that the water is able to pass the air-bubbles and surface tension films in the vessels, and yet the films are able to exert a back pressure increasing the resistance to flow. Further research must determine whether the explanation given is a true one, or whether unknown factors enter into play in the vessels.

When the walls of the vessels dry, or become covered internally over the whole or parts of their length by films of oily or similar substances, a true Jamin's chain may be set up in the vessel (Fig. 10). This, when once formed, is difficult to remove and interposes a relatively enormous resistance to flow when the vessel is narrow and the air-bubbles numerous. Even then, however, the presence of longitudinal pores containing water and longer than the air-bubbles may allow water to pass slowly even when the films appear to be adherent to the internal wall. The air in dry wood vessels always tends to break into shorter or longer bubbles when the wood is soaked in water, so that the normal conductivity can only be restored by forcing in water under such pressure as either to break the adhesion of the surface tension films to the walls of the wood vessels, or to render their attachment more labile. Naturally the conductivity restored in this way will be rapidly lost again if the wood is allowed to become depleted of water, and even if the supply is maintained by suction, the presence of any films of oily or impermeable material on the interior of the vessels will tend along with the increasing air-bubbles to produce an ordinary high resistance Jamin's chain. The latter involves an interrupted column of water, rapid upward flow requiring a movement of the entire series of air-bubbles and water-columns, which is impossible in vessels with imperforate partitions across them.

On the other hand, the valvular type of Jamin's chain with a peripheral adhesion film of water, allows local feeble pumping actions to be maintained from point to point in a staircase fashion. The least resistance to flow is shown when the vessels are filled with water, and continuous water-columns may support a tension of over 200 atmospheres in the absence of air¹. The transpiring leaves cannot exert the tensions required even momentarily in the wood vessels of the tallest trees (150 metres), since these are very much greater than is usually supposed².

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ON ENDOPHYTIC ADAPTATION SHOWN BY ERYSIPIHE GRAMINIS, DC., UNDER CULTURAL CONDITIONS³.—In recent papers by the author the fact has been pointed out that certain species of the *Erysiphaceae* are able, under cultural conditions, to infect their host-plants vigorously when their conidia or ascospores are sown on the cells of the internal tissues exposed by means of a wound, although the fungi in question are confined normally to the external surface of the epidermal cells.

The present paper gives the results of investigations carried out in the laboratory of Professor Marshall Ward at Cambridge, with the object of ascertaining the details

¹ Berthelot, Ann. de Chimie, xxx, 1852.

² Ewart, loc. cit., p. 55.

³ Abstract of a paper read before the Royal Society on April 6, 1905.

of growth of the fungus under these abnormal conditions, and of discovering to what extent the hyphae penetrated into the intercellular spaces of the internal tissues, and whether haustoria (normal or otherwise) were produced by these hyphae.

A rapid survey is first made of our present knowledge of the mycelial characteristics of the *Erysiphaceae* in relation to their parasitic habit. The species of the *Erysiphaceae* were regarded since De Bary's time as strict ectoparasites, until in 1899 Palla discovered the semi-endophytic habit of the genus *Phyllactinia*. With this exception the species of the *Erysiphaceae*, so far as they have been investigated, have been found to be strictly ectoparasitic in habit, the hyphae of the mycelium being confined to the external surface of the epidermal cells (never gaining access to the intercellular spaces of the internal tissues), and merely sending haustoria either into the epidermal cells alone, or, in the case of one species, into the sub-epidermal cells as well.

The experiments carried out and the methods employed in the present investigations are then described. The fungus used was the conidial stage of *Erysiphe graminis*, DC., a strict ectoparasite under normal circumstances. Young leaves of oats and barley were cut off from seedling plants, and a minute piece of tissue was cut out with a sharp razor from the upper surface of the leaf. In this operation the upper epidermis was removed, and often a considerable amount of the mesophyll also, so that in inoculation the conidia were sown on the sub-epidermal or deeper layers of the exposed mesophyll, or even on the internal surface of the lower epidermis. After inoculation, the leaves were placed on damp blotting-paper in a Petri dish. By the sixth to eighth day vigorous infection had nearly always resulted, the surface of the wound bearing patches of clustered conidiophores. The leaves were then fixed in Flemming's fluid or in chromacetic, and subsequently embedded in paraffin, microtomed, and stained with Diamant fuchsin and Lichtgrün.

It was found on examining such wounded leaves that the fungus had invaded the internal tissues to a remarkable extent. Where the mesophyll-cells remaining uninjured were several layers deep, the hyphae had penetrated inwards, winding through the intercellular spaces as far as the internal surface of the lower epidermis. Haustoria were sent into the cells of the superficial layer of the mesophyll by the hyphae creeping on the surface of the wound, and into all the deeper layers of the mesophyll by the hyphae running in the intercellular spaces. The cells of the lower epidermis were also attacked, the internal wall having been penetrated. The sheath-cells of the vascular bundles were much invaded by very vigorous haustoria. The haustoria formed in the cells of the internal tissues resemble in every way those which occur normally in the epidermal cells.

The hyphae enclosed in intercellular spaces, either just below the surface of the wound or deep down in the internal tissues, struggle to produce conidiophores. The respiratory cavities over the stomata of the lower epidermis were in a great number of cases full of vigorous hyphae producing young conidiophores. When the intercellular space, where the young conidiophore was produced, was shut off from the open air by only a thin membrane consisting of the walls of collapsed mesophyll-cells, the young conidiophore growing upwards, sometimes proved able to break through it and continue its growth. The direction of growth of the young

conidiophores produced in the respiratory cavities and other intercellular spaces was usually vertical, and towards the surface of the wound. Examples were observed, however, of young conidiophores growing horizontally in intercellular spaces between the mesophyll-cells, or, in a few cases, vertically, with the apex of the conidiophore directed away from the surface of the wound.

In several cases hyphae had penetrated laterally, in a direction parallel to the surface of the leaf, from the edge of the wound, and occurred in the intercellular spaces in the middle of the mesophyll, at places where all the tissues, including the epidermis above and below, were uninjured. In such places both haustoria and young conidiophores were produced.

Figures are given illustrating the details of the growth of the hyphae in the interior of the leaf, and the production of haustoria and intercellular conidiophores.

The author, reviewing the results of the investigations, points out that they afford proof that *E. graminis* is not, as perhaps might have been expected, so highly specialized as an ectoparasite as to be necessarily restricted for its food-supply to cells of the epidermis; but shows itself capable of immediate adaptation to conditions closely resembling those obtaining in endophytism.

This fact suggests the possibility that under some circumstances the mycelial hyphae of species of the *Erysiphaceae* which are normally ectoparasites may penetrate into the internal tissues of their host-plants exposed through wounds caused in nature by the attacks of animals or by physical agency. It is pointed out, however, that the successful entry of the hyphae might be prevented, either by the drying up of the superficial layers of cells, or by the healing processes shown by many actively growing leaves.

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KEW.

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<https://doi.org/10.1093/oxfordjournals.aob.a089012>.

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