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THE RÔLE OF ALGAL GROWTH IN THE COLONIZATION OF NEW GROUND AND IN THE DETERMINATION OF SCENERY.

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THE study of plant-ecology, *i.e.* of the relation between plant and habitat, between a piece of vegetation and the prevalent conditions in the area in which it is developed, is making rapid strides at the present day, and, as our knowledge in this respect increases, we are beginning to inquire more carefully into the methods of colonization of new ground by plants. The study is an important one, not only in its scientific aspects, but also from the economic and geographical point of view, and a brief consideration of some of the early stages in colonization may not be without interest.

In many cases new ground may from the very first be in a suitable condition for the growth of higher plants (Vascular Cryptogams and Phanerogams), as, for instance, in the case of a dried river-bed,* or the alluvial deposit laid down in the lower stretches of a large river. Here the ground afforded for colonization is both finely divided and impregnated with a certain amount of organic substance (humus), so that a soil is present at the outset. In other cases, however, the ground is not ready for immediate colonization, either requiring disintegration for the production of soil or formation of a certain amount of humus to render the soil fertile, and to enable it to retain a sufficient amount of water. Disintegration is, of course, always a primary necessity before any higher vegetation can make its appearance on a bare rock-surface, whilst frequently the formation of a certain quantity of humus is obligatory for the development of anything more than a very meagre growth of plants.

Not at all uncommonly various terrestrial or semi-aquatic Algæ play a very important part in preparing the way for higher forms of plants, serving either both as disintegrators and humus-producers, or merely in the latter capacity. Their agency is by far the most evident in the tropics, although Algæ are commonly found to be active in much the same way (though not to so marked an extent) in our parts of the world. The observations I have to record are very incomplete, and I have no doubt that many more facts than I can produce will become evident in course of time. Since the essential phenomena are so much more obvious and more readily studied in the damp parts of the tropics, I may be excused if I commence my description by detailing certain observations made in Ceylon in the course of a study of its subaërial algal vegetation.†

It is, moreover, in the tropics that these subaërial Algæ often place a very decided stamp on the scenery of a district, a point which is well illustrated by Welwitsch's ‡ description of 'The Pedras Negras of Pungo Andongo in Angola.' These black

* M. C. Stopes, "The Colonization of a Dried River-bed," *New Phytologist*, vol. 2, 1903, pp. 186-192; cf. also Scott Elliot, "The Geographical Functions of Certain Water-plants in Chili," *Geo. Jour.*, vol. 27, 1906, pp. 451 *et seq.*; V. P. Jaeger, "Jetzt und Einst. Eine pflanzengeographische Skizze," 52 Jahresber. d. fürsterbischof. Gymnasiums am Coll. Borromalum z. Salzburg, 1900-01 (Salzburg, 1901), pp. 1-48.

† Cf. also Fritsch, "A General Consideration of the Subaërial and Freshwater Algal Flora of Ceylon," Part i., *Proc. Roy. Soc. London*, Series B, vol. 79, 1907, p. 197 *et seq.* (Sect. a of this paper deals with the subaërial algal flora.)

‡ Welwitsch, in *Journ. of Travel and Nat. Hist.*, vol. 1, 1868; also 'Apontamentos Phyto-Geographicos solve a flora da provincia de Angola, etc.,' *Annaes do Conselho Ultramarino*, Parte não off. Ser. 1, Dez. 1858, p. 533.

rocks owe their colour to the abundant growth of a subaërial Alga (*Scytonema Myochrous* (Dillw.), Ag. var. *chorographicum*, W. and G. S. West), which "during the rainy season generates and multiplies so rapidly that the upper portions of the mountains are covered with it in a very short time. . . . Soon after the hot season has set in, at the end of May, when the horizon above the Presidium is generally clear and bright, the black plantlets begin to discolour with the intense heat. They gradually become dry and brittle, until they peel off altogether by-and-by, after which the rocks lose their sombre black aspect, and reappear in their natural grey or grey-brownish colour before the succeeding spring." I am not aware of any other definite record testifying to the abundance of subaërial algal growth in the tropics.* In the case of the subtropical Azores, however, Bohlin† describes the occurrence of four terrestrial Algæ (*Chroolepus aureus*, *Zyggonium ericetorum*, *Glæocapsa Magma*, *Stigonema minutum*), "vivant sur le sol nu . . . en très grand nombre."

I did not see anything quite as striking as the growth, described by Welwitsch, in Ceylon, but similar phenomena on a less extensive scale are abundant enough. If the damp regions of Ceylon were robbed of their subaërial Algæ, an important characteristic of local scenery would be lost. Every wall, rock, tree-trunk, etc., bears a more or less dense sombre covering of algal growth, and the drier localities in the island (e.g. Hambantota, Anuradhapoorā) show us how different our surroundings look when the conditions (viz. insufficient moisture) do not admit of the development of such algal vegetation. On the other hand, wherever the rainfall becomes excessive (as at Labugama, with 166 inches), the subaërial Algæ form a thick covering on every conceivable object. The marked difference cannot fail to strike any one who is at all observant of his environment.

In our parts of the world we are accustomed to see exposed objects covered with a bright green powdery or filmy covering, which is due to green Algæ like *Pleurococcus* and *Hormidium*. In many cases this covering presents a yellowish-green colour, owing to an intermingling of fungal hyphæ with the Alga (an initial stage in Lichen-formation, cf. p. 543). We are so used to the presence of such a coating that the general influence it has in brightening up the scene is scarcely noticed, until we visit a neighbourhood in which for some reason or other it is not developed. But the algal growth found on similar substrata in the tropics is much more extensively developed, and consequently much more obvious, whilst a little careful study teaches us that it fulfils a much more important duty than it generally does in temperate regions, viz. that of preparing the ground for vegetation of a higher type.

The agency of algal growth in this respect has already been emphasized by Treub‡ in describing the recolonization of Krakatoa after the eruption of 1886. He describes how members of the Cyanophyceæ (*Tolypothrix*, *Anabæna*, *Symploca*, and *Lyngbya*) are the first forms to put in an appearance. In his words: "Il s'est trouvé que les cendres et la pierre ponce composant le sol de Krakatau, sont presque partout couvertes d'une mince couche de Cyanophycées. . . . De beaucoup la plus fréquent est le *Lyngbya Verbeekiana*; ensuite vient le *Lyngbya minutissima*. . . . Grâce à ces six espèces d'algues et à leurs gaines vides . . . le sol aride de Krakatau est recouvert d'une mince couche gélatineuse et hygroscopique. . . . Les algues

* See, however, Warburg, 'Ökologische Pflanzengeographie,' German edition (Berlin, 1896), p. 215; cf. also Fritsch, "The Subaërial and Freshwater Algal Flora of the Tropics," *Annals of Botany*, vol. 21, No. 82, April, 1907, p. 237 *et seq.* (in which all the data regarding extent and composition of tropical subaërial growth are considered).

