SOME ADAPTIONS OF SOUTH AFRICAN PLANTS TO THE CLIMATE.

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EVERY living thing must be fitted to its environments or else it will cease to exist. This truth is so obvious with regard to animals that it hardly needs illustration. The fish is adapted to its life in the water as the bird to the air, and many peculiarities or special adaptions in the organisation of certain animals are regarded with interest even by the general public.

Few people, on the other hand, are aware that the vegetable kingdom illustrates the same law in no smaller degree, and that it does so is not surprising to us. While the animal is free to move about and to seek its shelter, the plant, which is also a living thing, has to endure the extremes of the climate on the spot where fate has placed it, and no life, whether animal or vegetable, is possible without water. It is not only the principal constituent of the sap of plants, and hence indispensable to all juicy parts, but during the growth of plants it is also necessary for the production of organic substance. The greatest part of the result of assimilation, whether it be finally turned into cellulose, starch or sugar, consists of carbohydrates, compounds which in respect of their percentage composition are carbon plus water, the former derived from the air, the latter from the ground. In regions with permanently moist soil or sub-soil, the plants require no special adaptions to secure the necessary amount of water. In localities, however, where the supply is irregular, only such vegetation can exist as is capable of surviving the drought. The means of resistance against the danger of dying by thirst are manifold, and it has been one of the greatest charms of my travels in South Africa to study the vegetation with regard to this question.

There is a large number of plants which have adopted the method of the badger; they produce their leaves, grow and accumulate organic substance during the rainy season and retire into the ground when it is over. Some of them also flower at the same time, thus accomplishing their yearly life. Others, concentrating at the period of rain all their energy on the formation of material, leave the display of their beauty for some later time when everything around them is dry and dead. To the former class belong most of our Gladioli, lovely Irideae, Amaryllideae, Liliaceae, Oxalides and Orchids, which turn our so-called winter into a most beautiful spring—at least to the visitor from northern Europe—and these are principally the plants which have gained for the Cape the designation of "the paradise of flowers."

The number of representatives of the second class is somewhat smaller, but among them are some especially noteworthy. The *Amaryllis Belladonna*, several species of *Haemanthus* and *Brunsvigia* are most remarkable for the size of their flowers or inflorescences as well as of their bulbs. They are usually called early flowerers, because it is thought that their blossoms, which appear towards the end of summer, belong to the leaves produced during the following winter, while it actually is the second stage of the plant's life, just as the European *Colchicum autumnale* (meadow's saffron) blossoms in October and November, hiding the fertilized ovary deep in the ground during the winter, and developing the fruit only in the following spring. This explains why it is useless to dig out a flowering Amaryllis bulb for the purpose of sending it to Europe with the expectation that it should blossom again during the summer. It has had no time to form its vegetative organs and to store up the material necessary for the production of the flower. Several handsome orchids, which are in blossom just now, belong to this group, namely the blue *Disa graminifolia* and the bright scarlet *Disa ferruginea*, both bearing their flowers on a reed-like stem, the leaves having died at the beginning of the summer.

There are a good many more very interesting questions connected with these bulbous plants; for instance, the various arrangements by means of which the bulbs and tubers are protected against the pressure of the hard ground, contracting during the dry season. This point, however, must now be left undiscussed, as it is necessary to pass over to that part of the vegetation which does not disappear at the end of the rainy season.

Leaving aside the annuals which die off altogether and spring up again from seeds as soon as rain has fallen, we have to mention those shrubby plants which meet the difficulty by tactics similar to those of the bulbs. They put forth their leaves only during the season which guarantees them a satisfactory supply of water, shedding them afterwards and passing the rest of the year in a dormant state. The celebrated *Testudinaria Elephantipes* is a plant of this description, whose wooden trunk resembles an immense tuber from which the thin trailing twigs spring only during the rainy season. Then there are several shrubby Pelargoniums and their nearest ally, the *Sarcocaulon* (the candlebush), which during the dry time of the year show only bare sticks, but when the rain happens to fall, it puts forth leaves and bears handsome flowers. The Cape Peninsula does not possess many such plants; very naturally they are more frequently found in the dryer parts of the colony, like the Karoo, Namaqualand, &c. One shrub of this group is also largely used here for hedges, namely, a *Lycium*, the so-called Wolf's doorn. I remember full well the impression these shrubs made upon me on my arrival here. It was the middle of summer, they were then bare, utterly devoid of leaves or fruit, and to all appearance quite dead ; but, a few months later, they presented a very different appearance with their green leaves and red berries. This was the first observation which demonstrated to me the fact that, at least in this part of South Africa, the season of rest for the vegetation is not the winter, but the summer.

