THE GEOLOGICAL STRUCTURE OF SCANDINAVIA AND THE SCOTTISH HIGHLANDS.

THE obvious connection and analogy between the geological structure of the crystalline rocks of the Highlands of Scotland and those of Scandinavia have long engaged the attention of geologists. Among the northern observers to whose labours we are largely indebted for our knowledge of the Scandinavian regions, Dr. A. E. Törnebohm has proved himself a keen and indefatigable explorer of the Swedish uplands. Many years ago he showed that above clay-slates and limestones, with recognizable Silurian fossils, there lies a great thickness of quartzites, gneisses, and schists, called by him the Seve group. In more recently studying the relations of these rock-masses, he encountered some great difficulties, of which he sent me at the time an account. I could not pretend to solve them, but suggested, as at least a working hypothesis, that the Scandinavian structure might be fundamentally similar to that now recognized as characteristic of the North-West Highlands, where the apparent conformable superposition of a series of schists upon fossiliferous Lower Silurian strata has been produced by great terrestrial displacements, whereby the overlying rocks have been crushed and deformed, until they have assumed a new crystalline structure along the planes of movement, these stupendous changes having occurred at some time subsequent to the Lower Silurian period. I have recently received from Dr. Törnebohm the following letter, which he gives me leave to publish, and which will no doubt be read with interest by those who are aware of the recent progress of research in this subject:—"It will perhaps interest you to learn that your suggestion four years ago regarding the construction of our Scandinavian *fjelds* has turned out to be correct, at least in my opinion. My late researches have little by little driven me to the conclusion that the crystalline schists belonging to what I have called the 'Seve group' have been placed over Silurian strata by an enormous eastward thrust. I admit that I have most reluctantly come to this conclusion, knowing that it implied a horizontal thrust of enormous masses of rock for more than 100 kilometres. Such a stupendous movement of entire mountain-regions is hard to realize; but facts are stubborn things."

It will be observed that Dr. Törnebohm speaks of the movement having been towards the east, whereas in the north-west of Scotland it has been in the opposite direction. In a more recent letter, in reply to one in which I had called his attention to this difference, he says:—"Though in Scotland the great thrusts are westward, in Scandinavia it is quite the reverse. Here the chief movement has been to the east or south-east. In the region of Trondhjem, indeed, there have been lesser movements towards the north-west, but these may have taken place somewhat later. At least I rather suspect this, but am not prepared positively to affirm it." I may remark that in Scotland also there are districts where the thrusts have not come from the normal direction but from the westward. In the Island of Islay, for example, I recently found the limestones and quartzites piled up by sharply-cut thrust-planes which had a general westward inclination at lower angles than the displaced strata. One of the great problems in working out the complicated geology of the Highlands is the determination of the positions and extent of such thrust-planes, and the direction in which the displaced rock-masses have been moved. There can be little doubt that much mutual help in this research will be gained by a co-operation between the field geologists who are engaged in the study of these problems in Scotland and in Scandinavia.

ARCH. GEIKIE.

TIMBER, AND SOME OF ITS DISEASES.[1]

VIII.

THERE is a large and important class of diseases of standing timber which start from the cortex and cambium so obviously that foresters and horticulturists, struck with the external symptoms, almost invariably term them "diseases of the bark"; and since most of them lead to the production of malformations and excrescences, often with outflowing of resinous and other fluids, a sort of rough superficial analogy to certain animal diseases has been supposed, and such terms as "canker," "cancer," and so forth, have been applied to them.

Confining our attention to the most common and typical cases, the following general statements may be made about these diseases. They usually result from imperfect healing of small wounds, the exposed cortex and cambium being attacked by some parasitic or semi-parasitic fungus, as it tries to heal over the wound. The local disturbances in growth kept up by the mycelium feeding on the contents of the cells of these tissues lead to the irregular growths and hypertrophies referred to; the wounds are kept open and "sore," or even extended, and there is hardly any limit to the possibilities of damage to the timber thus exposed to a multitude of dangers.