† Bohlin, "Etude sur la Flore Algologique d'eau douce des Açores," *Bih. K. Sv. Vet.-Ak. Handl.*, vol. 27, Afd. III. No. 1, pp. 12, 13, 50, 51.

‡ Treub, "Notice sur la Nouvelle Flore de Krakatau," *Ann. Jard. bot. Buitenzorg*, vol. 7, 1888, p. 213; see also Penzig, *loc. cit.*, vol. 18, 1902, pp. 92 *et seq.*

préparent le terrain aux Fougères, en quelque sorte comme celles-ci le feront à leur tour aux Phanérogames." Observations of an analogous kind were made in Ceylon, and are dealt with below.

Apart from its exceptional luxuriance, which is especially noticeable in hot regions with a high rainfall, the subaërial algal growth of Ceylon, and probably that of the tropics generally,* differs from that of our parts in its composition. It is not, as a rule, bright green, but is dark in colour; it is by no means always developed as a powdery or filmy covering, but more commonly as a relatively thick tangled or tufted mass, forming a carpet-like coating on the substratum. The difference in colour is due to the fact that green Algæ are as good as wanting in the subaërial vegetation, which is composed almost entirely of a large number of different representatives of the so-called blue-green Algæ (Cyanophyceæ, Myxophyceæ). This group, which includes unicellular, colonial, and filamentous forms, is not quite unimportant even in our parts, some of the bright blue-green, and especially the dark blue-green coatings, frequently seen on rocks, pavements, etc., being due to members of this group. But the large majority of the Cyanophyceæ require a high temperature for successful growth, being, for instance, amongst the only plants which are found in the warmer waters of hot springs (Carlsbad, Yellowstone Park, Iceland, etc.). Nor is it difficult elsewhere to convince one's self that a high temperature is a primary necessity for the rich development of these algal forms; any damp hothouse furnishes abundant proof (e.g. the *Nepenthes*-house† in the Royal Botanic Gardens at Kew, in which a number of the photographs illustrating this paper were taken). The Cyanophyceæ show many peculiar characters (e.g. the curious cytology, the heterocysts, the hormogonia, etc.), which seem to be archaic, and there seems also good reason to believe that numerous forms of this or similar groups existed in past ages of the world's history, though of necessity the fossil records are rather meagre. This being so, we need not wonder at the excessive development of this group in the moist tropics, for there we have conditions which probably come nearest to those obtaining in the earlier epochs. Certain members of the group have, indeed, learnt to suit themselves to the lower temperature and smaller humidity of temperate regions, but the evident paucity of most of them, both in number of individuals and in extent of development, points to the prevalent conditions not being the most suitable. In the tropics, however, we see this group in its natural habitat, and it seems very probable that many dubious points about it will be settled by studies carried on in those regions.

High temperature and a damp atmosphere are no doubt essential for the development of the luxurious algal covering seen in many parts of the lowlands of Ceylon; but these two factors are not the only ones to account for the abundant growth of blue-green Algæ, and the practical lack of subaërial green forms. The absence of the latter is due to the operation of a third factor—the light. It is a familiar fact that the chlorophyll of plants gets decomposed by light above a certain degree of intensity, and there can be no doubt that in an exposed situation in the tropics the light is too intense for simple green forms without adequate arrangements for the protection of their chlorophyll. Indeed, even Mosses and Liverworts, which form a luxuriant vegetation on the tree-trunks in the shady jungles, etc., are very scarce in all exposed situations. The blue-green Algæ, however, are better equipped. In their

* See Fritsch, in *Annals of Botany*, April, 1907, p. 238 *et seq.* The observations of Welwitsch, Bohlin, and Treub quoted in the preceding paragraphs point to the great importance of blue-green forms in every case.

† Cf. Fritsch, Algæ, in "The Wild Fauna and Flora of the Royal Botanic Gardens, Kew," 'Bull. Misc. Inform. Roy. Bot. Gards., Kew,' Addit. Series V., 1906, pp. 187 *et seq.*

cells the chlorophyll is accompanied by a blue or otherwise coloured pigment (phycocyanin), the two being so closely intermingled that even high powers of the microscope do not admit of their distinction. The resulting colour is in all shades from bright blue to blue-green or almost black; brown is also no uncommon tint. The additional colouring-matter certainly acts as a screen to the chlorophyll in these Cyanophyceæ, and thus enables them to exist in the intense light of exposed tropical habitats, which is fatal to the existence of the lower green forms. It seems very probable that the diverse shades of pigmentation observed in the blue-green group may be connected with the diverse types of illumination in different habitats. The cells of the Cyanophyceæ are, moreover, generally provided with thick mucilaginous sheaths, which are often highly coloured, and then no doubt serve as a further screen to the chlorophyll. Before leaving the discussion of the part played by the light in determining the essential character of tropical subaërial algal growth, we may notice that there is only one genus of the green Algæ that occurs abundantly in the latter. This is a filamentous form—*Trentepohlia* (*Chroolepus*), species of which are not uncommon in temperate regions, especially in mountainous districts (where there is strong insolation). They are very common in Ceylon, however, and form bright orange-red tufts arising amidst the dark Cyanophyceous growth and constituting a frequently agreeable interruption to its monotony. There is abundant evidence to show that species of *Trentepohlia* also play a great part in other tropical regions.* The orange-red colour is no doubt the secret of the success of this form; † the cell-sap contains a yellowish-red oil (hæmatochrome), which forms a mask to the chlorophyll, and, like the phycocyanin in the blue-green cell, protects it from the harmful action of the light. The colour of one and the same species of *Trentepohlia* varies according to the habitat; in exposed positions it is deep orange-red, in protected localities almost pure green. The masking colouring-matter thus appears to be developed under the influence of intense light only. The species of *Trentepohlia* are a particularly striking feature on the trunks of the coconut trees in the plantations near the seashore and on roadside embankments. They are also very common in the uplands of Ceylon.

