the north and by about 2° in the south, and, like the lines of horizontal component, the isoclinals have not been displaced parallel to themselves, but in a direction approximating to that of the parallels of latitude. The secular change is least in the north east and gradually increases towards the south, and attains its maximum along the Pyrenees and towards the Gulf of Genoa.

M. Moureaux is to be congratulated on the results of his work, for his countrymen have hitherto scarcely contributed their fair share to our knowledge of terrestrial magnetism. Even the surveys of their own country have been made for them by Germans and Englishmen. Now that Frenchmen themselves have made a beginning, it is to be hoped that the continuity of the work will not be interrupted, for it is only by systematic survey work of the kind so successfully accomplished by M. Moureaux that our knowledge of the magnetic state of the earth and of the laws which regulate its changes can be elucidated.

T. E. THORPE.

TIMBER, AND SOME OF ITS DISEASES.[1]

IV.

BEFORE proceeding further it will be of advantage to describe another tree-killing fungus, which has long been well known to mycologists as one of the commonest of our toadstools growing from rotten stumps, and decaying wood-work such as old water-pipes, bridges, &c. This is *Agaricus melleus* (Fig. 15), a tawny yellow toadstool with

FIG. 15.—A small group of *Agaricus* (*Armillaria*) *melleus*. The toad-stool is tawny-yellow, and produces white spores; the gills are decurrent, and the stem bears a ring. The fine hair-like appendages on the pileus should be bolder.

a ring round its stem, and its gills running down on the stem and bearing white spores, and which springs in tufts from the base of dead and dying trees during September and October. It is very common in this country, and I have often found it on beeches and other trees in Surrey, but it has been regarded as simply springing from the dead rotten wood, &c., at the base of the tree. As a matter of fact, however, this toadstool is traced to a series of dark shining strings, looking almost like the purple-black leaf-stalks of the maidenhair fern, and these strings branch and meander in the wood of the tree, and in the soil, and may attain even great lengths—several feet, for instance. The interest of all this is enhanced when we know that until the last few years these long black cords were supposed to be a peculiar form of fungus, and were known as *Rhizomorpha*. They are, however, the subterranean vegetative parts (mycelium) of the Agaric we are concerned with, and they can be traced without break of continuity from the base of the toadstool into the soil and tree (Fig. 16). I have several times followed these dark mycelial cords into the timber of old beeches and spruce-fir stumps, but they are also to be found in oaks, plums, various Conifers, and probably may occur in most of our timber-trees if opportunity offers.

[1] Continued from p. 229.

The most important point in this connection is that *Agaricus melleus* becomes in these cases a true parasite,

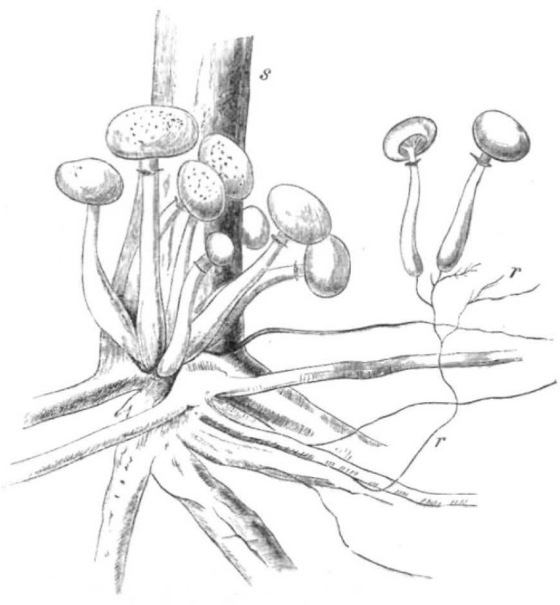

FIG. 16.—Sketch of the base of a young tree (*s*), killed by *Agaricus melleus*, which has attacked the roots, and developed rhizomorphs at *r*, and fructifications. To the right the fructifications have been traced by dissection to the rhizomorph strands which produced them.

producing fatal disease in the attacked timber-trees, and, as Hartig has conclusively proved, spreading from one tree to another by means of the rhizomorphs underground. Only this last summer I had an opportunity of witnessing, on a large scale, the damage that can be done to timber by this fungus. Hundreds of spruce-firs with fine tall stems, growing on the hill sides of a valley in the Bavarian Alps, were shown to me as "victims to a kind of rot." In most cases the trees (which at first sight appeared only slightly unhealthy) gave a hollow sound when struck, and the foresters told me that nearly every tree was rotten at the core. I had found the mycelium of *Agaricus melleus* in the rotting stumps of previously felled trees all up and down the same valley, but it was not satisfactory to simply assume that the "rot" was the same in both cases, though the foresters assured me it was so.

By the kindness of the forest manager I was allowed to fell one of these trees. It was chosen at hazard, after the men had struck a large number, to show me how easily the hollow trees could be detected by the sound.

The tree was felled by sawing close to the roots: the interior was hollow for several feet up the stem, and two of the main roots were hollow as far as we could poke canes, and no doubt further. The dark-coloured rotting mass around the hollow was wet and spongy, and consisted of disintegrated wood held together by a mesh-work of the rhizomorphs. Further outwards the wood was yellow, with white patches scattered in the yellow matrix, and, again, the rhizomorph-strands were seen running in all directions through the mass.

Not to follow this particular case further—since we are concerned with the general features of the diseases of timber—I may pass to the consideration of the diagnosis of this disease caused by *Agaricus melleus*, as contrasted with that due to *Trametes radiciperda*.

Of course no botanist would confound the fructification of the *Trametes* with that of the *Agaricus*; but the fructifications of such fungi only appear at certain seasons, and that of *Trametes radiciperda* may be underground, and it is important to be able to distinguish such forms in the absence of the fructifications.

The external symptoms of the disease, where young trees are concerned, are similar in both cases. In a plantation at Freising, in Bavaria, Prof. Hartig showed me young Weymouth pines (*P. Strobus*) attacked and killed by *Agaricus melleus*. The leaves turn pale and yellow, and the lower part of the stem—the so-called "collar"—begins to die and rot, the cortex above still looking healthy. So far the symptoms might be those due to the destructive action of other forms of tree-killing fungi.

On uprooting a young pine, killed or badly attacked by the Agaric, the roots are found to be matted together with a ball of earth permeated by the resin which has flowed out: this is very pronounced in the case of some pines, less so in others. On lifting up the scales of the bark, there will be found, not the silky, white, delicate mycelium of the *Trametes*, but probably the dark cord-like rhizomorphs: there may also be flat white rhizomorphs in the young stages, but they are easily distinguished. These dark rhizomorphs may also be found spreading around into the soil from the roots, and they look so much like thin roots indeed that we can at once understand their name—rhizomorph. The presence of the rhizomorphs and (in the case of the resinous pines) the outflow of resin and sticking together of soil and roots are good distinctive features. No less evident are the differences to be found on examining the diseased timber, as exemplified by Prof. Hartig's magnificent specimens. The wood attacked assumes brown and bright yellow colours, and is marked by sharp brown or nearly black lines, bounding areas of one colour and separating them from areas of another colour. In some cases the yellow colour is quite bright—canary yellow, or nearly so. The white areas scattered in this yellow matrix have no black specks in them, and can thus be distinguished from those due to the *Trametes*. In advanced stages the purple-black rhizomorphs will be found in the soft, spongy wood.

The great danger of *Agaricus melleus* is its power of extending itself beneath the soil by means of the spreading rhizomorphs: these are known to reach lengths of several feet, and to pass from root to root, keeping a more or less horizontal course at a depth of 6 or 8 inches or so in the ground. On reaching the root of another tree, the tips of the branched rhizomorph penetrate the living cortex, and grow forward in the plane of the cambium, sending off smaller ramifications into the medullary rays and (in the case of the pines, &c.) into the resin passages. The hyphæ of the ultimate twigs enter the tracheides, vessels, &c., of the wood, and delignify them, with changes of colour and substance as described. Reference must be made to Prof. Hartig's publications for the details which serve to distinguish histologically between timber attacked by *Agaricus melleus* and by *Trametes* or other fungi. Enough has been said to show that diagnosis is possible, and indeed, to an expert, not difficult.

It is at least clear from the above sketch that we can distinguish these two kinds of diseases of timber, and it will be seen on reflection that this depends on knowledge of the structure and functions of the timber and cambium on the one hand, and proper acquaintance with the biology of the fungi on the other. It is the victory of the fungus over the timber in the struggle for existence which brings about the disease; and one who is ignorant of these points will be apt to go astray in any reasoning which concerns the whole question. Anyone knowing the facts and understanding their bearings, on the contrary, possesses the key to a reasonable treatment of the timber; and this is important, because the two diseases referred to can be eradicated from young plantations and the areas of their ravages limited in older forests.

Suppose, for example, a plantation presents the following case. A tree is found to turn sickly and die, with the symptoms described, and trees immediately surrounding it are turning yellow. The first tree is at once cut down, and its roots and timber examined, and the diagnosis shows the presence of *Agaricus melleus* or of *Trametes radiciperda*, as the case may be. Knowing this, the expert also knows more. If the timber is being destroyed by the *Trametes*, he knows that the ravaging agent can travel from tree to tree by means of roots in contact, and he at once cuts a ditch around the diseased area, taking care to include the recently-infected and neighbouring trees. Then the diseased timber is cut, because it will get worse the longer it stands, and the diseased parts burnt. If *Agaricus melleus* is the destroying agent, a similar procedure is necessary; but regard must be had to the much more extensive wanderings of the rhizomorphs in the soil, and it may be imperative to cut the moat round more of the neighbouring trees Nevertheless, it has also to be remembered that the rhizomorphs run not far below the surface. However, my purpose here is not to treat this subject in detail, but to indicate the lines along which practical application of the truths of botanical science may be looked for. The reader who wishes to go further into the subject may consult special works. Of course the spores are a source of danger, but need be by no means so much so where knowledge is intelligently applied in removing young fructifications.

I will now pass on to a few remarks on a class of disease-producing timber fungi which present certain peculiarities in their biology. The two fungi which have been described are true parasites, attacking the roots of living trees, and causing disease in the timber by travelling up the cambium, &c., into the stem: the fungi I am about to refer to are termed wound-parasites, because they attack the timber of trees at the surfaces of wounds, such as cut branches, torn bark, frost-cracks, &c., and spread from thence into the sound timber. When we are reminded how many sources of danger are here open in the shape of wounds, there is no room for wonder that such fungi as these are so widely spread. Squirrels, rats, cattle, &c., nibble or rub off bark; snow and dew break branches; insects bore into stems; wind, hail, &c., injure young parts of trees; and in fact small wounds are formed in such quantities that if the fructifications of such fungi as those referred to are permitted to ripen indiscriminately, the wonder is not that access to the timber is gained, but rather that a tree of any considerable age escapes at all.

One of the commonest of these is *Polyporus sulphureus*, which does great injury to all kinds of standing timber, especially the oak, poplar, willow, hazel, pear, larch, and others. It is probably well known to all foresters, as its fructification projects horizontally from the diseased trunks as tiers of bracket-shaped bodies of a cheese-like consistency; bright yellow below, where the numerous minute pores are, and orange or somewhat vermilion above, giving the substance a coral-like appearance. I have often seen it in the neighbourhood of Englefield Green and Windsor, and it is very common in England generally.