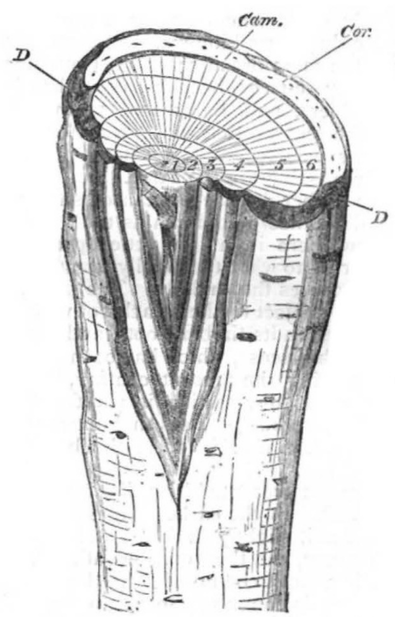


FIG. 28.—Piece of tree stem affected with "canker." The injury commenced after the two inner zones of wood (1 and 2) had been developed: it extended further in successive periods of growth, as shown by the receding zones 3, 4, 5, and 6, until all the cambium and cortex was destroyed except the pieces *D* to *D*. *Cam*, cambium; *Cor*, living cortex; *D D*, dead tissues. At each period of growth the attempt has been made to heal over the wound, as shown by the successively receding lips.

In Fig. 28 is represented a portion of a tree stem affected with "canker": the transverse section shows the periods of growth numbered 1 to 6 from within outwards. When the stem was younger, and the cambium had already developed the zones marked 1 and 2, the cortex suffered some injury near the base of the dead twig, below the figure 1. This injury was aggravated by the ravages of fungus-mycelium, which penetrated to the cambium and destroyed it over a small area: in consequence of this, the next periodic zone of wood (marked 3) is of course incomplete over the damaged area, and the cortex and cambium strive to heal over the wound by lip-like callus at the margins. The healing is prevented,

[1] Continued from p. 111.

however, by the mycelium, which is continually extending the area of injury: consequently the next zone of wood (4 in the figure) extends even a shorter distance round the stem, and so on with 5 and 6, the cambium being now restricted to less than half round the stem—*i.e.* from *D* to *D*, and the same with the living cortex. Of course the injured area extends upwards and downwards also, as shown by the lips of the healing tissue. As soon as the injury extends all round, the stem dies—it is, in fact, ringed. It is also interesting to note that the zones 4 and 5 (and the same would be true of 6 when completed) are thicker than they would have been normally: this is partly due to release from pressure, and partly to a concentrated supply of nutritive materials.

Much confusion still exists between the various cases: some of them undoubtedly are due to frost or to the intense heat of direct insolation; these are, as a rule, capable of treatment more or less simple, and can be healed up. Others, again, can only be freed from the irritating agents (which, by the bye, may be insects as well as fungi) by costly and troublesome methods.

I shall only select one case for illustration, as it is typical, and only too well known. As examples of others belonging to the same broad category, I may mention the "canker" of apple-trees, beeches, oaks, hazels, maples, hornbeams, alders, and limes, and many others; and simply pass the remark that whatever the differences in detail in the special cases, the general phenomena and processes of reasoning are the same.

Perhaps no timber disease has caused so much consternation and difference of opinion as the "larch-disease," and even now there is far too little agreement among foresters either as to what they really mean by this term, or as to what causes the malady. The larch, like other timber-trees, is subject to the attacks of various kinds of fungi and insects, in its timber, roots, and leaves; but the well-known larch-disease, which has been spreading itself over Europe during the present century, and which has caused such costly devastation in plantations, is one of the group of cancerous diseases the outward and visible signs of which are manifested in the bark and young wood.

The appearance presented by a diseased larch-stem is shown in Fig. 29. In the earlier stages of the malady the stem shows dead, slightly sunken patches, *a*, of various sizes on the cortex, and the wood beneath is found to cease growing: it is a fact to be noted that the dead base of a dried-up branch is commonly found in the middle of the patch. The diseased cortex is found to stick to the wood below, instead of peeling off easily with a knife. At the margins of the flattened patch, just where the dead cortex joins the normal living parts, there may frequently be seen a number of small cup-like fungus fructifications (Fig. 29, *b*), each of which is white or gray on the outside, and lined with orange-yellow. These are the fruit-bodies of a discomycetous fungus called *Peziza Willkommii* (Htg.), and which has at various times, and by various observers, received at least four other names, which we may neglect.