There is yet another factor operating in the tropics which may lead to the suppression of the growth of the simpler green forms, whilst the blue-green element appears well equipped to withstand it. I refer to the occasional occurrence of periods of desiccation, which, in all probability, come on much more rapidly, and are much more intense in their effect, than they are in our parts. The existence of gelatinous sheaths round the cells of the Cyanophyceæ already referred to above is, no doubt, of immense importance from this point of view, experiment having shown that such forms are able to withstand very prolonged desiccation without coming to harm. In many of the blue-green Algæ these sheaths are tough and hard (e.g. *Lyngbya*, *Tolypothrix*, *Scytonema*, etc.), whilst in others they are highly mucilaginous and slimy (e.g. *Nostoc*, *Aphanocapsa*, *Glaucocapsa*, etc.). The former seem more suited for extremes such as obtain in the lowlands of Ceylon than the latter, and it is interesting to note, in this connection, that the slimy forms are very much more abundant in the uplands (e.g. at Nuwara Eliya and Hakgalla at a height of 6000 feet and more). There they produce a scenic effect which is in striking contrast to the lowlands. The tree-trunks are frequently covered for several inches

* In certain parts of the tropics, however, species of *Trentepohlia* seem to be wanting (e.g. in the Sandwich islands; see Lemmermann, in Engler's *Bot. Jahrb.*, vol. 34, 1905, p. 609).

† It may be noted that *Zygnema ericetorum*, which is another green Alga, playing a somewhat similar part in the subaërial vegetation (cf. Bohlin, *loc. cit.*, pp. 50, 51), also has a protective pigment in its cells in the form of the violet phycoporphyrin.

with these mucilaginous masses, which at first recall the resinous exudations often to be seen on wounded trees. At other points similar jelly-like diffuent masses project from amidst the dense growth of Mosses covering the tree-trunks. The relative humidity of the air is much greater in these uplands, and that probably accounts for the very marked difference in the character of the subaërial algal growth. In fact, a mere superficial observation of the algal flora could not long leave one in doubt as to the altitude of any locality in Ceylon. Compare, for instance, the embankment alongside of Lady Horton's walk at Nuwara Eliya with a similar embankment or wall at Colombo or Kalutara. At the time of my visit the former was covered with a thin gelatinous sheet composed mainly of a species of *Schizothrix* (with highly coloured orange-red diffuent sheaths enclosing narrow filaments; apparently *S. Lamyi*, Gomont) with various unicellular blue-green forms (Chroococcaceæ) intermingled, the colouring varying very much at different points, but being prevalently reddish. In the damp lowlands, on the other hand, a similar substratum would either bear a thin filmy growth of bright blue-green *Oscillaria* or of some Chroococcaceous species, or be covered by a sombre tangled or tufted coating.

I must not omit to mention that in the damp tropics subaërial algal growth is not confined to the tree-trunks, etc., but that some of these forms even manage to settle down on the foliage of the luxuriant higher vegetation. One not uncommonly finds various blue-green forms (and species of *Trentepohlia*) as epiphytes on the leaves, although this only obtains in very moist regions. The *Nepenthes*-house at Kew again furnishes good examples, and the photographs on Plate II. (A and B) are taken of leaves from this house. In addition to these more casual epiphytes, a number of genera of the Green Algæ (e.g. *Mycoidea*, *Cephaleuros*) have become highly specialized to life as leaf-epiphytes. They are disc-like forms firmly adherent to the surface of the leaf, and, like *Trentepohlia*, have their chlorophyll protected by the presence of a reddish-brown pigment in the cell-sap.

The preceding facts regarding the scenic effect of Cyanophyceous growth in the tropics become apparent without much detailed study, but a little careful investigation carries one much further. In the first place we should find that the blue-green subaërial element varies considerably in its mode of growth, so that it becomes possible to discriminate between four distinct types; and these types are noticed to succeed one another in a more or less regular manner in the colonization of new ground. The four methods of growth may be distinguished according to their general aspect as adhesive, tangled, tufted, and stratified. The adhesive type (Plate I., A and B) is the simplest and commonest, and is constituted by those forms, which grow as an encrusting film or as a gelatinous mass more or less firmly adherent to the substratum. The most abundant forms showing this type of growth are species of the gelatinous genera *Aphanocapsa*, *Glæocapsa*, *Nostoc*, and of the two filamentous forms *Oscillaria* and *Lyngbya* (especially the section *Phormidium*); typical adhesive films are generally due to the two genera last named. As a rule such films do not attain any considerable thickness. They are probably too compact to allow of the inward diffusion of the necessary amount of air for respiratory purposes, and consequently, where they attain any noticeable development (as in *Phormidium*), the inner portions of the lamellæ are composed of dead filaments. Although this explanation is hypothetical, it affords a satisfactory basis for an understanding of the adhesive and tangled types.

In the tangled type of growth (exhibited by species of *Tolypothrix*, *Hapalosiphon*, *Seytonema*, etc.), which is widely distributed in the moist lowlands of Ceylon, and is not uncommon though rarer in the uplands, we have the algal filaments entangled and interwoven with one another, so as to form wefts of varying degrees of compactness

A

B

PHOTOGRAPHS OF ADHESIVE GROWTH OF SUBAËRIAL ALGÆ ON WALLS OF HOT-
HOUSES AT KEW.

C

D

TANGLED AND TUFTED GROWTH OF SUBAËRIAL ALGÆ ON WALLS OF *NEPENTHES*-
HOUSE AT KEW. THE LEFT-HAND PHOTOGRAPH SHOWS COLONIZATION OF
THE ALGAL SURFACE BY YOUNG FERNS.

PLATE I.

(Plate I., C; Plate II., C; Fig. 1, the lower part). This arrangement, of course, allows of the retention of a considerable amount of air between the filaments, and hence from the above point of view (viz. respiration) is much more advantageous than an adhesive growth. The air between the filaments would probably get dislodged by every fall of rain, and, as a consequence, it is often in no way manifest. But certain forms seem to take special precautions to prevent the frequent dislodgement of the air by growing in well-protected situations. Such forms, owing to the associated air, which, besides occupying the interspaces of the tangle, also covers its whole surface, are bluish-grey or bluish in colour, and often have a silvery appearance. They constitute quite a characteristic feature of the scenery in some parts of Ceylon. Thus, on the clay embankments round Peradeniya, I commonly found a brick-coloured or brownish-red tufted growth of *Schizothrix* in all exposed situations, whilst, wherever the embankment was more or less protected by an overhanging ledge, there was a dense tangled growth of *Stigonema* (near *St. minutum*, Hass.) exhibiting this characteristic film of air. Similarly, on the black rock which overshadows Dambulla, it is a species of *Tolypothrix* which presents this curious biological feature, being more or less restricted to patches protected by overhanging rocks. It forms greenish or bluish-green or almost white coverings on the rock-surface, having the appearance of fungal growth, the varying colour no doubt depending on the amount of associated air. The algal forms exhibiting this curious phenomenon, however, always show a peculiar incrustation on their sheath, which in one case was due to carbonate of lime, whilst in others it was unaffected by acids, and its nature is still unknown to me. One feels inclined to associate these incrustations with the retention of air, but what the relation between the two is, I am at present unable to say. In any case the air is held very tenaciously, for it has not been in any way displaced by the preserving fluid, which has now surrounded the material for three years.

