirable for the satisfaction of the eye, which is always unpleasantly affected by disorder ; but there is another and more urgent reason for regularity. A tree bears more fruit if its branches are equally distributed, so that each may receive the same share of sap, light and heat. If there is anywhere a gap among the branches, side-grafting will provide the means of filling it up and restoring the symmetry. A long twig is selected from a neighbouring branch that can well spare it, and by means of an incision is brought into contact with the point that needs supply, which is provided with a corresponding incision, and the two wounds are fastened together by a bandage. As soon as the join is complete the twig is cut below the point of junction, and resumes its position on the branch that bears it. In this way the rich branches supply additional ones to their poor neighbours without any loss to themselves.

Branch-grafting resembles propagation by means of cuttings, and consists in transferring a branch taken from its parent stem to another plant. The method most generally practised is called crown-grafting. This is performed in spring, when the shoots on the stock begin to develop. The last year's branches are selected for grafts, strong and well summered, having become hard wood in the summer, and able to endure the winter weather. There is one precaution that is most necessary. When the branch is transplanted, unless it is to dry up and starve, it must find on its new support nourishment in proportion to its needs. It would inevitably perish if its growth were more forward than that of the stem which is to be its nurse. The stock must be ahead of it in growth. For this reason, a month or two before the grafting takes place, the branches are cut off and buried in the ground, at the base of a wall with a northern aspect, where they remain stationary, while the stocks are growing and producing their sap.

Suppose that there is a poor pear tree in our garden, either grown from seed or brought from its native wood, and that we wish to make it produce good pears. The method to be adopted is as follows. The head of the wildling is cut clean off, and the surface of the section is made perfectly even with the pruning-knife, removing any laceration which, being slow to heal, might become a centre of decay. If the stem is small and is only to receive one graft, the section is slightly oblique and a small horizontal notch is cut on the upper edge. Through this horizontal notch the stem is split to a depth of three or four inches. Then one of the branches, which has been pruned in the way mentioned above, is taken and cut back to two or three shoots. the highest of which is to be the end of the branch. Starting from the lowest shoot, the branch is cut in the shape of the blade of a knife, of which the thickest part on the back is occupied by this same shoot. Then the graft is placed in the crevice in the stock, care being taken to apply the bark to the bark, and the wood to the wood. The whole is fixed with bandages, and the wounds are covered over with grafting-wax, which is bought in shops, and kept in place with a few rags. This wrapping preserves the stump from the air, which would dry it up. In time the wounds are healed, and the branch unites its bark and its wood with the bark and the wood of the amputated stem. Finally the shoots of the graft, fed by the stock, develop into branches, and in a few years the head of the wild pear tree will be replaced by one that has been cultivated, yielding pears similar to those on the tree that provided the graft.

During the operation of grafting, numerous shoots will not fail to appear on the stock. What is to be done with the growths to which they give rise? Evidently they must be suppressed, for they would use up the sap intended for the graft. But this suppression must be effected with discretion. We must not forget that the most active cause of the ascent of the sap is the evaporation from the leaves; so that until the graft has developed its shoots and unfolded its leaves, it is well to respect the young growths of the stock. They are real helpers, drawing up by their foliage the juices absorbed by the roots. But a time comes when the graft can do this work for itself, and it must then be relieved of these fellow-guests which, being stronger than itself, would soon cause it to starve. The lower growths are the first to be suppressed, and then, proceeding gradually upwards, the highest, which are not removed until the graft is nearly a foot long.

CHAPTER XXXVI

GRAFTING (*conclusion*)

THE aerial part of a plant and that which is underground depend on each other, and the development of the former calls for proportionate development of the latter. If there are too many leaves the roots will not be able to feed it ; and if the roots predominate there will be an excess of sap and food which cannot be utilised, and which will burden and injure the plant. Therefore if the stock has a large stem several grafts will be required in order that the number of shoots to be fed may be in proportion to the roots that have to feed them.

For this purpose the stem is not cut off in a slant, as if for a single graft, but horizontally. Then it is split right through, on a line passing through the pith, and two grafts are inserted in the split, one at each end. It is obvious that not more than two can be inserted in the same split, because it is absolutely necessary for the bark of the graft to be in contact with the bark of the stock, so that on either side the channels of the descending sap may communicate and mingle their new substances. If the size of the stock requires more than two grafts it is better, instead of repeatedly cutting through the centre, to make lateral splits, which will have less effect on the strength of the support.

The following method may be adopted, which does not require the splits which are so hard to heal in the old wood. Half of the lower part of the graft is cut away length-ways, and the thickness of the remaining half is gradually reduced from the upper to the lower extremity. When thus shaped the grafts are inserted between the wood and the bark of the stock. This operation is facilitated by the spring sap, when the bark is easily separated from the wood. If a rent is to be feared from the graft acting as a wedge, a slight cut is made in the bark to admit of free play. In this way the circumference of the stock may receive as many grafts as are thought necessary, and all that is now required is to fix the whole with bandages and to cover the wounds with grafting wax. This method is termed *crown grafting*, from the grafts crowning the contour of the section.

Shoot-grafting corresponds with that method of propagation by cuttings that consists in placing shoots separately in the ground. It consists in transferring to the stock a shoot with the fragment of bark to which it is attached. If the grafting takes place in spring, at the awakening of vegetable life, the shoot inserted in the stock will unite with it and develop immediately; but if it is postponed till July or August, the time of the autumnal sap, it will remain stationary during all the autumn and winter, after becoming incorporated with the stock.

The necessary implement is the grafting knife, which has a very sharp blade on one side and a short spatula of bone or hard wood on the other. The first thing to be done is to remove the shoot that is to be transplanted. On a sap-bearing branch a transverse cut is made with the grafting knife above the shoot and below it, and then, holding the knife in one hand and the branch in the other, a piece of bark is removed limited by the two cuts. This is called the shield. The leaf growing at the axil of the shoot is removed, but the stalk is left, as it may be used for holding the shield, and handling it more conveniently. The shield must have no rent and no sap-wood adhering to the bark. The bark must be absolutely intact, especially in the internal layers, which are the seat of life, and the cavity opposite to the shoot must contain a small amount of young greenish wood, which is the germ and heart of the shoot. If, through unskilful handling, the germ were removed, the shield must be rejected, as the graft would certainly be a failure.

Next, a double cut in the bark is made in the shape of a T, penetrating to the wood without injuring it. The two edges of the wound are raised with the spatula, and the shield is inserted between the bark and the wood, being held by the leaf stalk that was left. Then the edges of the wound must be brought together by some supple and elastic ligature, which will not arrest the development of the shoot. A reed, a thin strip of some long flexible leaf, or a thread of wool are most suitable for this purpose. If in spite of this precaution the ligature were to become too tight because of the growth of the graft, it should be relaxed at once. When the shields are incorporated the shoots of the stock are gradually removed, as was shown in the case of crown-grafting.

When the stock is too slender to receive a graft in the usual way, the difficulty may be overcome by the following method. From a branch, the same size as the stock, a rectangular piece of bark, furnished with a shoot, is removed by four strokes with the knife. This piece is immediately applied to the stock to serve as a guide, and its outline is followed by the point of the knife which at the same time cuts the bark. In this way a piece of bark of exactly the same size is removed, which is at once replaced by the other, held in place by a ligature.

Another way is to make two cuts in the bark all round the branch above and below the shoot. A cut is then made lengthways between the two, and the cylinder of bark is removed in one piece. On the stock of equal size a similar cylinder is removed, which is replaced by the one bearing the shoot that is to be transplanted.

CHAPTER XXXVII

Rotation of Crops.

Dinner at the farm. A great dish of pork chops and beans is steaming on the table. Everyone is helped, and it is a pleasure to see these worthy people eat with their good appetites. Jim, the big cowman, is the first to finish. He throws away his bone and Rover grabs it. Rover lies down on his stomach and takes the bone between his fore-paws. You can hear him biting his hard morsel. How it cracks! Rover must not be teased now. An angry growl and the display of four formidable fangs would warn the thoughtless person that he must stop his jokes at once, or else—I would not answer for what might happen. Rover is not ill-tempered—far from it; but Rover has a right not to be interfered with at dinner. He does his work as a dog thoroughly. The night before last wolves were prowling round the park, and he put them to flight. Let him eat his bone in peace. Puss, the great red cat, does not agree with this. He approaches, with fur on end and a tail the size of your arm, with the object of frightening Rover and taking away his food. Without dropping the bone Rover growls and raises one paw. It is enough, and the cat runs away. But, you impudent pussy, what business had you here? The bone is not for you, and your teeth are not strong enough to bite it. Run away; Martha is calling you to give you some crumbs soaked in sauce, which will suit you better than a bone as hard as a stone.

Other guests are arriving. The door is open, and the fowls come in from the poultry yard and pick up the crumbs that have fallen from the table. Rover would not touch these crumbs; they are too small for him. Neither would the cat care for them, because they are too floury; but they are a feast for the fowls.

And so the men, the dog, the cat and the fowls all dine at once; only each one must put up with something that is not wanted by the others. Rover is satisfied with the bone thrown away by big Jim, and the cat with a little crumbs and sauce, which would not be enough for Rover, while the fowls pick up the crumbs despised by Jim, Rover and the cat. Martha, as it seemed, had only prepared the dinner for the men and women on the farm, and behold—by making use of the remains not wanted by these, many others have had a share in the repast. With the leavings despised by man the dog will gain strength to defend the flock; the cat will develop the keen sight and sharp claws with which it sees and seizes the mice, by means of the remains left by the dog; while that which is scorned by the cat will enable the fowls to lay their eggs; and everything, every single thing, will have been a source of profit to the farm.

The husbandman, in his turn, in his own way, prepares the dinner for the harvest, by spreading manure on the ground—the fertile corruption which is the favourite food of the plant. The table is set; the field is thoroughly prepared, ploughed and manured. Who shall be the first guest, since obviously all cannot be invited at the same time? Who shall be summoned first? It may be wheat, a plant with particular tastes, but which will give us bread in return. Suppose that we sow wheat. If only the weather is favourable it cannot fail to do well in this ground overflowing with food. It will select that which suits it best, and will leave the rest.

It is done. The harvest has been gathered and abundantly satisfies our hopes. The wheat has converted the manure deposited in the ground into splendid grain; it has made food out of corruption. It has done its work well and made a clear sweep. It has appropriated everything that could be turned into wheat, leaving nothing behind. What would happen then if we were to sow wheat again in the same field? Just what would happen to Tom if he had nothing to eat but the bone left by Jim. He would die of hunger. Tom requires the food of man, and wheat must have the food of wheat. If the first harvest has exhausted all the wheat-forming materials in the ground, how can a second crop of wheat be produced? It would be impossible, and we should have either a very poor harvest or none at all. Therefore wheat must not be sown twice running in the same field, and the same thing is true of other crops. Where any plant has done well in one year the same plant will not do well in the next, because the substances that suit this plant will be more or less exhausted. It is folly to invite guests to a bare table.

If the table were spread afresh, if manure were again spread over the ground, it would be a different matter, and the wheat would do as well as ever. But it would be bad economy; for when a meal has been served it is well to make all possible use of it. Before we go to fresh expense in manure we will utilise to the utmost the expense already incurred. Rover made a good dinner on Jim's leavings, and the fowls did well on something that was despised by Rover and the cat. Let us follow the example of these feeders, who have successively utilised the remains rejected by the others. The wheat has almost, or entirely, exhausted everything that suits itself. But just as the cowman Jim left the bone, the wheat has left several substances which are excellent food for others. To derive every advantage from the first supply of manure, we must find a guest of a different nature. This guest may be the potato. The potato will find plenty to live upon in ground where the wheat would have starved, because its tastes are quite different from those of the cereal.

That makes two; and we have sacks of

potatoes without having spent anything more on manure. Is that all? Not yet. After the wheat and the potato, only scanty food will be left in the upper layer of the ground; but in the lower layers there is part of the manure carried away and dissolved by the rain, which could not be reached by the short roots of the two preceding crops. In order to make use of these lower substances, and to bring them to the surface converted into fodder, we now sow a plant with strong roots, such as clover or sainfoin, or better still, lucerne, which penetrates further. And that makes three.

After clover we might try a fourth crop of a different kind; but it is obvious that as the guests succeed one another at the same table, the remains must constantly become more scanty and less fit for use. And before very long a time will come when all will be exhausted: the supply of manure will have given back everything that it possessed. Then we must set the table afresh, manure the field, and begin the same crops over again —or try new ones. We need go no further. We understand that in order to make the best possible use of this valuable substance from which bread, vegetables, fodder, meat, fruit, milk, in a word everything is derived; in order to obtain every advantage from the manure, instead of keeping to the same plant in a field for several years in succession, it is better to cultivate in turn different kinds of plants, so that each of them may make use of that which is left by those that came before them. This succession of different crops is called *rotation*.

CHAPTER XXXVIII

Wine

When wine is made hot a vapour is given out which will take fire and burn with a bluish flame. Anyone who has seen wine heated will remember the curious blue tongues of flame that escape from the boiling vessel and hover over the liquid. This inflammable vapour proceeds from alcohol, the fluid which imparts its properties to wine and is therefore commonly called spirit-of-wine. So there are two different fluids in wine; alcohol, which is most easily converted to vapour, and water, which evaporates more slowly. This does not mean that water has been added to the wine. There is no fraud connected with this water. It belongs naturally to the wine, being, like the alcohol, a product of the grape. Wine is a natural combination of a small amount of alcohol with a large amount of water. In cheap wine the proportion of alcohol varies from 9 to 14 per cent.

Wine is made from the juice of grapes. This juice when extracted from the sweet grape has neither the scent nor the taste of wine, because it then contains no alcohol; but it has a sweet and pleasant flavour, which gives the grape its value as a table fruit. The grapes owe this taste to a kind of sugar. If you examine carefully the raisins that are sold by the grocers you will see on their surface small white specks, which crackle when bitten and have a sweet taste. These specks are tiny lumps of sugar which have come through as the grape dried. So there is sugar in grapes.

This sugar is precisely the substance at the expense of which the alcohol is produced. That which was sugar in the fresh juice of grapes is alcohol in the same juice which has fermented and become wine. We will shortly consider how this comes to pass.

The vintage is first crushed by men stamping on it in great vats, and then the mixture of juice and skins is left to itself. This liquid mixture soon becomes hot and begins to boil, sending out great bubbles of gas as if it were warmed by a fire. This process is called fermentation: it goes on in the very substance of the sugar, which is gradually decomposed and separated into two bodies, very different from each other and from the sugar that produced them. One of these is alcohol and the other a gas with which we are already acquainted—carbonic acid gas—the same that feeds the plants and causes coal to burn, but which cannot be breathed by animals. The alcohol remains in the liquid, which gradually loses its former sweet taste, and adopts that of wine. The gas, on the other hand, rises, stirring up the whole with a violent motion like that of boiling water, and is dispersed in the atmosphere.

You will remember that carbonic acid gas is as invisible as air itself, that it has neither smell nor colour, and will kill at once if inhaled freely. This will show how dangerous it would be to enter a vat in a state of fermentation, or even a cellar where there is not a sufficient draught to carry off the formidable gas. This should only be attempted while carrying before one a lighted taper attached to a long stick. As long as the taper burns as usual we may advance boldly—there is no carbonic acid gas. But if the flame turns pale, diminishes and goes out, we must retreat at once; for the extinction of the taper shows the presence of the gas and to proceed further would expose us to sudden death.

Let us go back to the wine. We have said that the sugar which gives the sweet taste to the must, the juice drawn from the grape, changes its nature by fermentation and is separated into two components—alcohol, which remains in the fluid and transforms it into wine, and carbonic acid gas, which is dispersed in the air. When this process is completed the wine is drawn off to separate it from the residuum, consisting of the skins and pips. The fluid will then contain a large amount of water derived from the grapes, a little alcohol from the lost sugar and a colouring matter from the skins of the black grapes.

White wine is made with white grapes, the skins of which hold no colouring matter; but it can be manufactured just as well with black grapes, however dark they may be. The whole secret lies in pressing the crushed grapes before they are allowed to ferment and thus separating the juice from the skins. When the skins have been removed the wine will be white, even if made with black grapes. The colouring matter of the grapes from which red wines derive their colour is contained exclusively in the skins. Moreover, it is not soluble in water, but is easily dissolved in alcohol. So it is only when the fermentation has made considerable progress that the liquid is coloured by the action of the alcohol in dissolving the colouring matter. If the skins are removed before the juice ferments and contains alcohol, the wine will remain white, since there will be no colouring matter to be dissolved.

There are some wines that drive out the cork from their bottles and that are covered with froth when poured into a glass. These are *sparkling* wines. To achieve this result the wine must be bottled before the fermentation is complete. The carbonic acid gas, which is still being produced and which can find no outlet because of the strong cork that stops its path, is dissolved in the liquid and accumulates there, while making a constant effort to escape. It is that which drives out the cork with an explosion as soon as the string that kept it in its place is cut; it is that which draws out the liquid in a frothy stream when the bottle is uncorked and covers the wine when poured into the glass with a coating of froth from which a slight crackling sound is heard proceeding from the bubbles of gas bursting in the air.

Sparkling wine has a somewhat sharp but pleasant taste, caused by the presence of carbonic acid gas. We can drink, dissolved in sparkling wine, the same gas which would kill us if it were breathed in any quantity. Carbonic acid gas is only dangerous as breath. Mingled with our drink it only imparts a slightly sharp taste, which is harmless and even wholesome, since it promotes digestion. Almost all the water that we drink holds carbonic acid gas in solution; and it is by means of this gas that water contains the small amount of mineral substance required for the formation of the bones. Sparkling lemonade, cider, beer and seltzer water owe their sharp flavour and their froth to carbonic acid gas.

CHAPTER XXXIX

ROTATION OF CROPS (*continued*)

WHEN we say that the ground is worn out and needs rest, we mean that it has been exhausted by the crops already produced. The crops deprive the ground of a large amount of the materials necessary to plant life, and when there are not enough of these left the ground will no longer produce and is exhausted. To restore the former fertility would entail great expense in manure; so it is often more profitable to proceed by one or other of the following methods.

Sometimes the land is left to lie fallow; which means that it is left without any attention for several years. The weeds grow freely, while the water, air and frost act on the soil, break it up, lighten it, and promote the formation of certain substances that are necessary to vegetation. The weeds are converted into humus and after a time of rest the ground is able to produce a fresh crop. This method of improvement is very slow and takes several years. It may be shortened by ploughing, or even by supplying manure, although it is not to be sown immediately.

But there is a way of getting crops from the same land uninterruptedly, unless it is very poor. All plants are nourished at the expense of the earth and the air, but some take most from the former and others from the latter. The plants which draw most of their food from the air are those with highly developed foliage, such as the potato. We know that it is by means of their leaves that plants absorb the carbonic gas dispersed in the air, so that the larger and more numerous the leaves the more abundant will be the absorption. The plants that take almost everything from the ground are those the leaves of which are few, small and thin, and which can therefore absorb but little carbonic acid gas from the air. Such an one is wheat.

On the other hand, nothing of the potato is used except the tubers, which are only a small part of the whole plant, while the stalk and the foliage are buried in the ground and converted into humus. So the potato enriches the ground with the substances that it has absorbed from the air ; and gives more than it receives. For this reason it is said to be a *restorative* plant. In cereals, on the contrary, the whole is used—the straw as well as the grain. Nothing remains in the ground but the roots, and as they derive almost everything from the ground, because of their scanty foliage, they receive much more than they give. They are *exhaustive* plants.

So it would be impossible, without going to ruinous expense in manure, to have a crop of cereals every year on the same ground. But what would happen if we were to use the wheat and the potato alternately? The latter, deriving most of their food from the air, might flourish in the ground that was too poor for the wheat, and their buried tops would restore some of its former fertility to the ground. The wheat might then again be cultivated with success. This practice which consists in growing successively on the same ground plants that do not injure one another and get the best result from the manure expended, is the rotation of which we have already spoken. The object is to diminish the amount of manure required while allowing continuous crops.

The fundamental principle of rotation consists in causing an exhaustive plant to be followed by one that is restorative ; a plant with poor leaves by one whose leaves are highly developed. The principal restorative plants are clover, lucerne, sainfoin, the potato, beetroot and turnip. Cereals, on the other hand, are all exhaustive plants.

Generally a series of different plants is grown on the same ground. This series comes to an end in four, five, six or more years, and then begins again in the same order. The following is an example of a six-years' rotation :

1st year	.. potato	.. restorative.
2nd year	.. wheat	.. exhaustive.
3rd year	.. clover	.. restorative.
4th year	.. wheat	.. exhaustive
5th year	.. sainfoin	.. restorative.
6th year	.. oats	.. exhaustive.

We will consider this rotation as an example. In the first year the ground is thoroughly manured. One effect of the manure is the appearance of a number of weeds which would infect the ground and impoverish the crop unless they were carefully removed. Hence the necessity of weeding. The weeds are removed either by hand or with an implement. It is not possible to weed every kind of crop. The plants must be some distance apart or they would be trodden under foot, cut off or uprooted by the implement used. We cannot think of weeding wheat, because the blades are too close to each other; but potatoes, which are far apart, can be weeded without difficulty. By the weeding all useless and noxious plants are destroyed and their return is prevented by pulling them up before the seed ripens. The ground is perfectly cleared and prepared to receive a more delicate crop. This shows the advantage of anticipating the cultivation of cereals by that of the potato, or of any other plant that can be weeded.

The second year will mark the arrival of the wheat. Having been cleansed by the former crop the earth produces no weeds. It needs no more manure; for although the tubers of the potato have removed certain substances, these substances are not the same as those required by the wheat; and, moreover, the heads which have been buried and converted to humus will compensate for that which the tubers have taken from the ground by the matter which they have absorbed from the air. So the wheat has come at the right time.

But it will not be to our interest to ask the ground to produce another crop of wheat in the third year. Exhausted by the crop that it has just produced the ground would give a poor result, unless fresh loads of manure were added, which would entail too great an expense. So the third year is devoted to the cultivation of a restorative plant—clover, for instance. After being used as fodder the last cutting of the clover is buried, and all its remains—roots, stalks and leaves—converted into humus prepare the ground for receiving wheat again in the fourth year. The same reasons will necessitate the use of another restorative plant in the fifth year. This restorative plant may be sainfoin, which will be followed by the last crop of cereals, possibly oats. This will complete the rotation, when the same series will begin again.

The succession of crops may be varied to any extent and the rotation may extend over a longer or shorter period. But one rule must always be followed, namely, that every crop of cereals must be preceded by that of a restorative plant.

CHAPTER XL

Burning the Weeds

We see a man on the slope of a hill armed with a great strong bladed hoe, stripping the ground by removing great slabs of earth covered with grass and heather. He places these slabs upright—either back to back or rolled over on themselves, or bent into an arch so that the air may circulate freely and dry them.

If we return in a few days we shall find that the sun and air have completely dried them and the man will be still at work. Now he is arranging the slabs in a heap, always with the grass inside, forming a hollow in the middle filled with brushwood and dry leaves. He then sets fire to it. Another heap is arranged in the same way and kindled in its turn. Soon the hill is covered with a number of these small ovens, which burn slowly and send out long trails of smoke. In a few days —three, four or more—the fire goes out. As soon as the heaps are cold the mixture of ashes and burnt earth is spread over the surface of the ground with a shovel. This operation is called clearing; and by this means a piece of ground, which has never been cultivated and which is covered with its wild plants, is rendered fit for use.

This clearing produces two effects, one of which relates to the clay in the ground and the other to the ashes produced by burning the weeds. Clay, as you know, is a tough and sticky substance which cannot be penetrated by air or water. Therefore ground which holds too much clay is unfavourable to the growth of plants, the roots of which always need air and moisture. But as soon as it has been strongly heated clay will have very different properties. It no longer combines with water, it is porous and permeable and easily penetrated by air and water. So burning the weeds improves a clay soil by burning the clay and making it permeable. This shows that although this is excellent for a heavy clay soil it is bad for poor or sandy ground.

The ashes of the weeds also produce their effect. After the complete combustion of any vegetable matter, an earthy powder or ash is left, which contains the mineral substances existing in the plants. These substances are not affected by combustion because of their power of resistance. The most remarkable of these is potash. All these substances, which formed part of the plants that were burnt, are evidently suitable for assisting in the growth of new plants. The ashes of the weeds that have been destroyed will be of great use to the plants that will be cultivated by man in the ground that has been burnt. But we may not profit by everything contained in the weeds: all that escapes in smoke is so much loss. The clay burnt in the slabs of turf renders another service in this way. Becoming porous by combustion, it is able to absorb and retain the gases produced by the burning and so far to mitigate the loss. But if there is no clay in the ground the burning is injurious, and it is better to bury the weeds, which will turn into humus, instead of their being dispersed in the air in smoke.

Ashes are also used as manure, though not often at once, because potash, a very valuable substance, is extracted from them for industrial purposes. After this process the ashes are called buck-ashes. They contain silex and carbonate and phosphate of lime, in which condition they are most readily absorbed by plants. Although not so strong as ordinary ashes they produce a good result in clay soil. Coal ash, which contains a large proportion of burnt clay, is used for lightening heavy ground.

The consideration of ashes naturally leads on to that of soot. This consists of vegetable substances not completely decomposed by heat. It holds ammonia, so it is very efficacious as manure. It is spread over young plants to increase their strength, and by its bitter flavour keeps off the insects that attack them.

CHAPTER XLI

THE GRAIN OF WHEAT

If we examine a seed of chickweed or ivy that has been split open, where shall we find the germ, or the little plant in its egg? It will be that small, slender, white object, enclosed in the substance of the seed. That of the chickweed takes up the whole length of the seed, but that of the ivy is on one side at the extremity. A fine line shows where the two cotyledons, which are now closely pressed together, will separate. This is the situation of the tigella, ending in the radicle. We notice how very small these cotyledons are, how very different from the enormous nursing leaves of the almond, the acorn, the bean, or the pea. These poor breasts will soon be dry, and if, when the seed awakens, the ivy and the chickweed had no other resource, they would soon starve to death.

But we see that under the skin of the seed there is an abundant floury substance, in which the germ is immersed. This amount of flour makes up almost the whole of the seed. This is the supplementary food, the provision which will assist the cotyledons, insufficient in themselves. This well-stored granary that encloses the germ, this magazine of food, is the *perisperm.* Neither the almond, nor the acorn, nor the pea, nor the bean, nor any number of others, have anything like it ; beneath the skin of the seed there is the germ, and nothing else—nothing at all. The reason for this difference is easily seen. The almond, the acorn and the bean, with their great cotyledons swollen with nutritive food, have no need of a supplementary ration ; their huge vegetable breasts are enough for the food of the little plant. But the chickweed and the ivy, with their poor little cotyledons, need some help, which they will find in the store of flour of the perisperm.

So, to satisfy the first needs of the young plant, the seed may contain a double provision for food—the cotyledons and the perisperm. All seeds contain the cotyledons, but the perisperm is not found in all. There is none in the seed of the almond, the oak, the chestnut, the apricot, the bean or the pea ; but to make up for this, their cotyledons are very large. On the other hand, buckwheat, chickweed and ivy, which have small cotyledons, are supplied with it. Generally speaking, the cotyledons and the perisperm have a similar office: they supply each other's deficiencies in feeding the young plant. As a general rule the seed with large cotyledons has no perisperm, and the seed with small cotyledons is provided with it.

Many plants have only one cotyledon, and this most frequently is a very small one. It is in these that we find the perisperm. The grain of wheat is one of the most remarkable of these. If we cut this seed lengthways and examine it with the microscope, we shall find at the base, and on one side, the germ which forms a very small part of the seed. Above this is the one cotyledon, which will provide the first, or seminal leaf, and next to this the gemmule, from which the following leaves are produced. At the opposite end there is a short projection—the radicle, the origin of the root. Suppose we compare the tiny cotyledon of the wheat with the two huge cotyledons of the almond. The latter, with their rich supply of food, are well able to feed the growing shrub until the roots are strong enough ; but would it be possible for the cotyledon of the wheat, so poor and so small, to act as nurse to the young plant ? Certainly not : the wheat must have a store of food, and this store is the perisperm, which makes up almost the whole of the seed. This same perisperm, the first food of the first shoot of the wheat, is also the chief food of man ; for under the millstone it becomes flour, which is the substance of bread. But how does the flour in the perisperm feed the plant ? We may learn this from a simple experiment. If we put some wheat in a saucer and keep it slightly moist, in a short time the seed will germinate. If we take a seed as soon as the green point of the young shoot appears, we shall find it quite soft. It may now be crushed by the finger, and will pour out a white liquid with a very sweet taste, that might be taken for a kind of milk. You may guess what has happened, from what you have been told of the wonderful change that may take place in starch. The perisperm of the grain of wheat consists chiefly of starch, and during the process of germination this store of starch has been converted into a sugary substance—glucose, which produces the kind of vegetable milk which now fills the seed. The germ is immersed in this sweet fluid ; it is saturated and penetrated by it like a fine sponge ; and by means of the material thus absorbed it increases its own substance, prolongs it into a root and stem, and forms it into leaves. The grain of wheat feeds its germ with the same matter that provides us with bread.

CHAPTER XLII

Germination

The germ in the seed seems to be sound asleep, with its life arrested and suspended. But by means of certain stimulating conditions it wakes up, throws off its wrappings, grows strong on its supply of food, unfolds its first leaves and appears in the daylight. This development of the seed is called *germination*. Moisture, heat and the air are the causes that determine it. Without the help of these the seeds would remain good for sowing for a time, but would gradually waste away and become incapable of germinating.

No seed can germinate without moisture. Water plays many parts in the process. In the first place, it saturates the germ and the perisperm, causing them to swell more than their envelope, so that this is forced to break—even if it is a very hard shell. Through the crevices of this broken envelope the gemmule projects at one end and the radicle at the other, and the little plant is now subject to the influence of the earth and the air. The germ takes more or less time to free itself, according to the degree of resistance of the seed-walls. If it is enclosed in a compact kernel it takes a long time to become saturated with moisture, and capable of bursting its cell. For this reason the shells of very hard seeds are rubbed away on a stone.

Besides this mechanical part played by water in causing the seeds to open, there is another which relates to nutrition. The changes by means of which the food materials of the perisperm and cotyledons are liquefied and become capable of absorption, can only take place through water. Besides this fluid is indispensable for dissolving the food substances, introducing them into the young plant, and distributing them equally throughout. So it will be seen that as long as it remains dry it is impossible for any seed to germinate, and if we wish to preserve seeds, the first thing necessary is to keep them free from damp.

Warmth is necessary as well as water. Generally speaking, germination is most successful at a temperature of fifty-five to seventy degrees—that of our spring and autumn. Above or below this limit germination will slacken, or cease altogether if the divergence is too great.

The help of air is no less indispensable. It would be of no use to submit the seeds to a suitable temperature and moisture; if air is lacking there will be no germination. This primary condition explains why seeds that are buried too deeply will not come up; why germination is much easier in ground that is light and permeable by air, than in that which is more compact; why delicate seeds should be covered very slightly with earth, or only scattered on the surface of the damp ground; and why ground that is turned over is sometimes covered with new vegetation, resulting from seeds that for long years have been sleeping inactively and that the air has caused to germinate when our excavation has brought them from the depth to the surface.

With the same conditions of temperature, moisture and air, all seeds by no means take the same time to germinate. *Cress* will generally germinate in two days. The parsnip, turnip and bean take three days to come up; lettuce, four; the melon and pumpkin, five; and cereals about a week. The rose, the hawthorn, and several fruit trees with kernels, take two years and more. Generally speaking, seeds with thick and hard envelopes are slowest to germinate, because of the resistance that they offer to the penetration of moisture. Seeds, sown fresh as they are, when they have just reached maturity, will germinate sooner than old ones, because the latter have to regain, by a lengthy stay in the ground, the moisture that has been lost by their long drying.

Seeds, according to their species, preserve their faculty of germinating for a longer or shorter time, but there is nothing to tell us the causes which determine the duration of this persistence in life. Neither the size nor the nature of the envelope, nor the presence or absence of a perisperm, seem to determine the longevity. One seed will remain alive for years, or even centuries, while another will not come up after a few years, for no reason that we can ascertain. The seed of angelica will not come up unless it is sown as soon as it is mature, while beans have been known to germinate after being kept for more than a hundred, and rye for more than one hundred and forty years. When sheltered from the air some seeds will last for centuries, capable of germinating as soon as the conditions are favourable. In this way the seeds of the raspberry, cornflower and camomile, taken from ancient sepulchres, have germinated as freely as the seeds of the present year. Seeds of reeds have been grown, taken from underground in the Ile de la Seine—the original site of Paris. These seeds no doubt date from the time when Paris, then called Lutetia, consisted of a few huts of mud and reeds, on the marshy bank of the river. In spite of these remarkable exceptions we must always remember that, for sowing, new seed is preferable to old; it comes up better and more abundantly.

We have mentioned that some seeds are very slow in coming up. Such, for instance, are those of the peach, the apricot, and the plum, which shut out the damp needed by the germ with the thick wall of their kernel. If placed in the ground at once, on the same spot that is afterwards to be occupied by the young plant, these seeds would be exposed to many dangers during their tedious germination. Prolonged rain might rot them, or many animals that enjoy them, such as rats, field-mice, jays, magpies or crows, might dig them up for a feast. Besides, they would occupy the ground in which they had been sown for a long time unprofitably. These disadvantages are avoided by means of a temporary sowing which is called stratification. First of all a layer of small stones is arranged in a large, deep, earthenware pan, pierced with holes in the bottom, or in any other receptacle—chest, vase, or tub—pierced in the same way. The object of these holes and of this bed of stones is to give free access to the air and to allow any excess of water used to escape. Next comes a bed of fine sandy earth, and then a layer of seeds placed side by side, covered by another bed of earth. Over this another layer of seeds is arranged, which is also covered with earth ; and this process is continued, placing the seeds and the earth alternately, until the receptacle is full. Then the whole is sprinkled with water and the pan is carried into a cellar or some dark shed. Now the contents of the vessel need only be kept suitably moist by occasional watering. Thus enclosed in a small space, and easily watched over, without being at the mercy of thieving animals, or unprofitably occupying ground that might be used for something else, the seeds may break their hard shells at their leisure and germinate as slowly as their nature requires.

As soon as the kernels are partly open and show the radicle, it is time to proceed to the final sowing, and the seeds that have begun to germinate are placed in the ground, separately, in the open air, in the place that the young plant is to occupy.

There is another advantage in stratification. Fruit trees and others produce a vigorous tap-root, which enters the ground vertically to a considerable depth, and presents a difficulty in transplanting. It would be an advantage to change this into a shallow root, branching horizontally. When considering the root we saw how the nurseryman obtains the result. With the edge of his spade he cuts the tap-roots of his young plants clean off. In stratification the process is much simpler and more likely to succeed. Before placing the seed in the ground the extremity of the tender radicle is nipped off with the nail. This is enough; for, deprived of its extremity, the young root will branch out horizontally instead of descending in a vertical direction.

CHAPTER XLIII

Animal Helpers

Those animals are helpers that, living without care on our part, come to our assistance by the war that they wage on the larvæ, insects and other devourers which would take complete possession of our crops if their excessive multiplication were not controlled by others as well as ourselves. What can man do against their hungry hordes renewed every year in numbers that defy all calculation? Will he have the patience, the skill, or the eye to carry on a successful war against the smaller species, when the cockchafer, despite its larger size, mocks all our efforts? Can he undertake to examine his fields sod by sod, his wheat ear by ear, or his fruit trees leaf by leaf? If the human race were to concentrate its whole strength on this one occupation it could not accomplish the tremendous work. The devouring brood would devour us unless others were working for us: others endowed with unwearied patience, with skill that detects all stratagems, and with vigilance from which nothing escapes. To watch for the enemy, to seek him out in his most hidden retreat, to pursue him without ever stopping, and to exterminate him—this is their only care, their ceaseless occupation. They are eager and pitiless; driven by their own hunger and that of their families. They live on those that live at our expense, and are the enemies of our enemies.

The bat, the hedgehog and the mole, the owl, the swift, the swallow, and all the small birds; the lizard, the adder, the frog, and the toad—all carry on this great work. Blessed be God Who has given us the swallow and the warbler, the red-breast and the nightingale, the swift and the starling, to protect us against that mighty eater, the insect. But these precious creatures, the salvation of our earthly goods, the delight of our eyes and ears, find their nests plundered by the stupid and cruel bird-nester. Blessed be God Who has given us the owl and the toad, the hedgehog, the bat, and the adder, the lizard and the mole, to defend our daily bread. Yet these useful creatures, that help us so bravely, are cursed, slandered and foolishly persecuted by aversion and hatred.

What eccentricity of mind is it that makes us destroy the animals whose assistance is so profitable to us? Almost all our helpers are persecuted. Their goodwill must be strongly founded since our ill-treatment has not driven them from our fields and dwellings for ever. The bats deliver us from a host of enemies, and they are outlawed; the mole purges the ground of vermin; the hedgehog makes war on vipers; the owl and all night-birds are clever rat-hunters; the adder, the toad and the lizard feed on the plunderers of our crops—and all these are outlaws. People call them ugly, and kill them for no other reason. Blind murderers, will you never understand that you are sacrificing your own defenders to an unreasonable dislike? You complain of rats and nail the owl on your door, allowing its carcase to dry in the sun—a hideous trophy: you complain of grubs, and kill the mole whenever the spade brings it to the surface; you set your dogs at the hedgehog for an amusement; you complain of the damage done by moths in your barns, but if the bat falls into your hands it rarely meets with mercy: you keep on complaining, and while they are all working to defend you, you treat them as accursed. Poor blind and foolish murderers!

Birds that devour insects are of tremendous assistance in agriculture. They share the work among them in fields, hedges, gardens and orchards, and wage continual war against every kind of vermin—that terrible brood that would destroy the crops if others beside ourselves did not keep an untiring watch; others more skilful, with keener sight and more patience, and with no other occupation. It is no exaggeration to say that if it were not for the insect-eating birds we should be decimated by famine. Who but a destructive idiot would dare to touch the nests of the birds that enliven the country with their song, and protect us from the plague of the devouring insect? But there are savage boys who, if they can manage to miss school, weary of books and lessons, take a delight in climbing trees and searching hedges, to steal the eggs, which are pitifully broken, and the poor little dying nestlings. Let us hope that the game-keeper will catch these rascals, and that they may experience all the severity of the law, so that, protected by the birds, our fields may produce their sheaves and our orchards their fruit.

We will say a few words concerning the habits of these valuable helpers. The bat feeds exclusively on insects. None come amiss to it; beetles with their hard wing-cases, skinny gnats, plump butterflies—especially those of the twilight—moths and all those destroyers of our cereals, our vines, our fruit-trees, our woollen materials, which attracted by the light come in the evening to burn their wings in our lamps. Who could tell the number of insects destroyed by the bats as they circle round the house? The prey is so small and the hunter's hunger so insatiable.

Let us notice what happens on a calm summer evening. Drawn forth by the mild temperature of the twilight, a number of insects leave their retreats and come to play in the air, to seek their food and to pair. It is the time when the large night moths fly hastily from flower to flower, to plunge their long trumpets into the corolla, and to suck the honey; the time when the gnat, greedy for man's blood, sounds his war-cry in our ears and chooses the most tender point to insert his poisonous lancet ; the time when the cockchafer leaves the shelter of the foliage, unfolds his humming wings and wanders in the air to seek his fellows. The ephemerids are dancing in merry bands, that are scattered like columns of smoke by the least breath ; the great moths, with wings powdered with silvery dust, and antennæ spread out like plumes, are gambolling in the air or seeking convenient spots to lay their eggs ; the little wood-eating beetles leave their galleries and wander over the bark of the old tree-trunks ; the winged insects rise in clouds from the heaps of corn which they have plundered and take their flight to fields where the cereals are ripe ; the pyralids explore the tendrils of the vine, the apple-trees, the pears and the cherries—all busy in the work of providing food and shelter for their disastrous progeny.

But suddenly among these joyous multitudes come the spoil-sport. It is the bat : he comes and goes in his crooked and tireless flight, rising and falling, appearing and disappearing, turning his head this way and that, and every time capturing some flying insect, crushing it, and swallowing it in a great mouth open from ear to ear. The hunt prospers. There are crowds of flies and beetles, and now and then a joyful cry proclaims the capture of a plump moth. As long as the expiring light of evening will allow the keen hunter carries on his work of extermination, until with his hunger satisfied he returns to his dark and peaceful retreat. On the next day, and throughout the summer, the same pursuit will begin again, always as eager and at the expense of insects alone. All children should respect the bat, that helps us by destroying the robbers of our crops.

CHAPTER XLIV

ANIMAL HELPERS (*continued*)

THE food of the hedgehog is chiefly composed of insects. The smallest are despised and are of no use to it, but the larva of a cockchafer, or a plump mole-cricket, is a prime capture. If they are not too deep down he digs with his paws and nose till he gets them up. All night he prowls about, seeking out and devouring any number of enemies without showing any special preference.

The following story is taken from a book by a learned observer: "In a chest in which a female hedgehog was nursing her young I placed a strong viper, who rolled himself up in the opposite corner. The hedgehog approached slowly, smelling the reptile, who at once raised his head, assuming a defensive attitude and exhibiting his poisonous fangs. For a moment the aggressor retreated, but soon returned boldly, when the viper bit her on the snout. The hedgehog licked her bleeding wound, received a second bite on her tongue without showing any alarm, and then seized the viper by the middle of his body. The two adversaries rolled over and over each other furiously, the hedgehog growling and the viper stinging repeatedly. Suddenly the hedgehog struck him on the head, which she crushed between her teeth, and then quietly began to eat the front half of the reptile. After this she returned to the opposite corner of the chest, and, lying down on her side, peacefully suckled her young. On the next day she ate the rest of the viper. The same experiment was repeated several times, after an interval of a few days, and always with the same result. Notwithstanding the bites that covered her muzzle with blood, the hedgehog always finished by eating the reptile, and neither the mother nor the young were ever the worse for it."

We may be sure that it was not without a purpose that the hedgehog received this gift of resisting the venom of reptiles. He must enjoy himself in the places frequented by the viper; in his nightly excursions in the thickets he is able to surprise the snake in its lair and to crush its head. What service it does in localities infested by this dangerous brood! And yet man persecutes the hedgehog and treats him as a disgusting animal, only fit to excite the rage of dogs that cannot bite his prickly back. Children must not imitate this bad example. They must respect the hedgehog which delivers us from the grub and the viper.

What does the mole eat? The most satisfactory method of determining the food of an animal is to examine the contents of its stomach. We will open the stomach of the mole and see what it holds; sometimes red fragments of the common worm, sometimes a mass of beetles, that can be recognised by the tough remains unaffected by digestion, the scraps of claws and wing-cases; more often a mixture of larvæ and grubs, especially those of the cockchafer, known by distinctive marks, such as the mandibles and the hard covering of the head. We find something of all dwellers underground—wood-lice and centipedes, insects and worms, chrysalids of twilight moths, and subterranean caterpillars, but the most careful search will not detect the least morsel of vegetable matter.

So the mole is exclusively carnivorous.

Also, the animal has a monstrous appetite and a furious digestion, which in twelve hours require an amount of food equal to its own weight. The existence of the mole is one of gluttonous madness, ever reviving and never satisfied. If the animal fasts for a few hours it will die of starvation. On what can it depend to allay the torment of such a stomach, where food passes, dissolves, and disappears at once? On the larvæ that live in the ground, and most of all on those of the cockchafer, as tender and fat as they can be. They are small for such an appetite, but their number makes up for their size. Then what an extermination of grubs must be effected by the mole, since the ground is full of this small prey! One meal is scarcely finished before the next begins, and dozens are consumed on each occasion. There is no helper equal to the mole for ridding a field of these formidable destroyers. It is unfortunate that in order to reach the vermin on which it feeds, it is obliged to dig among the roots inhabited by its prey. Roots which interrupt its work are cut through, plants are torn up, and the earth from the excavated galleries is collected in mole hills, which hinder the work of the scythe when the hay is cut.

No matter, the damage done by the grubs would be far more serious, and there is nothing like the hungry hunter for ridding a field of these. Children must not disturb the mole that protects us from the cockchafer.

The toad is harmless, but there is more than that to commend him to our notice. He is also a meritorious helper, a greedy devourer of snails, beetles, larvæ, and all vermin. During the day remaining discreetly under the cool shelter of a stone, in some dark hole, at nightfall he leaves his retreat and makes his round, dragging himself awkwardly on his great belly. There is a snail on its way to the lettuces, a wood-louse on the threshold of its burrow, a cockchafer laying its eggs in the ground. The toad comes very gently, opens a mouth like an oven, and in three mouthfuls the three are swallowed up with a smack of the throat as a sign of satisfaction. That was good, it really was ! Let us look out for some more !

The excursion is continued. When it ends at dawn, you can imagine the amount of vermin of every kind contained in the glutton's spacious stomach. And there are some who kill this valuable animal, who stone it to death because it is ugly. Children must never commit such a cruel action, which is foolish and harmful; they must not stone the toad; for the fields would be deprived of a vigilant protector. He must be left alone to carry on his work as a destroyer of insects and worms.

