SURVIVING AT THE EDGE OF LIFE

The tiny plants that eke out an existence on the frozen continent.

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Antarctica: for me the name conjured up seals and penguins, dimensionless expanses of white and forbidding frozen mountains in a sea of ice, but certainly not plants. On arriving in Dronning Maud Land I was not disappointed, yet as a botanist it was plants I had come to study.

Yes, there are plants on continental Antarctica which manage to cling to life under the most severe climatic conditions on earth. Dronning Maud Land (where South Africa conducts its Antarctic activities) has snow and ice covering 99% of its surface. Plantlife is thus restricted to the ice-free rocky outcrops or nunataks, where it grows either on the surface of rocks or on the soil between boulders. Even on the nunataks there are few suitable habitats for plants to occupy because of the extreme harshness of the environment. This scarcity of habitat leads to a very sparse plant cover. In fact, most nunataks appear to be devoid of plants altogether, but careful observation reveals tiny plants in sheltered places although most of the plant life is microscopic and lives in the soil. On a few warmer nunataks, such as Robertskollen in the northern Ahlmannryggen where our studies were centred, there are more suitable habitats and relatively abundant plant growth.

The Robertskollen group of nunataks (rocky outcrops) in the northern Ahlmannryggen, Dronning Maud Land, Antarctica (the names of many places in this part of Antarctica hale from the first inland expedition, which was Scandinavian and British). Photo: M. Cocks.

What type of plant survives in this harsh environment?

There are no vascular plants ('higher' plants including flowering plants) in continental Antarctica, although there is a species of grass and a small herb that grows on the Antarctic Peninsula. All the plants native to Dronning Maud Land are cryptograms or 'lower' plants - mosses, lichens and algae.

Mosses

The largest plants in the northern Ahlmannryggen are 5 species of moss. Unlike lichens and algae, mosses have tiny stem-leaf-and rootlike structures. The stems with their leaves are closely packed together to form mats or turfs. Even though they are the largest plants, the individual moss turfs cover on average about 50 cm^2, seldom more than a square metre. Moss turfs appear yellow, black, white or orange in the centre and green around the edges. The colours other than the green of the actual moss plant are due to lichens and algae growing epiphytically (on top of) the moss, probably acquiring moisture from the moss. The moss, on the other hand, does not seem to gain from the association and is often left with only a small green, growing section around the edges.

It is interesting to note that the mosses found on continental Antarctica very seldom, if ever, reproduce sexually: no spores are produced and new plants must therefore grow from vegetative shoots broken off from existing plants.

Lichens

The first plants that one notices on a nunatak are the lichens that occur in various colours and shapes on the rocks. There are approximately 25 different species of lichen native to the northern Ahlmannryggen. Some of the lichen species are 'crustose', forming a hard crust close to the surface of the rock, whereas others are 'foliose', forming delicately curled branching or plate-like structures.

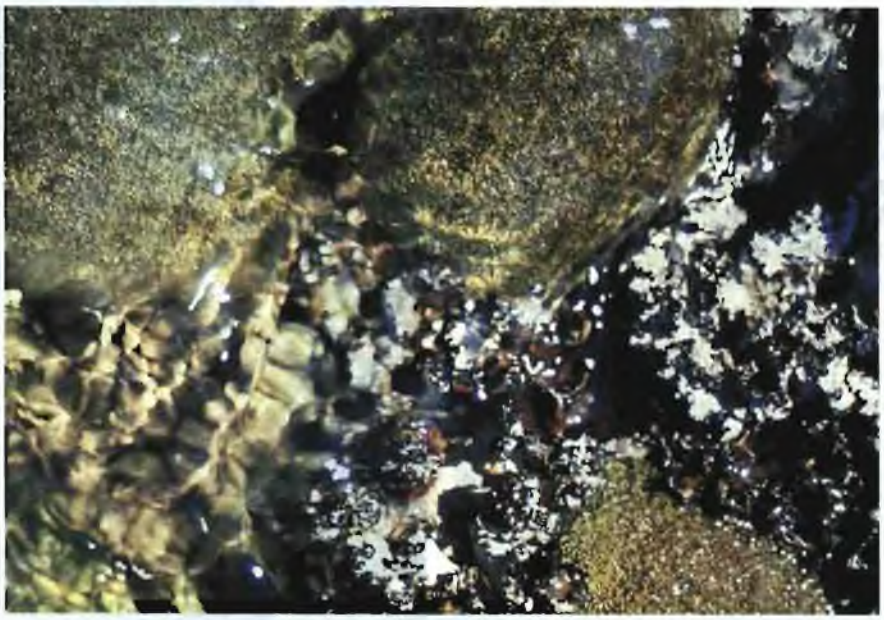
Lichens are not single plants, but an association between a fungus and an alga. The fungus provides support and protection for the 'plant' while the alga provides carbohydrates produced by photosynthesis. The association is very specific, the same species of fungus and alga are always found together and are usually treated botanically as one plant and given a single name.

