fission) do not exist for the damage range (up to say 500 displacements per atom) which we need to explore. For many purposes, beams of heavy ions can simulate neutron damage well enough. For example, about 10^{16} 7.5 MeV tantalum ions cm^{-2} in vanadium foils at 700 °C produce voids which are not dissimilar to those produced by 10^{22} fast neutrons cm^{-2} ($E > 1$ MeV). The latter irradiation would take months in the most powerful fission reactor while the former takes hours or minutes in an accelerator.

The working party makes two pleas —that the solid-state physicist should be brought more intimately into the nuclear programme and that, to save money, money will have to be spent on simulation machines and basic research. Good arguments are offered as to how overdesign through ignorance could undermine economic viability. Now, it is to be hoped that the agencies planning our future in the energy field will consider this message and implement it. Perhaps a similar call by European scientists, especially confirming the financial theme, would drive the point home to their own governments. □

Filamentous phage assembly

from P. J. G. Butler

THE filamentous bacteriophages of *Escherichia coli* are a family of viruses consisting of a single-stranded circular DNA molecule, encapsidated into a very long, narrow and flexible particle (reviewed by Marvin and Hohn, *Bact. Rev.*, **33**, 172; 1969). Unlike other bacteriophages, they are neither lysogenic nor do they establish a lytic infection, but rather a productive infection resulting in the slow secretion of progeny virus during a comparatively long period. This poses particular problems during virus release, which occurs without either lysis of the cell membrane or the budding off of regions of this membrane as with lipoprotein coated virions. The solution lies in a series of specific interactions between the viral coat protein and the cytoplasmic membrane of the cell, which are now beginning to be described.

The virus particles contain predominantly a single type of coat protein of about 5,000 daltons. Marvin and Wachtel (*Nature*, **253**, 19; 1975) have analysed the X-ray scattering from oriented gels of one of these bacteriophages (Pf1) and were able to fit this with a model in which the protein molecules are fully α helical and are themselves arranged helically in the particle, with the axes of the α helices lying almost parallel to the particle axis. This results in a tight interlocking of the coat protein molecules, giving a high degree of protection to the DNA while allowing flexibility of the particle. The sequences of the coat proteins are compatible with such a structure and Nakashima *et al.* (*Nature*, **253**, 68; 1975) showed that the hydrophobic central region could readily form stable α helices which could interact in the appropriate way, while there is a slight excess of basic residues at the C terminus, which could be at the inside of the protein coat and help to neutralise the DNA phosphate residues.

Although the attachment of the phage to the host cell, on or near the few molecules of attachment protein per particle, appears to be relatively straightforward, the transport of the viral DNA both into and out of the cell through the cytoplasmic membrane involves more complex mechanisms. The DNA uptake during infection requires DNA synthesis in the cell, during which Marco, Jazwinski and Kornberg (*Virology*, **62**, 209; 1974) found the single-stranded viral DNA to be converted into the double-stranded replicative form (RF). As the DNA is drawn into the host cell, the viral coat protein becomes incorporated into the cytoplasmic membrane and Smilowitz (*J. Virol.*, **13**, 94; 1974) showed that it is reused during the subsequent maturation of progeny virions, being incorporated dispersively into their protein coats, and thus leading to an economy of protein synthesis.

After the establishment of the infection, with viral protein and DNA synthesis in the host cell, the assembly of progeny virus occurs. Initially the new virion DNA strands are assembled into a nucleoprotein complex with the protein product from gene 5, which is not the virus coat protein. These nucleoprotein complexes are again long, flexible particles and the protein molecules are probably helically arranged. However, Pratt, Laws and Griffiths (*J. molec. Biol.*, **82**, 425; 1974), while demonstrating their formation *in vivo*, found that these particles are much less stable than the mature virions, in which the gene 5 protein has been replaced by the coat protein. They suggested that the intracellular coat serves to protect the DNA until it acquires its final coat while being extruded through the cell membrane, to which the coat protein has already bound, and then recycles onto fresh DNA.

The site of the interaction between the phage coat protein (of M13) and the cytoplasmic membrane has been examined by Wickner (*Proc. natn. Acad. Sci. U.S.A.*, **72**, 4749; 1975). He found that ^{125}I-labelled antibody raised against detergent-solubilised coat protein would bind specifically to both the intact phage and the coat protein in the membrane. Using this antibody to assay the coat protein, initially of the infecting virus, he confirmed that RF formation was necessary for the transfer of the protein from the incoming virus to the cytoplasmic membrane of spheroplasts, this process taking about 10 min and leaving the protein available for reuse in progeny virion assembly. After about 40 min, further coat protein begins to accumulate in the membrane as it is synthesised. Both the parental and the newly synthesised protein are similarly located in the cytoplasmic membrane, with the antigenic sites only detectable on the outside of the membrane and being masked if the spheroplasts are inverted by sonication. This observation implies that the protein must occupy a position in the membrane irrespective of whether it is inserted from the outside, during initial infection, or from the inside by *de novo* synthesis. Such rapid transport across the membrane is in marked contrast to the slow rate of flipping of phosphatidyl choline, which Kornberg and McConnell (*Biochemistry*, **10**, 1111; 1971) showed to have a half-time for equilibration of about 6.5 h, suggesting that some specific mechanism may be involved for its insertion through the membrane.

Further evidence for specificity in the insertion of M13 coat protein into the membrane, whether from the inside or the outside, comes from Wickner's observation that the antibody reaction is similar with either spheroplasts or intact cells. Since these cells do not release their periplasmic enzymes, the coat protein must have some special

A hundred years ago

SEVERAL letters have appeared in the *Daily News* calling attention to the fact that on Sunday week red snow was observed to have fallen in several parts of the country—at Forest Hill and Streatham in the south of London, at Reading and at Thurston in Norfolk. This phenomenon was observed in ancient times, and is referred to by Pliny; in modern times it has been frequently observed in all parts of the world, and is familiar to Arctic explorers. The phenomenon is generally ascribed to the presence of an algae, *Protococcus nivalis*.
from *Nature*, **13**, March 23, 415; 1876