Thus far those plants have been discussed which avoid the hardships of the dry season by a judicious retreat ; let us now turn to those which face the enemy bravely.

Before doing so, however, allow me to remind you of a few facts connected with the physiology of plants. The organs that absorb the water are the roots. Thence it passes into the stem, branches and leaves. The leaves and other green parts of plants are the organs which assimilate, that is to say, which prepare organic substance from the carbonic acid of the air, the water and other materials taken up by the roots. They inhale the carbonic acid and exhale the oxygen through the stomata, the so-called breathing pores. This latter name is not well chosen, and I think that it is partly responsible for the popular idea, according to which the leaves are considered as the lungs of the plant, while they are in reality its stomach and organs of digestion.

Quite independent of assimilation is respiration. The breathing process goes on continually not only in the leaves, but throughout the whole plant. During the exchange of gases liberated by these processes some water also necessarily evaporates. Little or nothing of this vapour can be lost during its passage through the stem, but during the necessary ventilation through the proper outlets, the stomata, the water vapour also escapes ; besides this, if not prevented by special means, there is also the evaporation of water through the epidermis of the leaves. Hence it is necessary for the leaf to regulate its rate of evaporation according to the supply and to reduce it to a minimum during the dry season.

Plants not exposed to very trying conditions are enabled to do this by the automatically-acting mechanism of the stomata, for these little slits close when the tissue of the leaf loses too much water, and open again when the supply is sufficient. With plants, however, of dry localities, or plants which have to last through periods of drought, other and more efficient means to check the loss of water or to secure a sufficient supply are necessary.

The variety of arrangements for this purpose is very great. In the following description they are arranged in seven groups. I need hardly add that the formation of these groups is quite arbitrary and simply a matter of convenience.

1. The evaporating surface is considerably reduced, either by transferring the function of the leaves to green stems or by developing only leaves of small size or narrow forms. The former case is represented by the genus *Stapelia*, several species of *Euphorbia* and the imported *Opuntia* (prickly pear) ; the latter by the heaths with their needle-shaped leaves; In fact, South Africa is exceedingly rich in plants of this group. The order Bruniaceae and the genus *Phylica*, which, with the exception of a few members of the latter genus, are peculiar to this country, have such leaves, and there are a great many composites and others which resemble them *e.g.*; *Metalasia*, *Stoebe*, *Helichrysum*, *Passerina*.

2. The surface of the leaves is impregnated with substances impermeable to water, so that the loss can occur only through the stomata. For this purpose either cork, wax or silica is used. By the word cork in this instance is meant the suberine, which changes the ordinary cellulose of the outer wall of the epidermis cells into the special layer called cuticula. This cuticula is often very thick *e.g.*; the *Aloë*, *Protea*, *Welwitschia*, and many others with leathery leaves.

A coating of wax or resin protects a good many species of *Rhus*. *Cotyledon*, *Protea*, and it is principally this peculiarity, in connection with the many hairy plants, which gives to South African vegetation the bluish hue which we so often notice in our scenery. There are several plants which produce wax in considerable quantities. The berries of *Myrica cordifolia* are covered with so thick a layer, that it is collected and exported. The stems of the candle-bush (*Sarcocaulon Burmanni and S. Patersoni*) will burn even when green, because the outer bark consists of cork well saturated with wax. On older branches this layer is about one-tenth of an inch thick, but if one extracts the wax by repeatedly boiling it in chloroform, it swells, becoming ten or fifteen times thicker and showing 10—30 annual rings, each consisting of numerons layers of cork-cells. On the plant, however, they are glued together by the wax, and form a solid mantle entirely enveloping the stem.

Silica is found principally on rushes and desert grasses.

3. The communication between the atmosphere and the air within is greatly impeded. This is accomplished in various ways. Many plants are covered with hairs, which not only diminish the direct heating effect of the sun's rays, but compel the escaping water-vapour to force its way through a series of narrow channels, thereby necessarily retarding the process. Everlastings (*Helichrysum* and *Helipterum*) and the silver tree (*Leucadendron argenteum*) are the most familiar examples. But there are a great many Composites (*e.g.*, *Oldenlandia*, *Euryops*, *Tarchonanthus*), Proteaceae (*e.g.*, *Leucospermum*, *Mimetes*), Leguminosae (*e.g.*, *Podalyria*, *Indigofera*, *Aspalathus*) and representatives of other orders protected by a similar coat of hairs or felt. It is interesting to notice how species of the same genus differ in this respect according to their locality. The genus *Hydrocotyle*, for instance, is a good illustration. Most of its species occur in moist places and possess round green leaves of delicate texture. A few, however, are found on dry ground and are well adapted to these different conditions of life. *H. virgata*, bearing cylindrical leaves, belongs to our first group ; *H. Centella*, having mostly narrow leathery leaves, to the second ; *H. Solandra*, which is well covered with white felt, to the third.

