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**Peptides from HCN**

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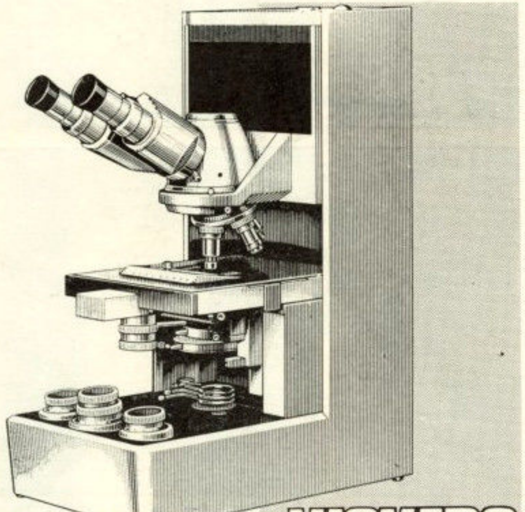





## PLANETARY SCIENCE

### Life in the Clouds of Venus?

WHILE the surface conditions of Venus make the hypothesis of life there implausible, the clouds of Venus are a different story altogether. As was pointed out some years ago[1], water, carbon dioxide and sunlight—the prerequisites for photosynthesis—are plentiful in the vicinity of the clouds. Since then, good additional evidence has been provided that the clouds are composed of ice crystals at their tops[2,3], and it seems likely that there are water droplets toward their bottoms[4]. Independent evidence for water vapour also exists[5]. The temperature at the cloud tops is about 210° K, and at the cloud bottoms is probably at least 260–280° K (refs. 4 and 6). Atmospheric pressure at this temperature level is about 1 atm.[7]. The observed planetary albedo falls steeply in the violet and ultra-violet[8], which accounts for the pale lemon yellow colour of Venus. The albedo decline would not be expected for pure ice particles, and must therefore be caused by some contaminant. Dust, ozone, $C_3O_2$ and other gases may possibly explain these data but, whatever the explanation, the ultra-violet flux below the clouds is likely to be low. If small amounts of minerals are stirred up to the clouds from the surface, it is by no means difficult to imagine an indigenous biology in the clouds of Venus. What follows is one such speculation.

A macroscopic organism living in the clouds of Venus must be regulated to live at an essentially fixed altitude. If it is carried, for example by convective downdraughts to the lower atmosphere, it will encounter uncomfortably high temperatures, and if it is carried to the cloud tops it will encounter very little moisture and very low temperatures. We therefore imagine an isopycnic organism constructed as a float bladder[9]. Because the atmosphere is primarily carbon dioxide and nitrogen, a float bladder filled with hydrogen would be very effective. Molecular hydrogen can be produced from water by photosynthesis, as is known in purple bacteria[10]. Although the observed cases are for aerobes there is no reason why photosynthetic production of hydrogen by anaerobes should not occur. We consider such an isopycnic organism near the 0·5 atm. pressure level; the atmospheric density here will be about $7 \times 10^{-4}$ g cm$^{-3}$, depending somewhat on composition. The organism is essentially a spherical hydrogen gasbag with outer radius $R_1$, and inner radius $R_2$. For the organism to have a mass equal to the displaced mass of atmosphere, we require

$$5 \times 10^{-5} R_2^3 + \rho(R_1^3 - R_2^3) = 7 \times 10^{-4} R_1^3$$

where $\rho$ is the density of the outer membrane. For $\rho \simeq 1{\cdot}1$ g cm$^{-3}$, $(R_1 - R_2)/R_1 \simeq 2 \times 10^{-4}$. If the minimum skin thickness is about 1μ, as in terrestrial organisms having a dermal layer one cell thick, the gasbags have a minimum diameter of about 4 cm, about the size of a pingpong ball. Much larger organisms would also be possible. If the skin were a unit membrane thick (about 75 Å), the organism could conceivably be as small as 75μ in diameter; but this is clearly a lower limit—it is unlikely that the requisite metabolic processes could be contained within a unit membrane.

The postulated photosynthetic organism would reside just below the Venus clouds, or in the lower cloud deck. Water would be collected either as rain or by contact with the droplets, and minerals blown up from the surface would be captured on the sticky underside of the organism, and ingested by pinocytosis. The mineral requirements would be modest, and the ash content would be a very small fraction of the dry weight. Metabolic schemes can be worked out using known terrestrial biochemistry. Much smaller non-isopycnic organisms can also be envisaged. If the Stokes–Cunningham fallout times to reach moderately high temperatures are less than the replication times and if updraughts exist, a stable population of micro-