development as in the context of learning. This raises the fundamental question of whether activity-dependent mechanisms of learning and development are related. After all, the repertoire of behaviours based on patterns of connections laid down during normal development provide 'memories' no less important than memories acquired in postnatal life. What-

ever the ultimate answer to this question, advances in developmental neurobiology are eroding the traditional distinction between the establishment of neural connections and their subsequent modification. □

Jeff W. Lichtman and Dale Purves are in the Department of Physiology and Biophysics, Washington University School of Medicine, St Louis, Missouri 63110.

Exotic particles debate

Demon nuclei — a closer look

from Sverker Fredriksson and Magnus Jändel

FRANK CLOSE has recently in *News and Views* (*Nature* 296, 305; 1982) questioned our idea that a new form of matter has revealed itself in certain high-energy experiments (*Phys. Rev. Lett.* 48, 14; 1982). Or rather, Close quotes, uncritically, a paper by H. Lipkin (*Weizmann Inst. Rep.* WIS 82/2) which claims that the exotic six-quark particle ('demon deuteron') suggested by us cannot exist, since its properties would violate basic physical laws.

The demon deuteron consists of three diquarks (tightly bound pairs of quarks), not two nucleons ('triquarks') like the normal deuterium nucleus. The gross features of the demon are indeed strange, even for the world of elementary particles. The conjecture that it be almost stable leads, for example, to the requirement that the three diquarks have a net motion (oscillation) relative to the strong force field that makes the whole demon stay together. Lipkin claimed that 'such states cannot exist', and supported this statement with arguments from a non-relativistic potential model. The truth is, however, that such exotic modes of internal motion (called 'spurious' by Close) have been discussed for at least ten years in the literature on ordinary three-quark particles (baryons).

Realistic models for the structure of elementary particles must be founded on field theory, and such models require the existence of 'spurious' oscillations. A particularly illustrative example is given by the appealing 'soliton bag model' of T. Lee and others, where the confining field explicitly carries mass and momentum, which in turn make it oscillate relative to the constituent quarks. The interesting question is whether such states are experimentally identifiable among all the hundreds of other quark configurations.

In a revised version of the *Weizmann Institute Report* reviewed by Close, Lipkin has now (*Phys. Lett.* 117B, 437; 1982) changed his view, and claims that although demons might exist they would be experimentally uninteresting. This statement is based on the view that no particles with net oscillations of ordinary quarks have ever been observed, which can be understood if such excitations occur only at very high

energies, at which the systems are highly unstable. Consequently, a corresponding motion of three diquarks would be even less interesting. To support this view Lipkin quotes a particularly popular quark model, the MIT bag model, which is a convenient approximation of the more fundamental field theoretical approach. A closer look at that model shows, however, that all those exotic baryon excitations are not 'pushed up' to high masses, as stated by Lipkin, and some of them are indeed suggested in the literature to correspond to experimentally observed particles. One of those (the ' Δ 35') has its three quarks in a configuration that resembles our three-diquark demon, and also a mass below that

Frank Close replies

A three-body system has only two independent 'internal' orbital angular momenta. The original version of the demon deuteron required three p-wave orbitals. This is the essence of Lipkin's criticism: for a system comprised solely of three diquarks such a demon deuteron cannot exist.

These ideas, well known to nuclear physicists, have been successfully applied to quark systems during the past 15 years. Lipkin was one of the pioneers and has probably published more papers on quarks than any other theorist. The statement made by him in the circumstances of his original critique is, in my opinion, correct.

But quarks are confined — unlike nucleons — and this might provide a hidden further degree of freedom, such as in bag models. In such an eventuality, three genuine orbitals and a demon deuteron could result. That is the essence of the above article which now draws heavily on the bag model.

Their statement that such exotic modes "have been discussed for at least ten years . . ." gives a misleading picture. It is indeed true that ten years ago Drell and Johnson and, later, MIT bag theorists proposed such states, but it might be amusing to report that they thanked Lipkin for 'clarifying discussions' about these very spurious states. These models, *prima facie*, predict numerous such states which have never been confirmed in any experiment.

needed for the demon to be stable.

Except for such purely qualitative hints, there is not much to go on when trying to compute the demon mass, because current quark models seem incapable of estimating, with accuracy, the masses of new classes of elementary particles, that is, quark configurations other than those the models were designed to describe in the first run. In addition, the extra complication of a net quark oscillation is difficult to treat in any model, and the calculations quoted by Lipkin are subject to such additional assumptions that they are of little value for the demon case.

The debate about the comings and goings of demons has thus turned into a discussion of the ability of quark models to explain the normal elementary particles. We are, however, expecting the final judgement about demon nuclei to come from our experimental colleagues. The ongoing experiments at the Lawrence Berkeley Laboratory will hopefully settle the matter in around one year's time. Some interesting preliminary results have, in fact, been published recently by T. Liss *et al.* (*Phys. Rev. Lett.* 49, 775; 1982) and reported on in *New Scientist* (21 October 1982, p. 160). □

Sverker Fredriksson and Magnus Jändel are in the Department of Theoretical Physics, Royal Institute of Technology, S-100 44, Stockholm, Sweden.

This suggests that they do not exist or (which for practical purposes may amount to the same thing) are pushed to high masses where they are undetectable. This is the modern view. The Drell-Johnson model is now superseded in the opinion of most experts. There is even dispute as to whether such states exist in a bag model context: bag model applications to excited systems are still crude and in their infancy.

Finally, the statement that some such 'exotic' baryon excitations are experimentally observed. There is one baryon resonance observed that could be a collective excitation of quarks relative to the bag — if the bag is dynamical and not phenomenological, a point by no means understood — the ' Δ 35' mentioned above. However this baryon is perfectly consistent with being a conventional three-quark excitation (at the $N=3$ level in a harmonic oscillator potential), and to claim support for 'exotics' thereby is, I think, very risky.

These are the reasons why I quoted Lipkin (not uncritically as they claim) and why I am pessimistic that demon nuclei exist in the way that Fredriksson and Jändel now argue for them. If experimental selection panels have managed to find time and money to search for such entities, then we naturally all hope that some unexpected and clear signal will be seen. □

Frank Close is in the Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX.