On the Effect of Lightning-Stroke on Trees.

BY

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With Plates VI. and VII.

There is a widespread popular belief that certain trees are less liable than others to be struck by lightning, and that during a thunderstorm it is quite safe to stand under a beech, for example, while the danger under a resinous tree or an oak is respectively fifteen and fifty times greater. Scattered throughout literature are many descriptions of the damage done by lightning to single trees and also to groups of trees, but these are confined almost without exception to the external appearance of the lightning-struck tree ; the internal damage caused by lightning has passed without notice.

In the year 1892 Professor Bayley Balfour exhibited and described to the Botanical Society of Edinburgh sections of the stem of a lightning-struck oak (*Quercus Robur*, Linn.), which grew in the woods of Methven Castle, Perthshire. One of the specimens exhibited is shown in Plate VI. If this figure be compared with Plate VII., which shows the damage caused to a tree of *Q. Ilex*, and which will be more specially referred to later on, it will be seen that the damage in both cases is the same.

In the course of the summer of 1896 the late Professor Robert Hartig of Munich* carried out a series of observations on the

* R. Hartig, Untersuchungen über Blitzschläge in Waldbäumen, in Forstl-Naturw. Zeitschr. VI (1897), Hefte 3, 4, 5 ; Id., Neue Beobachtungen uber Blitzbeschadigungen der Waldbäume, in Centralblatt für d. gesammte Forstwesen, August and September, 1899 ; Id., Schädliche Wirkungen des Blitzschlages, Lehrbuch der Pflanzenkrankheiten, 3rd ed., 1900.

internal effect of lightning on trees. The results were published by him as a first contribution to our knowledge of the subject, the facts being too isolated to allow of his drawing a clear picture of the whole phenomenon, and further exact investigation being required before a satisfactory explanation can be given of the various effects of lightning on the same tree at different times.

Hartig has examined, figured, and described the internal effect of lightning on the following trees:—spruce, silver fir, larch, scots pine, beech, oak, maple, ash.

Almost all of the damage done by lightning to those trees occurred in the living tissue of the bark and in the young immature portion of the youngest annual ring, and it consisted in the destruction of the protoplasm of the tissues. There are several conditions which modify the ultimate effect of lightning on trees, such as the strength of the discharge; the thickness of the bark it has to penetrate; and also whether the bark is wet or dry. Very strong discharges may rive the wood-body of the tree into splinters; while weaker discharges may cause splits or fissures in the wood-body which are not visible from the exterior. If the path is confined to one side, the result is that the sap-wood is more or less splintered, and may be thrown in long strips as far as a hundred yards from the tree. Weaker shocks do not cause very great damage, but produce peculiar and diverse lightning-tracks within or upon the stem, and these have remained undescribed as yet to a great extent.

In order to understand the phenomena properly it is necessary to know, in the first place, the conductivity of different parts of the tree.

Trees with thin bark, for example silver fir, show very peculiar *lightning-tissue*—by which is meant protoplasmic tissue which has been traversed and killed by lightning—in the outer rind. It frequently occurs as small roundish patches, either isolated or connected by zigzag lines, and these patches ultimately become cut off from the living bark by cork-layers.

If the tree has a thick covering of dead bark, then the lightning must force its way through this bad conducting tissue to reach the interior.

A distinction must be made between the conducting power of the several layers of the living bark. The middle and outer layers, which are poor in fatty material, conduct well ; the innermost (youngest) layer, including the cambium, which is rich in protoplasmic content and contains as a rule much fat, conducts badly. The innermost layer of the living bark is thus protected and may remain untouched, even when the middle and outer layers are partially or completely killed. In very strong discharges the electricity may also pass here and there through the cambium, so that a lightning-wound is made which may be ultimately closed by occlusion, in which case a lightning-track remains visible in the wood-body.

The best conducting tissue in the whole tree appears to be the young wood which is found in the stem from the time of the beginning of vegetative activity in spring until August, and represents the as yet unlignified portion of the year ring. It is very rich in water and contains very little air. The protoplasm lines the cell-walls as a thin layer, and there are only traces of fatty oils present. It has been proved experimentally that this protoplasmic layer is a good conductor, but it may be killed if the current is sufficiently strong. If the lighning-track has been in the young wood the cell-walls remain unlignified, and they are subsequently crushed together by the later formed tissue. In deciduous trees lightning-tissue in the wood is indicated by this collapse of the cells.

The alburnum being rich in water conducts the current better than does the duramen, but not nearly so well as the young wood and bark. At the same time the air-content of the sap-wood and of the splint-wood influences the conductivity of each. The heart-wood of conifers, which contains no liquid water, is the worst conductor of all.

In the Royal Botanic Garden, Edinburgh, an evergreen oak, *Q. Ilex*, stood for many years on the east side of the Palm House. Outwardly it showed very little sign of having been struck by lightning. There were here and there a few short furrows visible on the outside as they are shown upon the photograph (Plate VII.). The tree was so damaged by the gale of November, 1901, when H.M.S. Active was wrecked at Granton, that it was cut down. When the stem was sawn across, several well-marked concentric rings were seen, which proved on subsequent examination to be zones of lightning-tissue (Plate

VII.). The tree had been evidently struck by lightning on several occasions with a lapse of a few years between each stroke.

Along the fissures on the top and left-hand side (Plate VII.) the cambium had been killed in a narrow band and was in process of occlusion. The large split below was caused by subsequent shrinkage in drying, and shows well how the wood has split along a radial line of weakness, where on two separate occasions the cambium had been killed and the injury thereafter occluded. The concentric zones of lightning-tissue consists of parenchyma-cells only, on each side normal wood-elements occur. The cells of the medullary rays seem to undergo no change, but pass uninterrupted through the bands of lightning-parenchyma. There are three complete rings at fairly regular intervals passing from the centre outwards, the last complete ring is, however, in reality double, there being as it were a ring of normal wood bounded on each side by a parenchyma-band, and that is why this ring appears to be broader than the others.

The tree was 61 years old when cut down in 1901. The last complete lightning-zone was formed fourteen years before felling, that is to say when the tree was in its forty-seventh year; the preceding one when the tree was in its forty-sixth year; the third one when the tree was in its thirtieth year; the innermost zone when the tree was in its sixteenth year. Therefore the complete zones of lightning-tissue were formed respectively in 1887, 1886, 1870, 1856. The first time the tree was struck in 1856 the cambium seems to have escaped uninjured, but on the three subsequent occasions the cambium was killed in a very narrow strip always in the same radial line, as is shown by the occlusions. Between the bark and the zone formed in 1887 there may be seen in the Figure what appears to be another complete ring, but it is in reality made up of several parts all of which were formed in 1898, or four years before the tree was cut down. In these later shocks the cambium has suffered in one or two places, as is evidenced by the partially-formed occlusions.

As regards the liability of certain trees to lightning-stroke, Hartig states that no tree is immune, and as a result of his investigations he came to the conclusion that lightning will select one species quite as readily as another. He also found that the beech was struck quite as frequently as any other species. At the same time he points out that in some places one sees certain species more frequently struck than others, for example, in the Riviera—the eucalyptus; in Germany—the oak and pyramid poplar; and he explains this by the fact that these are the tallest trees in the neighbourhood.

The numerous statistical records have no doubt been collected with the greatest possible care, but Hartig points out how unreliable they must be, as it is very easy to confound the damage done by lightning with that due to other causes and *vice versâ*. In fact, he states that he himself would formerly have recognised a very small percentage of those trees which as a result of his investigations he was able to prove had been struck by lightning.

Lightning usually strikes the under part of the crown, the stem, or the larger branches. The crown remains healthy after the stroke for a time, but dies away subsequently when the stem has become dry. It is seldom that the top or stronger branches are knocked off by lightning.

The root-system does not seem to be ever damaged by lightning, or at most slight traces are left by the current, on some of the stronger side roots.

Only dead or dry parts of the tree can be set on fire by lightning.

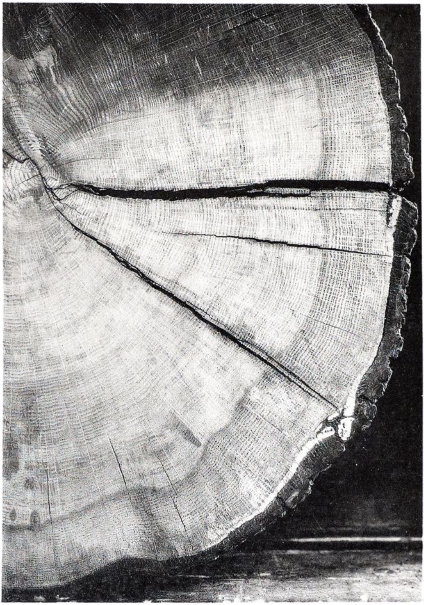
Hartig states that he never observed in the whole of his investigations any cells ruptured or torn by the formation of steam as might happen if the heating by the electric current was very great. The cells collapse and shrink up, but are never torn.

The whole phenomenon is a complex one, and notwithstanding Hartig's brilliant work there yet remains a wide field of investigation to be covered before we can satisfactorily explain all the effects of lightning on trees.

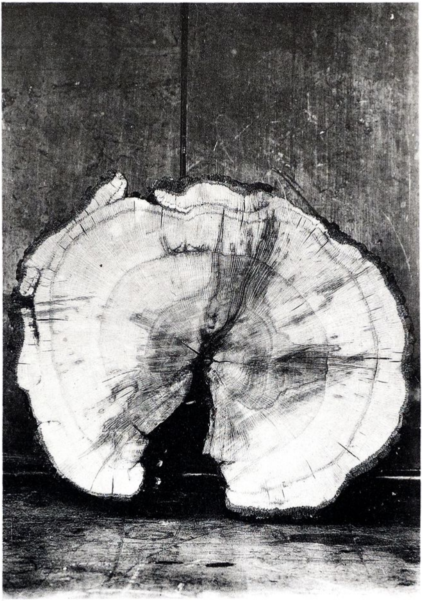
Explanation of the Plates VI. and VII.

FIG. 1.—Portion of stem of lightning-struck oak (*Quercus Robur*) from Methven Castle, Perthshire. Seen in transverse section.

FIG. 2.—Portion of stem of lightning-struck oak (*Quercus Ilex*) from the Royal Botanic Garden, Edinburgh. Seen in transverse section.



Lightning-struck Quercus Robur, from Methven Castle, Perthshire.



Transverse section of Quercus Ilex. L., photographed in dry condition, showing numerous lightning marks, also old and recent occlusions of lightning wounds.