If the spore of this *Polyporus* lodges on a wound which exposes the cambium and young wood, the filaments grow into the medullary rays and the vessels, and soon spread in all directions in the timber, especially longitudinally, causing the latter to assume a warm brown colour and to undergo decay. In the infested timber are to be observed radial and other crevices filled with the dense felt-like mycelium formed by the common growth of the innumerable branched filaments. In bad cases it is possible to strip sheets of this yellowish white felt-work out of the cracks, and on looking at the timber more closely (of the oak, for instance) the vessels are found to be filled with the fungus filaments, and look like long white streaks in longitudinal sections of the wood—showing as white dots in transverse sections.

It is not necessary to dwell on the details of the histology of the diseased timber: the ultimate filaments of the fungus penetrate the walls of all the cells and vessels, dissolve and destroy the starch in the medullary rays, and convert the lignified walls of the wood elements back again into cellulose. This evidently occurs by some solvent action, and is due to a ferment excreted from the fungus filaments, and the destroyed timber becomes reduced to a brown mass of powder.

I cannot leave this subject without referring to a remarkably interesting museum specimen which Prof. Hartig showed and explained to me this summer. This is a block of wood containing an enormous irregularly spheroidal mass of the white felted mycelium of this fungus, *Polyporus sulphureus*. The mass had been cut clean across, and the section exposed a number of thin brown ovoid bodies embedded in the closely-woven felt: these bodies were of the size and shape of acorns, but were simply hollow shells filled with the same felt-like mycelium as that in which they were embedded. They were cut in all directions, and so appeared as circles in some cases. These bodies are, in fact, the outer shells of so many acorns, embedded in and hollowed out by the mycelium of *Polyporus sulphureus*. Hartig's ingenious explanation of their presence speaks for itself. A squirrel had stored up the acorns in a hollow in the timber, and had not returned to them—what tragedy intervenes must be left to the imagination. The *Polyporus* had then invaded the hollow, and the acorns, and had dissolved and destroyed the cellular and starchy contents of the latter, leaving only the cuticularized and corky shells, looking exactly like fossil eggs in the matrix. I hardly think geology can beat this for a true story.

The three diseases so far described serve very well as types of a number of others known to be due to the invasion of timber and the dissolution of the walls of its cells, fibres, and vessels by Hymenomycetous fungi, *i.e.* by fungi allied to the toadstools and polypores. They all "rot" the timber by destroying its structure and substance, starting from the cambium and medullary rays.

To mention one or two additional forms, *Trametes Pini* is common on pines, but, unlike its truly parasitic ally, *Tr. radiciperda*, which attacks sound roots, it is a wound-parasite, and seems able to gain access to the timber only if the spores germinate on exposed surfaces. The disease it produces is very like that caused by its ally: probably none but an expert could distinguish between them, though the differences are clear when the histology is understood.

Polyporus fulvus is remarkable because its hyphæ destroy the middle-lamella, and thus isolate the tracheides in the timber of firs; *Polyporus borealis* also produces disease in the timber of standing Conifers; *Polyporus igniarius* is one of the commonest parasites on trees such as the oak, &c., and produces in them a disease not unlike that due to the last form mentioned; *Polyporus dryadeus* also destroys oaks, and is again remarkable because its hyphæ destroy the middle-lamella.

With reference to the two fungi last mentioned I cannot avoid describing a specimen in the Museum of Forest Botany in Münich, since it seems to have a possible bearing on a very important question of biology, viz. the action of soluble ferments.

It has already been stated that some of these tree-killing fungi excrete ferments which attack and dissolve starch-grains, and it is well known that starch-grains are stored up in the cells of the medullary rays found in timber. Now, *Polyporus dryadeus* and *P. igniarius* are such fungi; their hyphæ excrete a ferment which completely destroys the starch-grains in the cells of the medullary rays of the oak, a tree very apt to be attacked by these two parasites, though *P. igniarius*, at any rate, attacks many other dicotyledonous trees as well. It occasionally happens that an oak is attacked by both of these Polyporei, and their mycelia become intermingled in the timber: when this is the case the *starch-grains remain intact in those cells which are invaded simultaneously by the hyphæ of both fungi*. Prof. Hartig lately showed me longitudinal radial sections of oak-timber thus attacked, and the medullary rays showed up as glistening white plates. These plates consist of nearly pure starch: the hyphæ have destroyed the cell-walls, but left the starch intact. It is easy to suggest that the two ferments acting together exert (with respect to the starch), a sort of inhibitory action one on the other; but it is also obvious that this is not the ultimate explanation, and one feels that the matter deserves investigation.

It now becomes a question—What other types of timber-diseases shall be described? Of course the limits of a popular article are too narrow for anything approaching an exhaustive treatment of such a subject, and nothing has as yet been said of several other diseases due to crust-like fungi often found on decaying stems, or of others due to certain minute fungi which attack healthy roots. Then there is a class of diseases which commence in the bark or cortex of trees, and extend thence into the cambium and timber: some of these "cankers," as they are often called, are proved to be due to the ravages of fungi, though there is another series of apparently similar "cankers" which are caused by variations in the environment—the atmosphere and weather generally.

It would need a long article to place the reader *au courant* with the chief results of what is known of these diseases, and I must be content here with the bare statement that these "cankers" are in the main due to local injury or destruction of the cambium. If the normal cylindrical sheet of cambium is locally irritated or destroyed, no one can wonder that the thickening layers of wood are not continued normally at the locality in question: the uninjured cells are also influenced, and abnormal cushions of tissue formed which vary in different cases. Now, in "cankers" this is—put shortly—what happens: it may be, and often is, due to the local action of a parasitic fungus; or it may be—and, again, often is—owing to injuries produced by the weather, in the broad sense, and saprophytic organisms may subsequently invade the wounds.

The details as to how the injury thus set up is propagated to other parts—how the "canker" spreads into the bark and wood around—*are* details, and would require considerable space for their description: the chief point here is again the destructive action of mycelia of various fungi, which by means of their powers of pervading the cells and vessels of the wood, and of secreting soluble ferments which break down the structure of the timber, render the latter diseased and unfit for use. The only too well known larch-disease is a case in point; but, since this is a subject which needs a chapter to itself, I may pass on to more general remarks on what we have learnt so far.

It will be noticed that, whereas such fungi as *Trametes radiciperda* and *Agaricus melleus* are true parasites which can attack the living roots of trees, the other fungi referred to can only reach the interior of the timber from the exposed surfaces of wounds. It has been pointed out along what lines the special treatment of the former diseases must be followed, and it only remains to say of the latter: take care of the cortex and cambium of the tree, and the timber will take care of itself. It is unquestionably true that the diseases due to wound-parasites can be avoided if no open wounds are allowed to exist. Many a fine oak and beech perishes before its time, or its timber becomes diseased and a high wind blows the tree down, because the spores of one of these fungi alight on the cut or torn surface of a pruned or broken branch. Of course it is not always possible to carry out the surgical operations, so to speak, which are necessary to protect a tree which has lost a limb, and in other cases no doubt those responsible have to discuss whether it costs more to perform the operations on a large scale than to risk the timber. With these matters I have nothing to do here, but the fact remains that by properly closing over open wounds, and allowing the surrounding cambium to cover them up, as it will naturally do, the term of life of many a valuable tree can be prolonged, and its timber not only prevented from becoming diseased and deteriorating, but actually increased in value.

There is no need probably for me to repeat that, although the present essay deals with certain diseases of timber due to fungi, there are other diseases brought about entirely by inorganic agencies. Some of these were touched upon in the last article, and I have already put before the readers of NATURE some remarks as to how trees and their timber may suffer from the roots being in an unsuitable medium.

In the next paper it is proposed to deal with the so-called "dry-rot" in timber which has been felled and cut up—a disease which has produced much distress at various times and in various countries.

H. MARSHALL WARD.

(*To be continued.*)

PERPETUAL MOTION.[1]

IF we study the past in order to trace the development of machines, we cannot help being astonished at the long centuries during which man was content to employ only his own muscular effort and that of animals, instead of utilizing the other forces of Nature to do his work; for it is a striking fact that it is during little more than the last quarter of a century that the power of the steam-engine has in the aggregate become twice as great as that of the whole working population of the world.