In the spring or early summer, the leaves of the tree are found to turn yellow and wither on several of the twigs or branches, and a flow of resin is seen at the dead patch of cortex. If the case is a bad one, the whole branch or young tree above the diseased place may die and dry up. At the margins of the patch, the edges of the sounder cortex appear to be raised.

As the disease progresses in succeeding years, the merely flattened dead patch becomes a sunken blistered hole from which resin flows: this sinking in of the destroyed tissues is due to the up-growth of the margins of the patch, and it is noticed that the up-growing margin recedes further and further from the centre of the patch. If this goes on, the patch at length extends all round the stem or branch, and the death of all that lies above is then soon brought about, for, since the young wood and cambium beneath the dead cortex are also destroyed, the general effect is to "ring" the tree.

To understand these symptoms better, it is necessary to examine the diseased patch more closely in its various stages. The microscope shows that the dead and dying cortex, cambium, and young wood in a small patch, contain the mycelium of the fungus which gives rise to the cup-like fructifications—*Peziza Willkommii*—above referred to (Fig. 30); and Hartig has proved that, if the spores of this *Peziza* are introduced into the cortex of a healthy living larch, the mycelium to which they give rise kills the cells of the cortex and cambium, penetrates into the young wood, and causes the development of a patch which everyone would recognize as that of the larch-disease. It is thus shown that the fungus is the immediate cause of the patch in which it is found.

The next fact which has been established is that the fungus can only infect the cortex through some wound or injury—such as a crack or puncture—and cannot penetrate the sound bark, &c. Once inside, however, the mycelium extends upwards, downwards, sideways, and inwards, killing and destroying all the tissues, and so inducing the outflow of resin which is so characteristic of the disease. The much-branched, septate, colourless

FIG. 29.—Portion of stem of a young larch affected with the larch-disease, as indicated by the dead "cancerous" patch of cracked cortex, *a*: at and near the margins of the patch are the small cup-like fructifications of *Peziza Willkommii* (Htg.), which spring from mycelium in the dead and dying cortex and cambium beneath. (After Hess.)

hyphæ can penetrate even as far as the pith, and the destroyed tissues turn brown and dry up.

After destroying a piece of the tissues in the spring, the growth of the mycelium stops in the summer, the dead cortex dries up and sticks to the wood, and the living cortex at the margins of the patch commence to form a thick layer of cork between its living cells and the diseased area.

It is this cork-formation which gives the appearance of a raised rim around the dead patch. It has long been known that the patches dry up and cease to spread in the dry season. It should be pointed out that it is one of the most general properties of living parenchymatous tissue to form cork-cells at the boundaries of an injury: if a slice is removed from a potato, for instance, the cut surface will be found in a few days with several layers of cork-cells beneath it, and the same occurs at the cut surface of a slip, or a pruned branch,—the "callus" of tissue formed is covered with a layer of cork.

If it is remembered that the cambium and young wood are destroyed beneath the patch, it will be at once clear that in succeeding periods of growth the annual rings of wood will be deficient beneath the patch.

Next year, the cambium in the healthy parts of the stem begins to form another ring; but the fungus mycelium awakens to renewed activity at the same time, and spreads a little further upwards, downwards, and sideways, its hyphæ avoiding the cork-layer and traversing the young wood and cambium below. During this second spring, therefore, a still larger patch of dead tissue —cortex, cambium, and young wood—is formed, and the usual cork-layer describes a larger boundary. Moreover, since the cambium around the, as yet, undiseased parts has added a further annual ring—which of course stops at the boundaries of the diseased patch—the centre of the patch is yet more depressed (cf. Fig. 28).

And so matters go on, year after year, the local injury to the timber increasing, and ultimately seriously affecting, or even bringing to an end, the life of the tree.