Although probably advantageous from the respiratory point of view, tangled growth is not favourable to absorption of atmospheric moisture, and consequently we find that, wherever the air is humid, tangled growth sooner or later passes over into the third type—tufted growth (Plate I., D).^{*} In a tangle only occasional filaments stand out to act as capillary threads for the absorption of water-vapour from the air, and consequently this type of growth requires a wet substratum. On a dry substratum water-provision cannot be adequate, and tangled growth will be unsuccessful. Moreover, if the atmosphere is damp, the water-vapour in the air will produce a hydrotropic stimulus, and a number of threads of the tangle will grow out vertically away from the substratum. These threads will eagerly take up moisture, and will exert a strong hydrotropic attraction on neighbouring threads of the tangle. The latter will wind their way round the already outstanding threads, so that a thick wick-like tuft is developed (cf. Fig. 1). And thus the commencement of tufted growth is established. One very often finds thick tufted growth arising from a slight basal tangle of the same species, although sometimes the basal tangle is quite indistinguishable. From the preceding remarks it will have been gathered that certain Cyanophyceæ may exhibit either tangled or tufted growth according to the external conditions; this is the case with species of the genera *Tolypothrix*, *Scytonema*, *Stigonema*, etc. In other forms, however (*Symploca*, *Schizothrix*), the tufted habit is the prevalent one, and most species of these genera do not exhibit much tangled growth, although in all cases there is probably a slight tangle at first. Such purely tufted forms generally settle down on a tangle of some other species (e.g. on a *Tolypothrix* or *Scytonema*, cf. Fig. 1).

Tufted growth, although at a distance indistinguishable from a tangle, gives

^{*} Cf. also Fritsch, *Proc. Roy. Soc. London*, Ser. B, vol. 79, 1907, Fig. 1, p. 209.

a characteristic stamp when viewed from near at hand. When the tufts are closely placed (as in *Schizothrix*, *Tolypothrix*, etc.) we obtain a velvety appearance, recalling a thick and soft carpet, and such growth in the wet season is always saturated with water. In some species of *Symploca*, on the other hand, each tuft appears quite distinct from its neighbour, and the appearance is in striking contrast to that presented by the dense growth of such forms as *Schizothrix*. I am unable to say whether the varying types of tufted growth are due to conditions presented by the environment. But tufted growth in itself is certainly only developed under the conditions indicated in the preceding paragraph; in all dry localities (e.g. Anuradhapoora, Negombo), especially if both air and substratum are dry, we get practically no tufted growth except in particularly sheltered positions, whilst the wetter the district the more abundant does such growth become. Tufted growth is, indeed, a natural consequence of the moist heat of the tropics so familiar to all.

The assumption of tangled growth is thus probably due to the needs of respiration, whilst the appearance of tufted growth depends on the necessity of obtaining a better supply of moisture. The fourth mode of growth, which we will call the stratified one, is really only tufted growth which has developed in a certain definite way. The Alga concerned in the cases which I observed was generally some species of *Tolypothrix* or *Scytonema*, but it seems probable that other genera of Cyanophyceæ may also assume this habit. In the stratified mode of growth the tufts are arranged in definite strata one above the other, the tufts in each tier projecting out slightly beyond the tier above and showing a more or less marked downward inclination (cf. Plate II., D.; also at a few points in Plate I., D.). It is not of very common occurrence, and is found mainly on upright walls or tree-trunks in shaded situations. Such stratified growth, however, when developed, usually forms huge coherent sheets, which, with some care, may be detached as a whole (the photograph on Plate II. is made from a small portion of such a one). The appearance is very characteristic, reminding one of the growth of some Mosses. The essential feature of this habit may be a result of the shaded habitat or of the special conditions of moisture. In such extensive tufted growth on a vertical surface the individual tufts would considerably overshadow one another, but by the growth of the Alga in stratified layers, with each tier projecting well out beyond the one above it, this evil is somewhat remedied. In some cases the projecting portions of the tufts are of a different (brighter) colour than the inner shaded parts, and this points to illumination being in some way concerned in producing stratified growth. At the same time, it also seems comprehensible that if a large extent of tufted growth develops, it is advantageous for it to be arranged in downwardly directed tiers, so that each tier may catch up any drops of moisture (from rain), which run off the surface of the one above. Stratified growth is found mainly on substrata which do not furnish much water themselves, and hence it depends to a great extent on the supply of water from the atmosphere. I should think, however, that illumination plays the more important part in determining the stratified habit.

We may now pass on to consider, in slightly greater detail than has been done as yet, the mode of succession of these different types of growth, and the way in which they prepare the ground for higher vegetation; a few more words may also be said on the habitats in which they are customarily found. In the first place, we may note that the only truly successful forms in the subaërial algal vegetation of the uplands are the highly mucilaginous adhesive species, briefly discussed on p. 543. Tufted and tangled growth is rare, being practically absent on tree-trunks, where the Bryophytes and Lichens are too strong for them. Rocks are often without any algal covering, but tangles are sometimes developed on such substrata.

In the lowlands the hard smooth bark of many trees forms an unsuitable substratum for anything but adhesive growth. But in the wet regions, where there are very heavy downpours of rain, adhesive forms will find a difficulty in settling down on exposed substrata owing to the scouring effect of such rainfall. This probably explains how it is that even in very damp districts in the lowlands tree-trunks are often almost destitute of an algal covering.* Should adhesive forms, however, obtain a foothold, they may ultimately make the substratum suitable for tangled or tufted growth, as is not uncommonly seen where there is some protection from the action of the rain. Decayed trunks, of course, afford a much better base, and vie with an embankment in the richness of the algal covering. On such soft substrata, and particularly on an embankment, there is often no adhesive growth at all, especially if the surface is at all rough and crumbly. Tangled growth is very successful here, and since it undoubtedly helps to bind the clay of an embankment together, it will strengthen the latter to resist the effects of rainfall. Smooth objects such as walls, rocks, and some kinds of embankments are invariably colonized by adhesive growth at first, and this gradually prepares the ground for other forms.

The colonization of large smooth rock-surfaces seems particularly interesting, and I will describe a few observations made on the rock leading up to the tank at Nalande. The first forms to obtain a foothold are red-coloured gelatinous species (belonging to the genera *Gleocapsa*, *Aphanocapsa*) of the adhesive type (small Lichens are also important); these occupy every little crevice in the rock, giving its surface quite a red, granular, speckled appearance at certain points. These places serve as a centre for the growth of *Phormidium* (*P. laminosum* (Ag.), Gom.), another adhesive form, which develops huge thin papery films covering large portions of the rock-surface, as well as for small tangles of other filamentous species (chiefly *Scytonema*), which at diverse points constituted a slippery covering on the rock, making its ascent a by no means easy matter. In some cases the tangle of *Scytonema* was developed directly on the *Phormidium* as a base, or the latter bore a tangled growth of *Tolypothrix* from which very definite tufts arose. These tufts here and there even showed signs of stratification. Here we, therefore, have an interesting succession of the different types of growth, and these diverse forms undoubtedly have a slow but sure disintegrating action on the rock. In dry weather they shrivel up more or less, thus becoming detached from the rock-surface, and at the time of my visit (towards the end of the dry season) there were numerous detached patches, each with a small amount of soil adhering to it, lying about on the surface of the rock. In this way the latter is gradually prepared for vegetation of a higher type, although at most points matters have not as yet got beyond the stage described.

The stages in the colonization of walls are also often easily followed up, and two cases of this kind, noticed at Trincomalie and Kurunegala in Ceylon, may be briefly referred to. The wall at Trincomalie was an ordinary whitewashed one,

* It may be pointed out, however, that the difficulties of colonization of a tree-trunk may vary very considerably with the nature of the bark. A furrowed bark must constitute a much more favourable substratum in most cases than a smooth one, and a great deal probably also depends on the absorptive capacity of the superficial layer of the bark for water. That the problem is not quite a simple one is shown by superficial observations on the distribution of *Pleurococcus* in our country. Thus, in a country lane not far from London, we have a more or less continuous row of roadside trees, consisting of pines and elms in almost equal numbers, with a few intermingled ashes. The trunks of the pines are completely destitute of algal covering, whilst a rich growth of *Pleurococcus* is found on most of the elms and ashes.

overshadowed by a luxuriant growth of trees, and was almost completely covered by a dense carpet of blue-green Algæ and Mosses, the former often growing in definite vertical lines corresponding to the drip of water from the trees above. Such dense algal growth is rather unusual in the dry northern half of Ceylon, and no doubt its exceptional occurrence in this case is to be accounted for by the sheltered situation of the habitat.* At the base of the dense tufts and tangles constituted by the main mass of the algal growth one could just detect remains of the adhesive forms (members of Chroococcaceæ), which had prepared the way for the subsequent vegetation. These were followed by a tangle of *Scytonema javanicum* (Kütz.), Born., which very soon, however, raised its filaments into tufts, and at many points along the wall these tufts showed a well-marked stratified arrangement. Here again we have all four forms of growth following in succession, but three of them are due to the same Alga (*S. javanicum*). At Kurunegala much the same was observed. At the base a tangle of dead filaments of a *Tolypothrix*, with an admixture of unicellular adhesive forms, probably the survivors of the first algal growth at these points. Above that, tangles of living filaments of the *Tolypothrix*, which in most places had passed over into a dense velvety covering composed of very uniform tufted growth. The latter had become colonized by a few small Mosses, which were being entwined by the filaments sent out by the basal tufts of *Tolypothrix*.† This is an exceedingly interesting relation, which was frequently met with, and requires a brief discussion. Small Mosses, or Liverworts, almost invariably settle down on the subaërial algal growth, as soon as the latter attains a certain degree of thickness, and may be seen as little bright green patches on the dark background formed by the Alga. These Mosses are always more or less saturated with water, and thus exert an attractive influence on the Alga below. Filaments grow out from the latter and wind their way round the Moss, and as their number increases the Moss of course tends to get smothered. Its only way of saving itself is to grow on in front, and thus escape the attacks of the Alga. The latter, however, slowly but surely follows up its advantage, and in this way a thick stratum of vegetable growth accumulates, forming a humus on which small ferns, etc., soon settle down. This process is probably of great importance in rapid colonization of a substratum. In some cases I have seen the same relation holding good between the isolated tufts of a *Symploca* and the basal tangle of a *Tolypothrix*, etc., on which it had settled down (Fig. 1), and here again the activity of the two forms no doubt leads to the accumulation of a considerable mass of algal substance in a relatively short space of time.

The arrangement of the algal growth on the wall at Trincomalie in definite vertical lines determined by the drops of moisture falling from the trees above is a common phenomenon, noticeable even on the tree-trunks, etc., in temperate regions, and particularly striking in some of the hothouses at Kew (cf. Plate I., B). The distribution of moisture, however, also determines other peculiarities of the mode of growth of the subaërial Algæ. In the case of rugged vertical surfaces (such as a rough wall) moisture, of course, collects most readily around the outstanding points, and these are the first to become colonized by algal growth. In sheltered situations this state of affairs often obtains for a considerable length of time before the whole surface becomes overgrown. On the other hand, if the rough surface be horizontal, we very frequently find small gelatinous colonies of one or more

* It is not quite impossible that the richness of this growth is also partially due to the neighbourhood of the sea. The presence of such a huge mass of water must lead to greater humidity of the air.

† Cf. Fritsch, *loc. cit.*, fig. 2.

unicellular forms settling down mainly in the excavations which receive most water (cf. what was said above about the rock at Nalande). These colonies are often not much larger than a pin's head, and in the case of a rock are so firmly lodged in the small hollows that they are not easy to remove. They form centres from which the growth extends outwards. The growth of epiphyllous Cyanophyceæ (see Plate II., A and B) also furnishes frequent examples of the importance of moisture for the growth of these forms. Thus in the case of the leaf of *Anthurium radicans* shown on Plate II., A, the Alga is evidently crowded into the lower portions

FIG. 1.—STRUGGLE FOR DOMINANCE BETWEEN A *TOLYPOTHRIX* AND *SYMPLOCA*
($\times 85$ ABOUT).

At the base is a tangle of *Tolypothrix*, on which tufts of a *Symploca* (the dark shaded mass) have settled down. Numerous filaments arising from the basal tangle of *Tolypothrix* are winding their way round the *Symploca* tufts, almost completely covering them in some places. Note the way in which the tufts of the *Symploca* branch, the branches frequently contributing to the increase of neighbouring tufts. In the *Tolypothrix* only the sheaths of the filaments are shown.

(i.e. those nearest the drip-tip) of the channels formed by the deeply furrowed veins. These are the parts of the leaf-surface which are continually draining off the excess of moisture, and the latter comes to benefit the Alga concerned.

As an outcome of what has been described in the preceding pages we see that subaërial algal growth in the tropics gives its own peculiar character to the scenery in many regions, and probably plays a very important part in the progressive colonization of exposed surfaces. These Algæ, which so readily settle down on almost any object when the conditions of moisture and temperature are favourable, are

A

B

LEAVES FROM THE *NEPENTHES*-HOUSE AT KEW BEARING EPIPHYLLOUS BLUE-GREEN ALGÆ.

C

TANGLED GROWTH OF ALGÆ ON A ROCK IN THE *NEPENTHES*-HOUSE, KEW.

D

STRATIFIED GROWTH OF A *TOLYPOTHRIX* ON TREE-TRUNKS, CEYLON.

PLATE II.

certainly in large measure the agents to which the tropics owe the wealth of vegetation on every available substratum. The rapidity with which colonization is effected is often striking. I remember, on my arrival in Colombo, noticing a newly whitewashed wall absolutely destitute of visible traces of algal growth. I passed this wall again less than a week later, and it bore a bright blue-green film of some *Oscillaria*, although still uncovered at many points. Three weeks elapsed before I again saw it, but now it was one blue-green film with practically none of the whitewash visible. Careful examination, moreover, showed that tangles were appearing at a few points. When I left the island about three months after my arrival, the wall was nearly completely covered by tangled growth, and at many points tufts had arisen, whilst small Mosses were already growing on the tangle. I am informed that in the damp hothouses at Kew newly whitewashed walls tend to become covered with a thin film of blue-green Algæ in about six weeks, although the length of time required varies according to the temperature and degree of moisture.

I am not sufficiently familiar with districts having a heavy rainfall in our parts of the world to say whether algal growth ever plays the same sort of part it does in the damp tropics, but I should think not, for the stimulating effect of the high temperature is wanting. Gelatinous adhesive forms may sometimes develop in quantity on a rock-surface, etc., when the latter for some reason is exceptionally moist, but I have never seen other kinds of growth in any amount. This tallies with the prevalence of gelatinous Algæ in the subaërial algal flora of the uplands of Ceylon (cf. p. 533), which, although they have a high rainfall, of course have a relatively low average temperature (mean annual temperature a little over 60° Fahr.). I hope, subsequently, to be able to study subaërial algal growth in damp regions in Europe, but for the present must refrain from further observations on this subject. No doubt the experience gained in the tropics will be of immense value in interpreting the problems presented in temperate regions, and the study of this subject could not have been commenced in a better field than is to be found in the damp tropics.

The Cyanophycæ, in fact all subaërial Algæ, may be described as semi-aquatics. They still require more or less frequent saturation with water for successful development, and consequently they can only play an important part where the substratum is periodically very moist, or the relative humidity of the air high. Many subaërial Algæ have got over this difficulty by undergoing symbiotic combination with a Fungus to form a Lichen. Within the mycelial web of the Fungus the Alga finds adequate protection from desiccation, whilst the Fungus is much better equipped to collect such moisture as the substratum may afford, and to pass part of it on to the Alga. And, consequently, the ordinary growth on rocks and tree-trunks, etc., in temperate regions is nearly always of the nature of a Lichen. Every one is familiar with the many-hued Lichen-covering on the rocks in the high Alps, etc., and much the same sort of growth is of course often to be seen on the trunks of our forest trees.

We may now briefly consider certain cases illustrating the rôle of aquatic Algæ in preparing ground for higher vegetation, but the data I have to offer on this side of the subject are, I fear, rather meagre. The action of such aquatic Algæ is in great part a manuring one, but in some cases, at least, they help in the accumulation of a soil or in the absorption of moisture, which comes to benefit the higher vegetation growing amidst them. Cases of this kind are described by Welwitsch and W. and G. S. West. The former* deals with the abundant occurrence of a

* Welwitsch, "The Pedras Negras of Pungo Andongo in Angola," *Journ. of Travel and Nat. Hist.*, vol. 1, 1868.

Scytonema (= *Porphyrosiphon Notarisii*) in the damp sandy upper valley of the Cuanza river (Angola). According to this observer, it "frequently extends across the wide meadows, closely spread like a net over the soil, intergrown with the other herbs and smaller shrubs. Through its hygroscopic nature, it eagerly absorbs the atmospheric moisture during the dewy nights, affording by this means a refreshing protection to the roots of many other and larger plants during the glowing heat of the following day. The growth and thriving of the numerous small Phanerogamous plants in these places is conditional on the co-presence of the prolific *Scytonema*." In citing this description of Welwitsch's, Messrs. W. and G. S. West* refer to analogous observations made by them on the sandy heaths of the south and some parts of the north of England. According to their account, "at the drier and hotter periods of the year, thickly matted sheets of *Zygnema ericetorum* are to be found extending over wide patches of almost bare sand, round such plants as *Drosera*, *Carices*, etc. These interlacing masses have great absorptive capacity, greedily taking up water; it is also highly probable that they protect and render the growth of other plants more possible by regulating the moisture of the surface soil. It is interesting to note that *Zygnema ericetorum* is found intermixed in small quantity with the *Porphyrosiphon Notarisii*, which covers such extensive areas in Angola." In both of the cases quoted, I think it probable that the Alga has an important manuring effect on the soil in addition to the other functions indicated.

I will, in the first place, describe a similar case from a salt marsh in the Bouche d'Erquy, in Brittany. Extensive vegetation-studies have been carried on during the past three summers at Erquy by the staff and students of the Botanical Department, University College, London, and in this connection certain observations of a preliminary nature have been made on the influence of the abundant algal growth on the colonization of new ground in the marsh. Scattered all over the latter are small pools of varying size—the pans. According to the level they occupy, these pans are more or less frequently overrun by the tides, and their water is consequently brackish. They harbour a rich growth of *Rhizoclonium* and *Lyngbya*, often intermingled with abundant colonies of *Chroococcus*, etc., and Diatoms; in some pans the *Rhizoclonium* predominates, in others the *Lyngbya*. The algal growth is often very thick, and when this is the case near the shallow edges of a pan, the algal weft, together with the mud and sand silted up between its filaments, gradually forms a soil on which *Salicornia* and subsequently *Suaeda* settle down. In this way some of the pans appear to be slowly filling up, and are becoming populated by the neighbouring marsh-plants. It is not quite impossible that some of the pans themselves are due to the operation of the same sort of silting-up process on the tributaries of the river, which passes through the marsh. Moreover, in whole areas of the marsh the soil is rich in filaments of *Rhizoclonium* or *Lyngbya*, these filaments being more or less decayed and giving the sand or mud a dark black colour. The brackish Algæ at Erquy thus appear to play an important part, not only in the formation of new soil, but as humus-producers. In many parts of the marsh the *Rhizoclonium* also forms a bright green weft, covering the soil and ramifying through the superficial strata for long distances in a way evidently comparable to the cases described by Welwitsch and Messrs. W. and G. S. West. Such a covering probably affords an excellent moist substratum for the growth of the higher vegetation. Moreover, almost every tide will probably deposit a small amount of mud and sand on the surface of the Alga, and the latter will thus gradually become embedded. The buried portion will form humus by decay, whilst fresh branches from the Alga will continue the growth on the surface. The soil thus formed constitutes a black evil-smelling sandy mud, owing to the decomposing algal

* *Journal of Botany*, vol. 35, 1897, pp. 303, 304.

substance. Borings have shown that strata of a similar black sandy character are present at varying depths below the present level, and they no doubt testify to the occurrence of similar processes to those mentioned above at earlier periods in the history of the marsh.

We may next notice somewhat analogous phenomena recently described by W. G. Smith.* In dealing with the vegetation of sandy shores and sand-dunes in the botanical survey of Forfar and Fife, he mentions how "the hollows or troughs between the dune-ridges nearest the sea are sandy flats devoid of vegetation and still liable to inundation at high tide. When completely enclosed by protecting ridges, the dune-hollows become occasional pools of rain-water, where fine dust and organic materials collect. The catch-water has as its first vegetation evanescent growths of slimy blue-green and green Algæ, which aid in consolidating the bottom, and add to the organic matter till the soil is impervious enough to retain water throughout the winter and spring." This recalls Moss's description of the formation of moor-pan on the edges of many of the cotton-grass moors of the Pennines.† Such moor-pan is "initiated by the growth of slimy Algæ, of Lichens, of small Liverworts . . . on the bare earth and at the bases of the stems of the larger plants. . . . Over the remains of the pan-forming plants the creeping stems of heath-plants spread; and seedlings of the shrubby heath-plants also begin to grow." Both of these cases, though not directly comparable to the phenomena observed at Erquy, are parallel in their nature.

My friend, Mr. L. A. Boodle, has kindly drawn my attention to a very striking example of accumulation of algal growth leading to the production of a crust on the soil. This crust consists of a curious substance resembling elastic bitumen, and is found on the surface of the ground in South Australia. It is apparently derived by drying and other changes from an accumulation of gelatinous Algæ, Diatoms, etc. A similar deposit, which seems to be due to a member of the Cyanophyceæ, has been found in tropical Africa. I refrain from further discussion, as a description of these cases has just been published in the Kew *Bulletin*.‡ Earlier accounts of the Australian deposit are to be found in articles by W. T. Thiselton Dyer§ and J. R. Jackson.||

I made somewhat similar observations on some of the tanks or irrigation-reservoirs in Ceylon. During the dry season the water-surface often shrinks to a small fraction of its original area, and a large portion of the bottom of the tank becomes exposed. This latter appears as a soft black mud near the water's edge, but further away is hard and cakey, being traversed by cracks running in all directions. The softer portion often bears a considerable quantity of algal growth, which gets on well until this mud also dries up. The hard cakey part away from the water's edge always shows remains of algal growth, and its substance is generally found to be impregnated with algal filaments to some slight depth (1 or 2 inches). The surface, moreover, is often covered with abundant bleached remains of higher aquatics (e.g. at Lake Kantelai), so that this hard ground is well manured. In spite of this, it is only rarely found to bear a growth of higher terrestrial plants. This is no doubt due to the dried substratum and strong insolation of the tropical sun, against which there

* *Scottish Geographical Magazine*, vol. 21, 1905, p. 69.

† *Geographical Journal*, May, 1904, p. 10 (separate copy).

‡ L. A. Boodle, in 'Bulletin of Miscellaneous Information, Royal Botanic Gardens, Kew,' No. 5, 1907, pp. 145 *et seq.*

§ "On a Substance known as 'Australian Caoutchouc,'" *Journal of Botany*, New Ser., vol. 1, 1872, pp. 103-106. In this paper a number of similar cases are also mentioned (pp. 104, 105).

|| "Coorongite, or Mineral Caoutchouc of South Australia," *Pharm. Journ. and Trans.*, 3rd series, vol. 2, 1871-72, pp. 763 *et seq.*

are no means of protection. In some few of the tanks, however, the height attained by the water-level in the wet season is decreasing for some reason or other, and certain portions of the bottom near the edge of the tank are permanently exposed. These ultimately become colonized by quite a rich growth of land-plants, which no doubt by their progressive advance are able to overcome the difficulties of a dried substratum and intense insolation, and find favourable conditions in the well-manured soil. Similar phenomena on a smaller scale are common enough in Ceylon.*

In our parts of the world the same thing may be seen in the gradual encroachment of marsh-plants on a piece of water.† Sinking of the water-level, of course, always takes place in a hot summer, and if the water concerned is shallow, a certain amount of the bottom will become exposed. The area thus exposed, however, is not subjected to such extreme conditions as obtain in the tropics; especially if a considerable mass of water-plants is left by the retiring water, the exposed strip will tend to remain somewhat marshy in character, and will therefore be invaded by marsh-plants. If exposure is sufficiently long to enable the latter to obtain a proper footing, most of them will hold their own even after the return of the water. The growth of water-plants, and more particularly of filamentous Algæ, between the bases of the stems of these marsh-plants and the sediment washed in amongst the former will gradually cause silting up, and the marsh will become more pronounced. Of course, it frequently happens that a considerable rise of the water-level takes place, and makes matters impossible for the marsh-plants, which then have to retire to their own ground. Good examples of this kind may be seen on Sheen Common, Richmond. A number of the small pools there show a constant struggle between the water and these marsh-plants, resulting now in the victory of the one, now in that of the other; but, as far as I can see, in this case it never leads to an end.

One of these pools on Sheen Common shows another phenomenon, which is of interest to us here; and I was able to study several examples of the same kind in Ceylon.‡ I refer to the formation of deposits of reddish-brown hydroxide of iron, which often accumulates in very considerable quantities on the bottoms of pools, whose waters contain a certain amount of dissolved iron salts. There is a remarkable uniformity in the algal flora of such pools, which are characterized by containing an often very abundant Conjugate flora (species of *Spirogyra*, *Zygnema*, *Pleurotænium*, *Closterium*, *Netrium*), as well as forms like *Edogonium*, *Ulothrix* and Diatoms (species of *Pinnularia*, *Navicula*, *Surirella*, *Synedra lunaris*). The filamentous Algæ and larger water-plants occurring in these pools are generally found to have their filaments coated by a granular or filmy covering of this ferric hydroxide, so much so that they are often completely obscured. There seems no other way for accounting for this investment than by assuming that it owes its presence on the surface of the plant-growth to the metabolic processes of the latter; probably the dissolved iron salts in the water are oxydized by the activities of the plants, and are then precipitated as insoluble ferric hydroxide.§ As the latter accumulates it will sink down to the bottom of the piece of water, thus giving rise to a characteristic

* A very striking case (that of Lob Nor in Central Asia) of an analogous kind is mentioned on pp. 462, 463 of the *Geogr. Journal*, vol. 27, 1906 (discussion by Sir T. Holdich of Scott Elliot's paper).

† Cf. Pawson, "Water-plants as Land-winners," *Naturalist*, No. 511, 1898; also, Moss, *loc. cit.*, p. 6 (separate copy).

