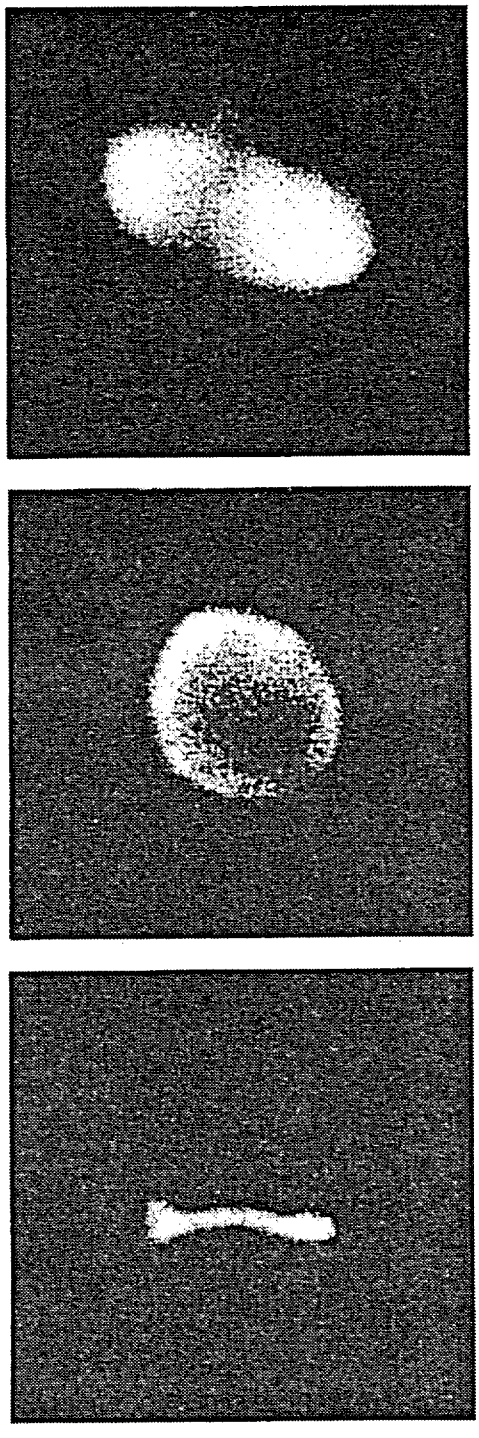
Fig. 2. Micrographs showing bacteria found in samples from 3 m depth in permafrost in marine sediments on the Kara Sea coast. The sediments are believed to have been frozen continuously over at least the last 10,000 years.



metres deep beneath the Antarctic ice sheet, just above the sub-glacial Lake Vostok. Organisms within the lake itself are presumably living and reproducing in the normal way, and may have done so since the lake was isolated. However, ice which was hundreds of thousands of years old and at a depth which could not have been contaminated from the surface or from below in recent time, was thought by Abyzov et al. (1982) to contain viable bacteria.

Freezing temperatures in themselves certainly do not preclude bacterial growth. Forster (1887) first established that bacteria grow at 0°C. Although most microorganisms do not grow at temperatures below 0°C (Foter and Rahn, 1936), certain bacteria and fungi can be physiologically active and Friedman (1994) and Rivkina et al. (2000) note metabolic activity in permafrost bacteria at -20°C. Hubbard et al. (1968) also reported a living bacterial population in cold Antarctic permafrost. Others reporting evidence concerning bacterial activity in soils below 0°C, include Flanagan and Veum (1974); Bunt and Lee (1970); Kalinina, Holt and McGrath (1994); and Clein and Schimel (1995).

Water is the solvent for the molecules of life, and availability of water is a critical factor affecting the growth of all cells. But the particular water which is unfrozen in permafrost, although at less than 0°C and in the presence of ice, differs from 'ordinary' water. It has a modified energy content, or potential, being similar in this respect to the last water in a drying soil. Being 'bound' to the soil mineral particle surfaces it is not available to plants, which commonly wilt when the soil moisture content falls below a critical amount.

Many plants in cold regions have xerophytic characteristics (adapted to dry conditions) presumably because they are repeatedly exposed to the frozen condition of low water content around their roots. The thin layer of 'bound' water on the soil particles, in fact, tends to pull water to itself. This is also the cause of frost heave of the soil, with accumulation of water as 'excess' ice (Williams and Smith, 1991). But some organisms, including, presumably, those in the permafrost, can mount a counter attractive force so as to resist being desiccated in this way. Thus certain fungi are able to take in water even when this has a potential (cryosuction) of -7 MPa (Bruehl et al., 1972). Nevertheless, while it is certain that bacteria survive in freezing soils at temperatures several degrees below 0°C, it remains hard to believe that organisms could survive a water potential of -36 MPa which is that predicted for water in a soil at -3°C (Williams and Smith, 1991). Perhaps the unfrozen water in the