At the margins of the diseased patches, as said, the fungus at length sends out its fructifications. These appear at first as very minute cushions of mycelium, from which the cup-like bodies with an orange-coloured lining

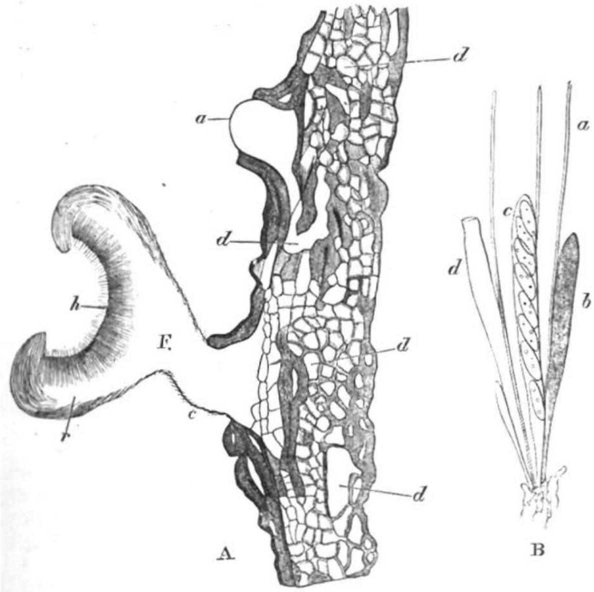


FIG. 30.—A, vertical section (magnified) through the dead cortex of a larch, infected with the mycelium (*d*) of *Peziza Willkommii* (Htg.), which is developing its fructifications (*a* and *E*). The mycelium fills up the gaps in the cortex, *d*, with a white felt-work. *a* is a boss-like cushion of this felt-work bursting forth to become a cup-like fructification; *F*, the mature *Peziza* fructification (in section); *c*, its stalk; *r*, the margins of the cup; *h*, the layer of spore-sacs (*asci*). B, four of the asci from *h*, very highly magnified. *a*, hair-like barren filaments between the asci; *c*, a fully-developed ascus, containing the eight spores; *d*, an ascus emptied of spores (they have escaped through the hole at the apex); *b*, a young ascus in which the spores are not yet formed: to the left below is a small one still younger. (After Hartig and Willkomm.)

arise: the structure of this fructification is best seen from the illustration (Fig. 30, A). The orange-red lining (*h*) is really composed of innumerable minute tubular sacs, each of which is termed an *ascus*, and contains eight small spores: as seen in the figure (Fig. 30, B), these asci stand upright like the pile of velvet lining the cup. They are formed in enormous numbers, and go on ripening and scattering the spores day after day. There are many interesting details connected with the development and structure of these fructifications and spores; but we may pass over these particulars here, the chief point for the moment being that very large numbers of the minute spores are formed, and scattered by the wind, rain, animals, &c. Moreover, as already stated, it has been shown by experiments that the spores will infect the stem of the larch if they are introduced into a wound; but it is important to notice that the fungus cannot penetrate the sound cortex.

It now remains for us to see if, in the natural course of events, infection of the larch can take place to any great extent; for, unless this is the case, we cannot reconcile the above peculiarities of the fungus with the prevalence of the disease.

It must be borne in mind that the larch is an Alpine tree, growing naturally at an elevation of from about 3000 to 6000 feet above sea-level, and even more. In its native heights, both the larch-disease and *Peziza Willkommii* occur associated as we have described them, but the malady does not become epidemic, as it has done in the valleys and plains of Europe.

Several insect-enemies of the larch are known, some of which feed on the buds, and others on the leaves, &c.: it is not impossible that insect-wounds may serve occasionally as points of entry for the fungus.

But attention should be directed to the remark made when describing the symptoms of the disease—namely, that a dead branch often springs from near the centre of the patch. Now it is a well-known fact in the hill-forests of Switzerland, Germany, Austria, &c., that heavy falls of snow often load the branches until they bend down to the ground, and the bark in the upper angle where the branch joins the stem is ruptured; similar cracks are also caused by the bending down of the branches under the weight of water condensed from mists, &c. If a spore alighted near such a place, the rain would wash it into the crevice, and it would germinate in the moisture always apt to accumulate there. This certainly accounts very completely for the situation of the dead branch, which of course would at once suffer from the mycelium. Another way in which such wounds as would give access to the parasite might arise, is from the blows of hailstones on the still young and tender cortex.

