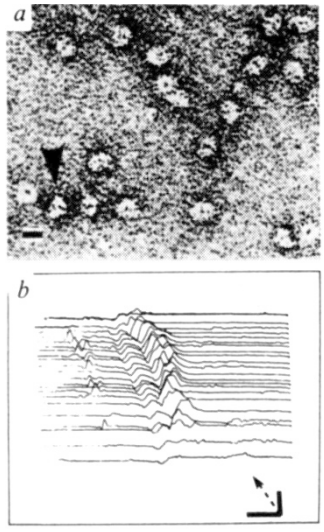

Fig. 3 *a*, Electron micrographs of the upper collar of bacteriophage $\phi 29$. The upper collar protein of phage $\phi 29$ was purified[8,9] and dialysed against 0.2 M ammonium bicarbonate containing 0.1% glycerol to prevent destruction during the air-drying procedure. This sample was negatively stained with 2% uranyl acetate and observed by transmission electron microscopy. The collars appear as circular structures with a hole in the centre. Occasional side views show a dumbbell shape with a hole running through the centre of the neck (arrowhead). Scale bar, 100 Å. *b*, STM surface topography curves obtained from a collar-containing sample deposited over graphite and air-dried. The scans show profiles of a structure (100 Å in diameter along the *x*-axis and 80–90 Å in height along the *z*-axis) that correlates with the collar structure inferred from the images shown in *a* (ref. 9).

air-dried specimens, commonly observed in all electron microscope methods[7], is also seen in the present experiments for empty viral heads (Fig. 2*c*, *d*). Repeated scans over the same area always showed very similar topography, implying that STM does not drastically alter the biological surface structure.

The second sample studied by STM was the oligomeric protein structure that forms the upper collar of $\phi 29$ (refs 8, 9). Transmission electron micrographs of this oligomer showed a circular front view (135 Å diameter) with a hole in the centre (Fig. 3*a*). Occasional side views showed that the oligomer has a dumbbell shape (125 Å on height). The collar sample was dialysed against 0.2 M ammonium bicarbonate (containing 0.1% glycerol) to remove salts and low-relative molecular mass components and then analysed by STM.

Over a general flat surface, some series of scans were observed that could be correlated with the presence of the phage collars (Fig. 3*b*): the more characteristic feature is a structure ~100 Å in diameter (*x*-axis) and 80–90 Å in height (*z*-axis) showing a hole in the centre, which is in good agreement with the structure of this collar observed by transmission electron microscopy[9] (Fig. 3*a*).

Most of the pictures presented were scanned insufficiently in the *y*-direction, which prevents the observation of the entire object. This limitation resulted from the difficulty in controlling the piezo movement in the slow direction (*y*-axis), because both piezo relaxation and external scanning may have a similar value.

We stress that we have obtained real corrugated structures in the STM of as much as 250 Å for an applied voltage of 0.4–0.8 eV, giving a tunnel current of 10 nA. Assuming an average tunnel area of 300 $Å^2$, as indicated by the experimental lateral resolution[4], an effective tunnel resistivity of ~1 Ω cm^{-1} is obtained. This resistivity is much too small for a single tunnel process over ~200 Å. We propose a transport mechanism to explain the effective conductivity of the biological material analysed by assuming the existence of regions where the electrons tunnel (conduction levels higher than the kinetic energy of the electrons) and regions where they propagate (conduction levels lower than the kinetic energy of the electrons). If such regions of tunnelling and propagation of electrons exist in the specimen, electrons can easily move by percolating in the propagating regions, whereas resonant tunnelling in the tunnel regions can substantially enhance the conductivity over single tunnel processes. Calculations on one-dimensional disordered systems show an enhancement of the conductivity[10]. We believe that both type of regions are provided by the different bonds and radicals existing in the protein of the biological material. More information will be provided in a forthcoming paper.

In conclusion, our results show that STM can be used to determine the surface topography of air-dried untreated biological specimens at atmospheric pressure and room temperature without altering the material. Real-space three-dimensional topographic profiles giving a vertical resolution of the order of 1 Å are obtained, which can be correlated in terms of size and shape with biological objects. In addition, STM can be used to determine the surface microstructure of other materials such as metals, semiconductors, thin films and polymers. The operation of the microscope at atmospheric pressure opens the possibility for investigation of the technological applications of these materials in such fields as metallurgy, microelectronics and catalysis.

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Corrigendum

High-affinity binding site for a specific nuclear protein in the human IgM gene

L. Hennighausen, U. Siebenlist, D. Danner, P. Leder, D. Rawlins, P. Rosenfeld & T. Kelly Jr
Nature **314**, 289–292 (1985)

Lines 8 and 9 of Fig. 3 should read "in the absence (lane 4) or presence (lane 3) of the".

Erratum

Functional modifications of cytotoxic T-lymphocyte T200 glycoprotein recognized by monoclonal antibodies

L. Lefrancois & M. J. Bevan
Nature **314**, 449–452 (1985)

ON page 450, column 2, line 6 of the first paragraph should read "... precipitated proteins with apparent M_rs of 240,000 (240K), 220K ...".