New steps in the formation of phage T4 heads and DNA packaging

from P. J. G. Butler

THE large bacteriophage T4 has a long history of interest and current developments are maintaining this standard. Since it was shown to have a DNA-containing head connected by a hollow tail to the fibres which are involved in the attachment to the host cell, interest has centred on the mechanism for the assembly of such a complex structure. As shown by the groups at Caltech and Geneva, it is particularly suitable for such study because of the ability of the incomplete fragments, which accumulate in cells infected with mutants in many of the assembly steps, to form complete phage either by *in vitro* complementation with the fragments from another suitable mutant (Edgar and Wood, *Proc. natn. Acad. Sci. U.S.A.*, **55**, 498; 1966) or by subsequent activation of the blocked step (for example by the removal of a temperature sensitive infection from a non-permissive temperature to a permissive one).

The assembly occurs as a series of subassembly steps, with the head, tail and tail fibres being assembled separately and then joined together, first the tail on to the DNA-containing head and finally the tail fibres added to the fibreless particle to give the complete phage (reviewed by Wood *et al.*, *Fedn. Proc.*, **27**, 1160; 1968). During the infection of a host cell, the incoming DNA is expelled from the head through the tubular tail without any requirement for an energy source. This has led to speculation that the DNA is packed into the head in a special way, as if under pressure, so that its release occurs like that of a spring. A highly condensed state for the DNA is also required for the total amount to be packed into the volume available.

Head assembly

Unlike a number of simpler viruses, the heads of T4 seem to be largely assembled before much of the DNA is inserted into the pre-existing shell (Luftig *et al.*, *J. molec. Biol.*, **57**, 555; 1971; Simon, *Proc. natn. Acad. Sci. U.S.A.*, **69**, 907; 1972), and recently some of the steps have been described. A hierarchy of partially characterised steps (Laemmli *et al.*, *J. molec. Biol.*, **49**, 99; 1970) leads to the formation of the first recognisable head structure, prohead I, with a sedimentation coefficient of about 400S, containing at least four protein species (P23, P20, P22 and IP III) but no DNA (Laemmli and Favre, *J. molec. Biol.*, **80**, 575; 1973). These particles are converted to prohead II (about 350S) by the cleavage of

the major protein (P23) to give P23*. This cleavage seems to require the action of two distinct phage proteins, P21 and P24, and failure of either of these leads to the accumulation of 'τ-particles' (Epstein *et al.*, *Cold Spring Harb. Symp. quant. Biol.*, **28**, 375; 1963; Laemmli *et al.*, *J. molec. Biol.*, **49**, 99; 1970) which are smaller than the normal heads.

Though the τ-particles produced in the absence of functional P21 seem to be completely aberrant and cannot be rescued to form normal heads (Laemmli and Johnson, *J. molec. Biol.*, **80**, 601; 1974), those formed without P24 can act as a subassembly for head formation, without being disrupted in the process (Bijlenga *et al.*, *Nature*, **249**, 825; 1974). Analysis of the proteins in these 24 τ-particles shows that they

contain uncleaved P23 and that this is converted to P23* upon activation of P24, and it thus seems probable that these τ-particles represent an intermediate in the pathway between proheads I and II (Bijlenga *et al.*, *J. supra-molec. Struct.*, **2**, 45; 1974).

The conversion of prohead II into prohead III (550S) again involves the action of two phage proteins, P16 and P17, and is the first step in which the proheads become associated with the replicative DNA and the DNA packaging starts. During this conversion of II to III the cleavage of two further proteins, P22 and IP III, begins. This process is finished during the final maturation of the prohead III into mature phage heads. This requires the action of yet another protein, P49, and goes in close parallel with the com-

The magnetic field of Jupiter

from D. Stannard

THE latest development in the exploration of the Solar System by spacecraft came with the arrival of the Pioneer 11 probe at Jupiter in early December. Following almost a year after Pioneer 10, its predecessor to the planet, Pioneer 11 swept within 0.6 planetary radii (R_J) of the Jovian surface before continuing on its way towards the planned encounter with Saturn in 1979. With remarkable promptness, Acuna and Ness present a preliminary interpretation of the Pioneer 11 measurements of the structure of the inner Jovian magnetic field in this issue of *Nature* (page 327).

Ground-based studies of the radio emission from Jupiter over the past twenty years have suggested a picture of the field structure which is basically that of a magnetic dipole, with the axis of the dipole inclined by just under 10° to the rotation axis of the planet. Asymmetries which are present in both the decametric (noise burst) and decimetric (synchrotron) radio emission suggest that there may well be fine structure associated with the dipole field at distances of between 1 and 2 R_J from the planet. In particular there is evidence of a localised field distortion close to the longitude of the magnetic pole in the Northern Hemisphere (Conway and Stannard, *Nature*, **239**, 142; 1972).

The magnetometer measurements from Pioneer 10 confirmed the essential dipole character of the main Jovian field at distances greater than the spacecraft's closest approach of 2.8 R_J . A better fit to the data in the inner field region was however obtained using a 'dual dipole' model, with a weak secondary dipole close to the position of the field anomaly indicated by the radio astronomy measurements (Smith *et al.*, *J. geophys. Res.*, **74**, 3501; 1974).

The close approach of Pioneer 11 to the Jovian surface has now enabled the structure of the inner field region to be studied in detail. As shown in Figure 3 of Acuna and Ness's paper, the field is indeed complex, and at least an octupole expansion is required to describe the data. Particularly prominent is the asymmetry in the pole strengths of the two hemispheres, with a field of 28 Gauss at the north magnetic pole, and only 16 Gauss at the south. The magnetic equator within 2 R_J is highly distorted and steeply inclined with respect to the zenographic equator. With this detailed information about the field structure it should now become possible to perform more reliable quantitative calculations on the radio astronomical data to enhance our knowledge of the physical processes in the Jovian magnetosphere.