But probably the most common source of the crevices or wounds by which the fungus gains an entry is frost; and to understand this we must say a few words as to what is known of the larch at home in its native Alps.

It is well known, since Hartig drew attention to the fact, that in the high regions of the Alps the trees begin to put forth their shoots very late: the larch in the lowlands of Germany and the British Isles often begins to shoot at the end of March or beginning of April, whereas in the mountains it may be devoid of leaves in May. This is because the transition from winter to spring is very sudden on high slopes, whereas in the lowlands and valleys it may be very gradual. The consequence is that in the Alps, when the buds once begin to open they do this rapidly and vigorously, and the tender leaves and shoots are quickly formed and beyond the reach of those late spring frosts which do so much damage in our country: in the lowlands, on the contrary, the leaves slowly develop at a time when late frosts are very apt to recur at night, and they are for several weeks exposed to this danger; and if a sharp frost does come, the chances are that not only will the first output of tender leaves be killed off, but the whole shoot suffers, and frost-wounds are formed in the young cortex.

Another point comes into consideration also. In warm damp valleys the whole tree is apt to be more watery, and it is well known that the soft tissues, like the cortex, suffer more from frost when filled with watery sap, than do harder, drier, more matured ones. It has been shown, according to Sorauer, that dead patches, exactly like those which characterize the larch-disease in its early stages, can be artificially produced by exposing the stem to temperatures below zero, so as to freeze the water in the cells.

Given the above conditions for producing frost-wounds, then, and the presence of spores of *Peziza Willkommii*, there is no difficulty in explaining the well-known phenomena of the larch-disease.

But Hartig has brought to light some other facts of great importance in considering this admittedly complex question. We have already stated that the *Peziza* does occur at the margins of the wounds in the Alps where the larch is native. In these higher regions, however, the air is usually dry during periods of active growth and the young fructifications of the fungus are particularly sensitive to drought; consequently, even when many scattered trees are infected, the cups developed at the edges of the wounds are apt either to dry up altogether, or to produce relatively few spores, and these spores have fewer chances of germinating. In fact, the fungus enjoys at best a sporadic existence, chiefly at the bases of trees where the herbage affords a certain degree of dampness.

When the larch was brought down to the plains and valleys, however, and planted in all directions over large areas, the *Peziza* was also brought with it; but it will be clear from the foregoing discussion that the climatic conditions were now proportionally raised in favour of the fungus, and lowered to the disadvantage of the larch. Plantations in damp valleys, or in the neighbourhood of the sea, or of large lakes, were especially calculated to suffer from frost, and the damp air favoured the propagation of the fungus, and the disease tended to become epidemic. The enormous traffic in larch plants also shows how man too did his share in spreading the epidemic; and in fact the whole story of the larch-disease is of peculiar interest biologically, as illustrating the risks we run every day in trusting to the chapter of accidents to see us safely through any planting undertaking, no matter how great the stake at issue, or how ruthless the interference with those complex biological and physical conditions which always play such an important part in keeping the balance in the struggle for existence between all organisms living together.

Let us now very shortly see what are the chief lessons taught us by the bitter and costly experience which the larch-disease brought to foresters. It is evident that the larch should not be planted at all in low-lying situations exposed to late frosts; and even in more favoured valleys experience points to the advantage of mixing it with other trees: large areas of pure larch are planted at enormous risk in the lowlands.

As to the treatment of trees already diseased, it is possible (when it is worth while) to remove diseased branches from trees of which the trunk and crown are healthy, but it hardly needs mention that such diseased branches must be burnt at once. As regards trees with the stems diseased—in those cases where the patches are large, and much resin is flowing from the wounds, experience points to the advisability of cutting them down. In those cases where the tree is already very large, and the diseased wound but small, it may be expedient to let them alone: theoretically they ought to go, or at any rate the diseased tissues be excised and burnt; but it seems to be proved that such a tree may go on forming timber for many years before the wound will spread far enough to reduce the annual increment below the limits of profit, and we all know the view a practical forester will take of such a case. At the same time, it is the duty of the man of science to point out that even such a tree is a possible source of danger to its neighbours.

