transitions between a high-force (on) and zero-force (off) state in the myosin motors. The force in the on state, assumed to be a constant in this simple model, is about 1 piconewton. The rate of transitions between these two states matches the rate of ATP hydrolysis, as expected in the simple tight-coupling model.

If a greater length of actin filament interacts with the myosin-coated surface or the needle is less stiff, the filament may slide at almost constant velocity, as in active shortening of muscle. At near-maximum velocity, the amplitude of the force fluctuations is very small. Interpreting these results with the simple on–off model implies that each myosin stays on for almost the whole period of each ATP hydrolysis cycle, during which the filament slides by more than 100 nm, a distance much greater than the conventional 10 nm power stroke. But this conclusion may depend on the use of the simple on–off model, which cannot account for many of the mechanical properties of muscle. These properties can be explained by postulating an elastic element and a power stroke within the attached myosin head[4,7], and it may be useful to analyse the *in vitro* data in terms of these more complex models. The Osaka group[1] have already embarked on such an analysis for the isometric case.

The results from Uyeda *et al.*[2] complement those of Ishijima *et al.*[1] in showing that filament velocity is also quantized. Actin filament sliding on surfaces coated with a very low density of myosin heads has been characterized at high resolution. Filament velocity decreases with decreasing myosin density or filament length[5], suggesting that velocity depends on the number of actin–myosin interactions. This in turn implies that each myosin actively pulls on the actin filament (executes a power stroke) for only a small fraction of the duration of each ATP hydrolysis cycle. This fraction, called the duty ratio, has been estimated[5] as 0.05. To emphasize the similarity with the on–off model used by the Osaka group, I will refer to this model as the go–stop model. Both models assume random independent action of the motors with a fixed quantum of force or movement. Both omit the elastic character of the motor which is a fundamental element of conventional muscle models[7].

In the go–stop model, when only a few myosins pull on a filament, their contributions to filament velocity effectively add, because it is unlikely that two pull at the same instant. If only one myosin can interact with the filament, its velocity should be the maximum sliding velocity multiplied by the duty ratio. Two myosins should give roughly twice this velocity, and so on. In their new work, the Stanford group[2] has directly observed the predicted quantization of velocity. Multiplying the unitary velocity by the ATP hydrolysis cycle time gives a sliding distance of about 10 nm for each molecule of ATP hydrolysed. This value is equal to the conventional power stroke, as expected in the tight-coupling model.

Passenger interaction

However in the long waiting period between power strokes the motor does not detach from the filament, but continues to interact with it and suppress its brownian motion[2]. When many motors interact with one filament so that it slides at maximum velocity, the total sliding distance during the time each motor hydrolyses one ATP is about 10 nm/0.05, giving a value of 200 nm. This distance is made up of the 10 nm active power stroke, plus a much larger distance over which the motor is effectively a passenger. When many motors interact with a filament, the total sliding distance per ATP molecule hydrolysed over which a given motor interacts with the filament, either as locomotive or passenger, could be almost 200 nm. This interaction distance is much bigger than the length of the myosin head, implying multiple detachment/attachment cycles in the passenger interaction, in contrast with the simplest form of the tight-coupling model.

Both the power stroke and the interaction distance can also be measured in intact muscle fibres in which some of the constraints and uncertainties of these *in vitro* systems do not apply. Many myosin motors and actin filaments are involved in the motion, so the unitary action of a single myosin cannot be observed directly. Nevertheless it is possible to estimate the fraction of myosins that are interacting at any instant by measuring the stiffness of the muscle. During filament sliding at maximum velocity, these measurements[3,8] suggest that the interacting fraction is about 40 per cent. Higuchi and Goldman[3] have now measured the filament sliding produced by liberation of small amounts of ATP in muscle fibres and show that the sliding distance is proportional to the amount of ATP released. At near-maximum sliding velocity, the interaction distance (assuming that 40 per cent of myosins are interacting at any instant) is estimated to be at least 40 nm and probably larger. A similar calculation can be made from the steady state ATP turnover rate in intact muscles, which is five per second for each myosin head during filament sliding at 2 $\mu m\ s^{-1}$ (ref. 9). With 40 per cent of the heads interacting at any instant[8], the interaction distance estimated from these data is 160 nm.

Within the uncertainties of the experi-

RÉSUMÉ

Tunnelling in

THE first tourists to emerge from the British end of the channel tunnel were not Frenchmen in search of warm beer and boiled mutton served with mint sauce, but spiders. The linyphiid spider *Minicia marginella* (Wider) is common in northern Europe, but was unknown in Britain until R. Snazell collected specimens from the British end of the Shakespeare Cliff tunnel workings near Dover, just 5 metres above the shingle beach (*J. Zool., Lond.* **224**, 381–384; 1991). Home Office officials will be interested to learn that the spiders could be permanent immigrants rather than day-trippers: two were found, a male and a female.

Do it yourself

FREE lunches are on the agenda again for high-temperature superconductors. Already H. Matsuzawa and colleagues have demonstrated that electron beams passing through a ring of superconductor will focus themselves to a point. Now, they show (*Appl. Phys. Lett.* **59**, 141–142; 1991) that a suitably shaped tube of superconductor could be used to replace the bulky 'wiggler' magnets of synchrotron radiation sources and free-electron lasers. In each case, the twin principles at work are that the moving electrons generate magnetic fields, and that magnetic fields cannot penetrate superconductors. The back reaction of an electron beam's magnetic halo steers it away from the superconductor surface, so that the electrons can be led around bends like light in an optical fibre. So far, Matsuzawa *et al.* have demonstrated merely that the sinusoidal surface of their shaped superconductor does wiggle relatively low-energy electron beams. But they argue that ultimately such devices will be cheaper and easier to use than the permanent magnets currently used in radiation sources.

Cancer confirmation

A STUDY from S. A. Narod *et al.* (*The Lancet* **338**, 82–83; 1991) provides confirmation of last year's linkage mapping of an early-onset breast cancer locus to the long arm of chromosome 17. In three out of five large families with hereditary breast–ovarian cancer, positive evidence for linkage to the same part of the chromosome was found, although it is still too soon to know if the ovarian tumours in these families are due to mutations within the same gene. The work is the first separate confirmation of a positive linkage for a complex clinically heterogeneous disorder, and contrasts with the disappointing mapping results for disorders such as schizophrenia and manic depression.