Figure 1 Early morning in the Namib — the optimal time for crustal photosynthesis.

superficial layers, derived from dew, fog and showers. The ecological value of the layer in protecting the soils from wind erosion and as an absorptive organ for water is generally appreciated, as is its role in providing germination sites for the seeds of flowering plants².

The presence of free-living, nitrogen-fixing cyanobacteria in the upper layer, together with lichens that contain cyanobacterial symbionts, suggests a pathway by which atmospheric nitrogen enters the desert ecosystem. Moreover, the extensive cover of even a thin layer of photosynthetic organisms is an important source of carbon fixation in an environment where primary production is low. In their studies of the Namib Desert of southern Africa (Fig. 1), Lange and colleagues have shown³ that the chlorophyll density of the microbial mat is around 200–500 mg m⁻² — of the same order as in the leaf of a higher plant. So the crust has considerable photosynthetic potential, although this is limited by the need for hydration before it can be exploited.

In the Negev Desert of Israel, Lange and his team showed⁴ that they could induce maximal photosynthesis from the crust by moistening it with the equivalent of just 0.2–0.3 mm of precipitation. These photosynthetic rates were around 20% of those achieved by local desert shrubs, such as *Zygophyllum dumosum*, illustrating the ability of the crust to act as a carbon sink. In the Negev, as in the Namib, moisture mainly comes in the form of condensation — as dew and fog during the cold night. So, although these moisture levels are often achieved, the rising sun soon desiccates the productive crust into a dormant state, and crustal photosynthesis is limited to an early-morning window when moisture and light briefly coincide.

Now that general taxonomic surveys of crust communities and their physiological properties have been carried out, questions of geographical and ecological variations are being tackled. For example, not all deserts depend on condensation. The intermontane deserts of the western United States

are watered by occasional showers or storms rather than by fog and dew — do their crusts have a different species composition and physiology? To answer these questions, Lange *et al.* have done their latest work¹ in southern Utah.

One evident taxonomic feature of the Utah desert is that, although there are many lichens with green algae as their symbionts (as in the Negev and Namib deserts), the most abundant crustal constituent is a gelatinous lichen, *Collema tenax*, with a cyanobacterial symbiont. This lichen requires a greater water supply (equivalent to over 1 mm of precipitation) than do the green-algal lichens to attain its maximum photosynthetic rate. But, it then shows the highest photosynthetic capacity of any arid-zone soil lichen yet studied. Moreover, *C. tenax* can maintain photosynthetic activity over a wide range of temperatures, from near freezing to over 40°C, with an optimum around 30°C. It also requires a high light intensity for maximal photosynthesis, and it has a high light-compensation point (the minimum light intensity at which it can break even in terms of carbon balance). All of these are features that plant physiologists would associate with a 'sun plant'.

Collema tenax has a distinctive physiology that equips it well for the water regime in Utah, where erratic showers bring larger quantities of rain at any given time than are experienced in the 'fog' deserts. The gelatinous nature of its thallus means that *C. tenax* serves as a reservoir, maintaining its hydrated state long enough to provide for extended photosynthesis even in the hot conditions, when the light is high, in the middle of the desert day. Lichens with cyanobacterial symbionts are already known to need more water to set photosynthesis in motion than lichens with algal symbionts. So, perhaps the features described for *C. tenax* will be of wide taxonomic, physiological and biogeographical significance.

Recognizing that such niche differentiation exists among the primary producers in desert crusts is an important step towards appreciating the complexity of crustal micro-ecology. Because these soil features are so important in the water relations and nutrient cycling of desert soils, and because we know that they are sensitive to disturbance by the trampling pressures of humans, domestic animals and motor vehicles, further understanding of crustal ecology should soon provide a basis for conservation of desert crusts. □

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Daedalus

Plane and fancy

The synthesis of nylon is a well-known demonstration. One component is dissolved in water, and a second one in an immiscible solvent. On mixing the two, a nylon film forms at the liquid interface, renewed as fast as it is pulled from the mixture.

In principle, the interfacial film should be a perfect monolayer separating the two reagents. Sadly, nylon with its chain-molecules is very permeable. The reagents can still get at each other; they react further to thicken the film. A polymer which cross-linked into a true sheet molecule would be a far better barrier. So Daedalus is devising two-solution syntheses of dense, cross-linked, water-repellent polymers with fluorocarbon or organometallic side-chains, excellent barriers to their precursor reagents. At the solution interface a true monolayer film will form, regenerated as fast as it can be hauled out of the bath.

Monolayer film will be quite invisible. Furthermore, being essentially all surface, its two faces will absorb almost its own weight of air. Unless it is chemically non-inflammable, it will be highly explosive. So it will be quite tricky to handle. On the other hand, it will be immensely strong for its weight, the highest of high-tensile films. It will also be the ultimate electrical capacitor, holding a vast charge-density per unit weight. Monolayer film will make amazing new electrometers, electrostatic speakers, balloon fabrics, and so on.

A wider range of products could be made by bringing many monolayers together into a loosely bonded multilayer. The resulting macroscopic film would be immensely tough. A crack could not propagate easily from layer to layer, so the film should sum the tenacity of its individual monolayers. Even better, Daedalus plans to make multilayers of two or more types of film, interleaved into a multiple laminate structure. If one of the layers were organometallic, the resulting bulk 'superlattice' structure might give a transparent magnet, a high-temperature superconductor, an interference filter, a specular X-ray mirror, a large-scale quantum-tunnelling device or some other supermolecular marvel.

A simpler sandwich structure could have just three films: a central crumpled one bonded to two flat monolayer faces. It would be a wonderful heat insulator. Being transparent, indeed invisible, it could not radiate. Applications to Emperors' new winter clothing should follow.

David Jones