H. MARSHALL WARD.

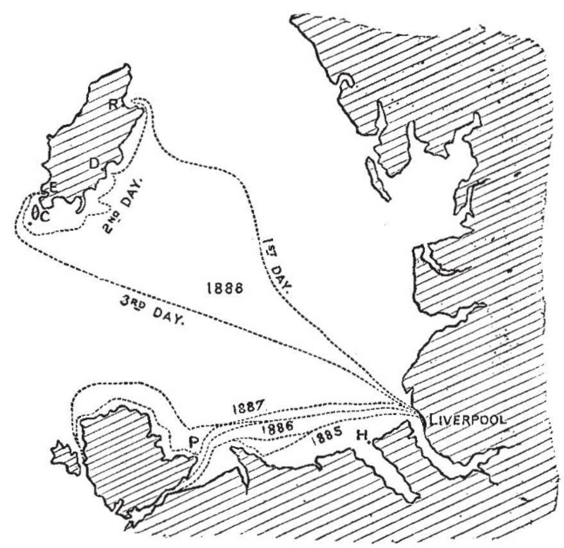
(*To be continued.*)

MARINE BIOLOGY AND THE ELECTRIC LIGHT.

THE Liverpool Salvage Association, with their usual liberality, placed their famous old steamer the *Hyæna* once more at the service of the Liverpool Marine Biology Committee this Whitsuntide, for a three days' dredging expedition. During the three former biological cruises of the *Hyæna* in 1885, 1886, and 1887, the region explored has been the southern part of the L.M.B.C. district, around the coasts of North Wales and Anglesey (see Fig.).

On the present occasion the Committee decided to run a couple of lines of soundings and dredgings between the Mersey and the Isle of Man, and to spend some time dredging round the southern end of that island; the general objects being (1) to get some knowledge of the depths, bottom, and animals, across the eastern half of the Irish Sea, and (2) to investigate the rich fauna living around the "Calf" and south end of the Isle of Man.

About 7 a.m. on Saturday morning, May 19, the *Hyæna* left the Liverpool landing-stage, with a party of nearly twenty biologists on board, and provided with dredges, trawls, tow-nets, sounding-line, deep-sea reversing thermometer, microscopes, and the other necessary instruments, dishes, bottles, and reagents. After the well-known sand-banks round the mouth of the Mersey had been passed, soundings and bottom temperatures were taken occasionally, and several times during the day a stop was made for trawling, dredging, and tow-netting. A fair amount of material, including some interesting larval forms, was obtained, and for the most part preserved for further examination. No greater depth than 23 fathoms



Map of the L.M.B.C. District, showing the course of the *Hyæna* in 1885, 1886, 1887, and 1888. H, Hilbre Island; P, Puffin Island; R, Ramsey; D, Douglas; E, Port Erin; C, the Calf.

was, however, met with; and there was nothing specially noteworthy amongst the animals dredged, so far as could be seen at the time.

It had been intended to anchor for the night in Douglas Bay, but during the dredging and trawling the vessel had drifted so far out of her course that when evening came it was found advisable to run for Ramsey. Here half the party went on shore for the night, the rest staying on board for the electric light experiments which will be described further on.

On the following morning an early start for the south was made, and the rest of the party was picked up at Douglas, and then the work of the day commenced. The *Hyæna* steamed slowly round the east and south coasts of the island to Port Erin, dredging and tow-netting at intervals, with very good results. When a stop was made for collecting, the fullest advantage was taken of it. The sounding-line and deep-sea thermometer were over amidships, and two dredges, a large bottom tow-net and one or more surface tow-nets, were put out astern. The deep tow-net, devised and worked by Mr. W. S. McMillan, was so weighted and buoyed as to work steadily at a