‡ Cf. Fritsch, *Proc. Roy. Soc. London*, Ser. B, vol. 79, 1907, Sect. b (ii.), pp. 236 *et seq.*

§ Similar deposits are known to be formed as a result of the activity of iron-bacteria. Such Bacteria may also to some extent be concerned in the case described, although in early stages at least, they were not found to be present. Cf. also Hanstein, in *Sitz. ber. d. Niederrhein. Ges. Bonn*, 1878, pp. 73-75.

granular deposit. The plant-growth in the water, moreover, as it dies away will fall to the bottom, and bring a further mass of reddish-brown hydroxide with it. In Ceylon I observed many different pools suggesting different stages in this process. Some had no bottom-deposit at all, but merely a red flocculent or filmy covering on the aquatic vegetation; in others there was a certain amount of deposit in addition to an abundant covering on the plant-growth. The final stage is found in pools with a thick red deposit all over the bottom, but little or no macroscopic plant-growth. It appears as though extensive accumulation of the deposit leads to unfavourable conditions for the continuance of vegetation, although in the absence of consecutive observations of the same pool it is difficult to say whether this is a passing phase or not. In the Sheen Common pool above mentioned accumulation of the red deposit is going on steadily, and has at sundry times appeared to have a very depressing influence on the algal vegetation, although as yet the latter has generally managed to recover. I hope to be able to study this interesting subject in greater detail subsequently; a few more facts about it are contained in my general paper on the Algae of Ceylon (*loc. cit.*).

Such deposits must, of course, involve a gradual shallowing of the piece of water, and from this point of view they interest us here. We have the formation of a peculiar kind of soil as a result of algal activity.

Finally, I desire to briefly refer to an interesting occurrence of terrestrial Algae on the seashore in many parts of Ceylon.* On the sandy spit which fringes in the lagoon at Kalutara, large quantities of a foliose *Nostoc* are to be found lying loosely on the sand amongst the numerous fruits (some of them, e.g. *Cerbera*, *Otodes*, had germinated and formed seedlings) cast up with the drift. At Bentotta and Matara the same form is found on the sand of the seashore above high-tide level. It lies loosely on the shore, and at a first glance is difficult to distinguish from the dead blackened leaves of the *Ipomœa Pes-Capræ*, which grows in abundance in the same locality. It appears that this *Nostoc* favours a sandy substratum, for it was found in quantity in the coconut plantations at the back of the beach as far as the sandy soil extended, and was also met with about 2 miles inland near the Bentotta river—again growing on sand. This species has markedly xerophytic characters, which are in keeping with its habitat. The colony is surrounded by a tough outer sheath, which does not swell up in water, and each of the contained filaments has a fairly compact yellowish sheath of its own. Its only source of water can be atmospheric moisture in the form of dew or rain, and hence the necessity for adequate protection from desiccation in the form of thick sheaths. The point that interests us most here is the possible important manuring effect of this abundant form, large masses of which are often found to be overgrown by the *Ipomœa*. It may also, by the absorption of atmospheric moisture, play much the same part as the Algae described by Welwitsch and the Wests in supplying moisture to the plants of the tropical sandy shore.

In concluding this paper, I should like to point out that many of the phenomena dealt with are readily observed, and do not require protracted investigation. It would be highly valuable if travellers would devote a little attention to such features, and would contribute data as to their distribution and relative importance in different regions of the Earth.†

* Cf. also Tansley and Fritsch, "The Flora of the Ceylon Littoral," *New Phytologist*, vol. 4, No. 1, 1905, pp. 13, 14.

† Many of the results recorded in the present paper were obtained with the help of a grant from the Government Grant Committee of the Royal Society, to whom I am much indebted for the assistance thus offered me. I should also mention that Fig. 1 is the work of my wife.

DESCRIPTION OF THE PLATES.

PLATE I.—Photographs illustrating the colonization of bare surfaces by subaërial Cyanophyceæ in the hothouses of the Royal Botanic Gardens, Kew. A, dense gelatinous adhesive growth on north wall of Aroid house; tangles are appearing at a number of points. B, adhesive growth on wall in tropical fern-house; the growth consists of large gelatinous masses of *Nostoc* and *Glæocapsa*. C, colonization of a rock-surface in the *Nepenthes*-house. Dense tangle of a *Scytonema*, covering an adhesive base (not visible), the tangle being overgrown by young ferns. D, tangled and tufted growth of blue-green Algæ on walls in *Nepenthes*-house.

PLATE II.—A, photograph of a leaf of *Anthurium radicans* from the *Nepenthes*-house at Kew, bearing a dense growth of epiphyllous Cyanophyceæ; the Alga is mainly present in the furrowed veins in the upper half of the leaf. B, leaf of *Nyrosma kummeriana*, bearing numerous rounded patches of epiphyllous Cyanophyceæ (*Nepenthes*-house, Kew), which appear as dark areas. C, typical tangled growth of a *Scytonema* on a rock in the *Nepenthes*-house at Kew. D, portion of a sheet of a stratified *Tolythrix*, found on tree-trunks, Ambalangodda, Ceylon.

REVIEWS.

EUROPE.

PHYSICAL HISTORY OF DEVONSHIRE.

‘The History of Devonshire Scenery.’ By Arthur W. Clayden. London: Chatto & Windus. 1906.

THERE are few counties in England which possess a more varied succession of rocks than Devonshire. They range from Lower Devonian, at least, to Pleistocene, and probably among the schists of the Start and the slates of North Devon formations older than the Devonian may be represented. Mr. Clayden has set himself the task of depicting the changes through which the county has passed in such a way as to make them intelligible and interesting to a reader not specially versed in geological methods. He is intimately familiar with much of the field evidence, and knows how to direct his readers to the localities where they may find for themselves the proofs of his assertions. The book, moreover, is adequately illustrated with reproductions from photographs, and with a limited number of maps. To those who know the district this volume is full of charm, and geologists must praise the lucid and vigorous treatment which the subject receives at the author's hands. Of course, there is much that is obscure and controversial in the past history of Devonshire, and these difficulties are not to be avoided, but they are not allowed to obtrude themselves unduly on our notice. The later chapters are devoted to the origin of the present scenery, the history of the river-valleys, and their relations to the earlier plateaux which form so well-marked features of the general landscape. From all Devonians and all who have made or are to make a tour in Devon this work well deserves a careful perusal. It is evidently the fruit of years of special study and of a close acquaintance with the results of geological investigation in the west of England.

J. S. F.

A CORNER OF DEVONSHIRE.

‘The Hills and Valleys of Torquay.’ By A. J. Jukes-Browne. Torquay: published by the Author. 1907.

In Mr. Jukes-Browne's latest work we have a complete little monograph of the scenery of a small but intensely interesting corner of England. The geological