Algae

Although in certain parts of Antarctica, particularly areas close to penguin colonies, algae are found living in the ice and snow, such plants have not been found in northern Dronning Maud Land. There are a few species of macro-algae that are readily seen in the right habitat on nunataks like the green alga *Prasiola crispa*. Most of the 20 species of algae found in the northern Ahlmannryggen, however, are microscopic and live in soil patches between the boulders. In places in Dronning Maud Land where the rocks are sufficiently porous the algae may penetrate rock, living inside it and in so doing, escaping some of the harsh outside conditions.

Top. The green alga, *Prasiola crispa*, in front of a snow petrel, *Pagodroma nivea*, nest at Robertskollen.
Above. Moss from a drier habitat covered in an array of colourful lichen species. Photos: M. Cocks.

One of the main factors affecting the distribution of these algae is the availability of nutrients, in particular nitrogen. Some of the algae are able to extract their own nitrogen from the atmosphere in the process of nitrogen fixation, whereas others are dependent on nitrogen in the soil. Where birds are breeding, nitrogen is more abundant in the soil, thus the alga *Prasiola crispa* is only found near bird nests where it can obtain the high levels of nitrogen it needs from the bird guano, even though such levels are toxic to other plants.



Turfs of the moss *Grimmia lawiana* with the lichen *Umbilicaria aprina* in between, growing in a wet habitat created by meltwater. Photo: M. Cocks.

How do these plants survive?

Naturally, extreme cold is the first harsh condition which one imagines any plant growing in the Antarctic having to survive, but other conditions such as strong winds, harsh light and even heat in summer, no light and continuous freezing in winter make it very unpleasant indeed. Most of the water in these habitats is in the form of ice or snow and liquid water, which is essential to life, is in short supply. The richest plant life is found in sheltered areas between boulders on the north-facing slopes of nunataks which have a nearby area of accumulated snow which melts on warm days, providing the plants with water. These habitats are also sheltered from strong winds during blizzards and from too much direct sunlight on warm days.

The mosses and lichens found in the Antarctic are able to freeze or dry out completely and survive long periods in this state. The effect of drying or freezing on the plants is similar, as they both cause tissues to lose water. When favourable conditions return the plants are able to recover quickly by absorbing water through their thin outer layers and start to photosynthesize. The compact form of the moss turfs helps to prevent moisture loss by evaporation from the individual moss branches. Their robustness under such harsh conditions is remarkable, with many moss and lichen species being able to survive being frozen for years at a time. Some lichen species are even able to survive after being frozen to the temperature of liquid nitrogen at -190 °C.

Once the moss or lichen is hydrated during the brief periods of warm weather their trials are not over. In both mosses and lichens photosynthesis is reduced by very bright sunlight and temperatures at or above 30 °C can cause damage to their tissues. Such temperatures are possible within centimetres of the rock surface on warm days. The number of black lichens present is evidence of this because the black colouration serves to protect the plant. Those growing in more shaded sites between boulders tend to be less black than those growing in direct sunlight. Added to this stress is the fact that the plants will freeze once again during the night hours of a warm day even when there are 24 hours of daylight. This continuous freezing and thawing puts added strain on the plants.

With all this stress, and the fact that warm days occur for only a very short period during the year, few plants can survive in this environment and those that can grow very, very slowly: large moss and lichen plants may be hundreds of years old.

Strangely, however, research has shown that these plants are not specifically adapted to Antarctic conditions. Most of the moss and many of the lichen species are also found in much milder and in some cases even tropical climates. When plants of the same species from a warmer area are compared experimentally to those from Antarctica they react to stresses similar to those of the Antarctic environment in a similar manner. It seems that many of the plant species that are found in the Antarctic are there, firstly because they could reach the continent with their very small and widely dispersed propagules and, secondly, because they can cling to life under the harshest conditions by taking advantage of the few warm days and shutting down completely for most of the rest.

The Robertskollen group of nunataks in the northern Ahlmannryggen of Dronning Maud Land has a small breeding population of snow petrels *Pagodroma nivea*. The South African Biological Antarctic Research Sub-Programme, based at the Percy FitzPatrick Institute of African Ornithology of the University of Cape Town has, over the last four years, been investigating the effects of products produced by these birds, especially guano, on the ecosystem here and at other inland nunataks in Dronning Maud Land. Research in Antarctica is of value because it gives ecologists a better understanding of what limits the survival and distribution of plants and animals at the very edge of life on our planet.