Some plants secrete mineral substances (Carbonate of lime, salt), which form a protecting layer either over the whole leaf [*Tamarix articulata*], or only over the little depressions in which the stomata are situated ; *e.g.*, *Statice*, *Vogelia africana* and other Plumbagineae.

Another peculiarity evidently serves the same purpose. The stomata are often placed in depressions or in grooves of leaves and stems, or the edges of the leaves are rolled so far back, that they nearly touch each other, turning the leaf into a tube, which bears the stomata on its inner side. All Aloes, many Proteaceae, Crassulaceae and the famous *Welwitschia* have such deeply depressed stomata, and many species of heath *e.g.*, *Erica cerinthoides*, *urceolaris*, *caffra* exhibit such rolled leaves.

More complicated and more efficient is the arrangement of the stomata on several grasses, on *Bobartia spathacea* and *Acanthosicoys horrida* (Naras). Leaves and stems of this *Bobartia*, which, as I may mention, are used for making the little strawberry baskets, are long and round like rushes. They are smooth but show longitudinal lines. These lines are deep grooves, the sides of which possess alternate projections. The stomata are situated only in the valleys between these ridges. If the heat is too strong and the loss of water too great, the sides of the grooves are pressed together by an automatic mechanism, the ridges fit in between each other, and the communication with the atmosphere is interrupted in a double way. Quite similar is the arrangement on the twigs of the Naras plant,* which grows on the sand-dunes near Walfish Bay.

4. The leaves assume the most favourable position towards the sun. The best example of this group is the Australian bluegum (*Eucalyptus globulus*), so largely cultivated here. It bears horizontal leaves only on its younger twigs, later on developing those hanging falcate leaves which turn the edge towards the sun

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* See figure in R. Marloth, *Acanthosicyos horrida*, Engler's Botanische ahrbucher, vol. IX, tab. 3.

This peculiarity is almost as strongly exhibited by our indigenous *Protea grandiflora* (waageboom). In this species only the very base of the sessile leaf is horizontal ; immediately above the base the leaf is so twisted as to become vertical and a mere edge is presented to the rays of the burning sun.

Some other plants, mostly belonging to the order Leguminosae, perform periodical movements with their leaves or leaflets. Most species of Oxalis, several Acacias *e.g. A. Giraffae, detinens, tenax, horrida* and *Cassia obovata* fold up their leaflets during the hottest part of the day and open them again in the afternoon.

5. Plants which possess reservoirs, either underground or in their stems and leaves. The *Elephantorhiza Burchellii* is a delicate herb, one or two feet high, but it possesses a huge watery rhizome, sometimes weighing ten pounds. Several asclepiads of the Kalahari region accumulate so much water in their large tubers that the Bushmen often depend entirely on it.

The *Stapelias* and *Euphorbias* store the water in their stems like the imported Cacteae and retain it with great tenacity. This is the reason why it is so difficult to kill such a plant, for every separate bit carries enough water and food material for the production of new roots and buds. A remarkable plant of this kind is the *Cissus Cramerianus* of Damaraland, a near ally of the vine. It has a fleshy trunk often ten feet high, with a diameter of two feet at its base, and forms only a few thick branches. A similar trunk of smaller dimensions has *Cotyledon fascicularis* of the Hex River district.

Most succulents utilise the leaves as a store room. A section through an Aloe leaf shows that the green cells form only a thin layer round a colourless watery tissue. We can make the same observation about many others. Almost all species of *Cotyledon*, *Crassula* and *Mesembryanthemum*, *e.g.*, *M. acinaciforme* (Hottentot's fig) possess a similar structure, not to mention *Augea capensis*, several *Zygophylla* and *Portulacaria afra*, the celebrated spekboom. But the water tissue is not always in the centre of the leaves. Many species of *Mesembryanthemum e.g. M. crystallinum* develop their epidermis cells into little vesicles, which give the leaves such a shiny appearance. Many orchids *e.g. Satyrium carneum*, *Holothrix* possess epidermis cells of such a height that this layer of water forms the greater part of the mass of the leaf. With *Haemanthus* it is the same. The little *Peperomia retusa*, an inhabitant of moist and shady places, provides still better for the times of drought, for its epidermis is multiplied, being several times thicker than the green tissue, covering it like a sponge.

6. The sap contains certain substances which prevent rapid evaporation. Such substances are slime, gum or salt. All succulents are protected in this way, gum occurring in the Acacias, salt in *Augea capensis* and *Zygophyllum Marlothii* and slime in a great many others. The amount of salt is often so large, that during the drying of the plant it crystallises and forms a thick crust on it.

7. The plants possess special organs for the absorption of dew. Such organs are specially adapted hairs, glands or sheaths, and they will be particularly useful to plants occurring in localities, which are dry but often visited by fog or clouds. The hairs on the leaves of *Salsola Zeyheri* enable it to exist in the coast districts of the Kalahari region, where rain is a rare occurrence. I found the little shrubs on the rocks near Angra Pequena, and later on in numerous specimens in the Namib, the desert eastward of Walfish Bay. In the same way the Naras plant most likely derives some benefit from the water deposited on its branches by the thick fog which so often occurs along the Western coast.

The depressed glands at the base of the acacia leaves seem to serve the same purpose, for drops of dew running down along the rachis must moisten them. The handsome *Rochea coccinea*, which adorns the rocks of Table Mountain with its dark crimson flowers, has fleshy leaves like its allies, but the leaves are fringed with little teeth. Each tooth, however, is an inflated cell which absorbs the moisture deposited on it by the South-East cloud.

Another plant found on the South-Western mountains, namely *Watsonia Meriana*, utilises the water deposited on it in a different way. It grows at an altitude of 2,000 feet and more, is four to six feet high and flowers in December and January, the middle of our dry season, when rain is a very rare occurrence. The stem usually consists of five or six internodes, each surrounded at its base by a large inflated sheath, which is almost closed at the top. These sheaths always contain water, even many weeks after rain has fallen, and I have often been glad to meet the plant with its hidden treasure on my rambles over dry parts of the mountain, for there is sometimes an ounce of water in a single sheath.

It is derived from the clouds that cover the mountain during the South-East wind. As two other species of *Watsonia*, of similar size (*W. rosea and marginata*), which flower earlier in the season and occur mostly at a lower level where the mist rarely reaches them, do not possess such pitchers, the natural conclusion seems to be that the plant draws on this resource for the development of its flowers and seeds. This is, however, not the case. Anatomical examination and a series of experiments have shown me, that the stem cannot absorb this water, but that it is there only for the use of the sheaths. As the sheaths, however, protect the more delicate regions of the stem the whole plant benefits indirectly from this arrangement. This case shows very clearly how easily the scientist may fall into an error if he judges from appearance only and does not base his opinions on experiment.

The attempt, which I have made in the preceeding pages, to group these means of protection does not in the least imply, as already stated, that the plants could be classified accordingly. On the contrary, many of them combine various arrangements to secure the same result, and it is very interesting to see how far this combination goes in extreme cases. One example of this kind is furnished by the Naras.

Unlike other cucurbitaceous plants, which usually possess a rich foliage, it does not produce any leaves at all, forming with its trailing twigs hedge-like shrubs on the sand-dunes. These twigs are protected by a thick epidermis, strongly covered with wax and in its younger parts by hairs. The stomata are situated in deep grooves, which close by an automatic arrangement when the loss of water becomes too great. In addition to this, there is a water reservoir (*hypoderma*) under the epidermis and a sponge-like tissue around the stomata through which the air has to pass before it can reach the green cells. Finally there are the hairs for the absorption of the water from the fog. Surely one can hardly imagine anything more complete, and we can understand how this plant is able to exist under such trying conditions, and to produce numerous juicy fruits on which a whole tribe of natives lives.

What I have brought before you to-night is only a flying survey of a large and for the greater part unexplored field. To treat such a question satisfactorily and especially in a country with such a rich flora as ours, would fill a volume. We should have no time for it, and I admit with regret that I have not had the time to study it more than superficially. Most of what I have said to-night is already the property of science, but I have felt obliged to include it in my paper in order to demonstrate the range of the subject.

To the popular mind, a botanist is still a man who carries a big tin on his back, collects all kinds of little weeds and calls them by long names. But such work is only the preparation for the real study. It is very interesting and also very useful to science, but, if the collector stops short there, he is a botanist only to the same extent as the sportsman who shoots birds and stuffs their skins is a zoologist.

Concluding these fragmentary notes, I beg to express the hope that more observers, who have taken up botany as a study or pastime, will devote their attention to these questions, and by accumulating more material from time to time will enable us gradually to obtain a better insight into the relations which exist between vegetation and climate in South Africa.