CHAPTER XLV

Animal Helpers (*continued*)

It is among birds that our most active helpers are found. The owls, those nocturnal birds of prey, hunt in the fields the field mice, those formidable devourers of our crops ; they also watch for the rats and mice in our barns. They are feathered cats, having all the good points of the domestic cat without its faults ; fierce destroyers of the small furry races, of which the mouse is the most familiar example. They are birds of night, hidden during the day in some dark retreat, which they only leave in the evening to hunt in the twilight or by the light of the moon. Their large, widely opened eyes allow them to see distinctly in a very poor light.

We will follow the bird in its nocturnal excursion. It skims over the barren plain, the ploughed fields and the meadows. It inspects the furrows and the grassy lawns that are the haunt of the field mouse, and the hovels inhabited by the rats and mice. Its flight is silent, the soft wing cleaves the air without the least noise, so as not to alarm its victims. Nothing betrays its sudden approach, and the prey is seized before the presence of the enemy is suspected. On the contrary its exceptionally sharp hearing warns it of everything that goes on in the vicinity. If a field mouse disturbs a blade of grass in passing or stops to gnaw an oat, the sound, which is imperceptible to any other ear, is enough for the bird of night. A blow of the beak breaks the captive's head, and the prey, after being crushed by the claws, disappears in the abyss of the throat. Everything, bones and fur, all goes down. It is seldom that one victim suffices, and so the hunt goes on. Mice and field mice follow one another, always slain by a blow from the beak, and always swallowed whole. If he comes across any large beetles the bird will not despise them. When quite satisfied the nocturnal hunter returns to his resting-place—the cleft of a rock, a hollow trunk, or a hole in some hovel. Children must not disturb the owl: above all he must not be nailed to the barn door; for, far from being an evil-doer, he renders the most valuable service.

Almost all small birds are capital caterpillar hunters, and without them the produce of the earth would be in great danger. We cannot speak of all, but a few at any rate may be mentioned. The tits are pretty little birds, lively and sprightly, never still for a moment, fluttering from tree to tree, carefully examining the branches, hanging at the end of the weakest twigs, maintaining themselves in any position, often head downwards, following the sway of their slender support without letting go and without ceasing their inspection of the worm-eaten shoots, which they split open to extract the maggots and the eggs. It has been calculated that one tit consumes three hundred thousand insects' eggs in a year. It is true that it has to supply the needs of an exceptionally numerous family. Twenty nestlings and more to be fed at the same time in the same nest are not too great a burden for its activity. It is then that the shoots and cracks in the bark must be visited in order to catch larvæ, spiders, caterpillars and maggots of every kind to feed the twenty beaks always gaping with hunger in the nest. The mother arrives with a caterpillar. The family is in a state of excitement, twenty beaks are opened, but only one receives the morsel, and nineteen are left in expectation. The tit at once sets out on another expedition, returns, starts again unwearied, and when the twentieth beak has been filled the first has for a long time been gaping with hunger. You may imagine the amount consumed by such a household. Whole tribes of birds—woodpeckers, wrynecks, nuthatches, tits, wrens and many others, carry on this patient pursuit, seeking for the eggs in the wrinkles of the bark and the clusters of leaves, for the larvæ in the scales of the shoots and in worm-eaten wood; and for the insects in the crevices where they lie hidden. In this kind of hunting the bird has not to follow its prey, or to vie with it in speed: it is only necessary to find it in its lair. For this a keen eye and sharp beak are required; the wings being only of secondary importance. But other races carry on the great hunt in the air; they follow in their flight the ephemerids, moths, gnats or beetles. These need a short but widely opened beak, which will catch the ephemerids as they pass, notwithstanding their uncertain and uncontrolled flight; a beak in which the prey is swallowed up without the bird slackening its speed for a second, and sticky so that a little butterfly cannot graze it without being caught fast. But above all they must have tireless and swift wings, that will not be wearied by the desperate rush of a prey at full speed, or outwitted by the crooked flight of a moth at its last gasp. A very widely opened beak and highly developed wings must mark the bird addicted to the great hunt in the air. These conditions are shown in the highest degree by the swallow and the swift. Both of these hunt the flying insects, coming and going endlessly ; crossing and recrossing a thousand times, swallowing the insect in their wide throats and passing on without stopping for a second.

The grain-eating, or *granivorous*, bird has a large conical beak, wide at the base and strong, because it is intended for opening hard seeds. Such are the chaffinch, the greenfinch, the linnet, the goldfinch and the sparrow. The insect-eating, or *insectivorous*, bird has a slight, thin delicate beak, weaker because destined to catch the soft vermin. Among these are the nightingale, the warbler, the wagtail, the wheatear and the stonechat. Agriculture has no better defenders against the destruction caused by vermin than these small birds with their fine beaks ; for they are eager devourers of larvæ and insects. They live exclusively on that which is harmful to us. But the granivorous birds are not altogether blameless. There are some who rob the cornfields, who extract the wheat from the ear, and who are impudent enough to claim a share of the oats thrown to the fowls in the poultry yard. Others prefer the juicy flesh of fruit ; they know before we do when the cherries are ripe and the pears mellow. But these misdeeds are compensated for by many services. The grain-eaters gather in the fields a great number of seeds, which if they were allowed to grow up would infest the crop with weeds. With this character of weeders they combine another that is even more deserving. Grain, it is true, is their usual food, but the insect is not so much despised that most of them will not feast on it when abundant and easily caught. Better still, when young, feeble and featherless, receiving their beakful from their parents, many grain-eaters are fed with insects. The sparrow, for instance, is a decided grain-eater. He plunders the dovecots and the poultry yards, stealing the food of the pigeons and fowls ; he reaps the cornfields near our dwellings before we can. Many other misdeeds are laid to his charge. He strips the cherry trees, robs the gardens, forages among the rising seeds and refreshes himself with the young lettuces and the first leaves of the green peas. But when the time of laying eggs has come the impudent robber becomes an exceptionally good helper. Twenty times in the hour at least the father and mother in turn bring a beakful to the young —sometimes a caterpillar, sometimes an insect large enough to be divided into quarters, or again a plump larva, a grasshopper or any other prey. In one week the brood will consume three thousand insects, larvæ, caterpillars and maggots of every kind. Round the nest of one sparrow the remains of seven hundred cockchafers have been counted, besides innumerable small insects. This was the amount of food required to bring up one brood. So children must not harm any of the little birds that protect us from the destructive insects.

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