Although the early history of the subject is shrouded in obscurity, there is little doubt that the power of water was the first to be employed. We can easily imagine that, in those early days when the laws of Nature were so little understood, the idea would arise that, if some machine could be contrived which would not get tired like man or animal, as machines appeared to do when left to themselves, and, moreover, one which did not depend upon a capricious and variable supply of water, such a machine would go on for ever—in short, would have perpetual motion. As a matter of fact, Geiger, the German philologist, has adduced strong grounds for believing the Buddhist praying-wheels—on which the prayers of the worshippers were fastened, and which were turned by water power—to be probably the first kind of water motor; and at the same time the first record of a proposal for a perpetual motion machine appears to be in the "Siddhânta Ciromani," a Sanskrit text-book on astronomy, in which a wheel for this purpose is suggested, having a number of closed equidistant holes half filled with mercury upon a zigzag line round its rim. No doubt other suggestions of this kind were made from time to time, but writers and literary men did not condescend to notice them, or even the progress of the really practical and useful machines. We are thus brought from that distant date down to the thirteenth century, when we find in the sketch-book of an architect, Wilars de Honecort (the original being now in the École des Chartres, at Paris), a drawing of a proposed perpetual motion machine, with the statement which, translated, runs:—"Many a time have skilful workmen tried to contrive a wheel that shall turn of itself: here is a way to make such by means of an uneven number of mallets or by quicksilver." The engraving shows four mallets upon what is evidently meant to be the descending side of the wheel, and three upon the ascending side, the former therefore overbalancing the latter. To get the mallets into this desirable position the top one on the descending side has evidently been made to fall over before its time; but independently of this there is to the ordinary mind a strong suggestion of speedy dissolution in any structure a greater number of whose parts are going in one direction than in the other, but this little difficulty M. de Honecort does not allude to or discuss. The unevenly weighted wheel in which the action of gravity is to be cheated in some way or the other has appeared in a great variety of forms since, and, from the words "many a time," probably before, and is by far the most important type of proposed contrivance for perpetual motion.

About two centuries after De Honecort, the famous Leonardi da Vinci gives sketches of six designs, either due to his own fertile brain or taken from other sources, and since then there has been an incessant flow of proposals of this type of machine, a large number of which are given in the work of Dr. Henry Dirks, "Perpetuum Mobile," and several in vol. xii. of the *Mechanical World.*

The next class of proposed machines we may consider are those in which gravity was to be made use of in one direction and evaded in the opposite, by the agency of falling water, amongst these being the devices of Schott, Scheiner, Böckler, and others. The idea in all these was that a quantity of water might be kept circulating between two tanks, one above, and one below; being raised to the upper one by means of pumps driven by a water-wheel which derived its motion from the selfsame water in falling the same distance, there being a balance to the good in the form of extra work to be done by the wheel.

A third class of proposals suggests the application of capillary action to raise the water instead of employing pumps, one of the earliest being that of a Professor of of Philosophy in Glasgow about 200 years ago. In this case and others the drawings show (in anticipation) the water thus raised flowing out at the top in a good substantial stream, as, for instance, in the scheme of Branca about the date of the Professor's production.

The fourth and last class, which partook more of a philosophic nature, proposed to employ magnets, the attraction of which is to be effective in one position, and masked in another. There are many proposed ways of effecting this, all equally futile, although one contrived by a shoemaker of Linlithgow actually deceived for a time Sir David Brewster, who communicated an account of it to the *Annales de Chimie.* In the simplest a ball is to fall through a certain distance, so as to come into a position where it can be raised up an inclined plane by magnetic attraction. The first part is carried out in strict

[1] Abstract of a Lecture delivered by Prof. Hele Shaw, University College, on December 21, 1887, in St. George's Hall, Liverpool.