100 YEARS AGO

A few interesting facts with regard to the kea, or sheep-eating parrot, of New Zealand are related in the July number of *Leisure Hour* by Dr. F. Truby King. The intense curiosity of these birds is stated to be sufficient to account for the habit of eating sheep acquired by them. Dr. King thinks it is probably a mistake to suppose that the kea designedly makes at once for the kidney fat of the sheep upon which it has pounced. It eats into various parts of the body, though perhaps more often into the region of the kidney, as it is there that the kea gets the firmest stand on the back of the running sheep. This view is strengthened by the fact that the bird prefers double-fleeced sheep – that is, such as have remained a whole season unshorn, on which it obtains a firmer grip.

From *Nature* 29 June 1899.

50 YEARS AGO

According to Darwin the long neck of the giraffe is the result of natural selection acting through the animal's tree-feeding habit. He wrote: "the individuals which were the highest browsers and were able during dearths to reach even an inch or two above the others will often have been preserved." There are serious objections to this argument. (1) During dearths … the recurrent wastage of young giraffes would threaten the species with extinction. (2) Under such extreme conditions of dearth the grass-eating African ungulates would also have been so short of food that it is difficult to see why more of them did not develop the leaf-eating habit and the excessively long neck. (3) Bull giraffes tend to be several inches taller than the cows, so that during each dearth males would be naturally selected at the expense of the females – another factor likely to lead to rapid extinction. An alternative theory free from these criticisms has occurred to me. … The giraffe is actively preyed upon by lions and leopards. It is reasonable, therefore, to explain the excessive length of its forelegs as the effect of natural selection acting continually through the hunter–hunted relationship. … That the neck has elongated to a degree only just sufficient to keep pace with the increasing length of the legs is suggested by the fact that the giraffe has to splay its forelimbs awkwardly to drink.

From *Nature* 2 July 1949.

Box 1: Designer photons

The basic principle of the powerful microscopes used to examine proton interiors is extremely simple. Electrons (or positrons) are accelerated to high energy, and made to collide with protons (or other atomic nuclei). The main interactions of electrons are through the well-understood processes of electrodynamics. In quantum electrodynamics (QED), its modern version, these interactions are pictured and calculated as the exchange of real or virtual photons.

Real photons are completely characterized by their energy. Their momentum is simply equal to their energy (divided by the speed of light). For virtual photons, which exist only for a limited time, the energy and momentum are independent variables. In either case, real or virtual, the wavelength is inversely proportional to the momentum.

When an electron at SLAC interacts with a proton it generally gets deflected, so that its energy and momentum change. The difference is carried off by a virtual photon. If the momentum of this virtual photon is large, it will have a short wavelength and provide excellent spatial resolution. If, in addition, it is a 'highly virtual' photon – that is, if there is a big mismatch between its energy (divided by the speed of light) and momentum, then it has a very short lifetime and provides excellent time resolution. By analysing how frequently virtual photons of different kinds get absorbed – that is, by noting how frequently you observe different electron deflections – you can effectively take snapshots, with adjustable spatial and time resolutions, of the charge distribution inside protons. **F. W.**

the proton that are electrically neutral do not show up in these snapshots. (Biologists face a similar problem, in that they are often interested in materials that are basically transparent. They use various tricks, such as staining or attaching fluorescent molecules, to work around this difficulty.) What you see in an accelerator is quarks[2]. Although these unusual particles are notoriously 'well confined', that is, impossible to isolate, they show up quite clearly in these short-time-exposure snapshots. You can even measure their peculiar fractional electric charges, their spin and the energy and momentum they carry.

When this is done, and the results analysed, physicists discover that they have a missing-mass problem on their hands, rather similar to the one faced by astronomers. The total energy in all the quarks does not add up to the energy in the proton. It is less than half. In the early days of this subject, Richard Feynman (who first carried out this kind of analysis) greatly annoyed his colleague Murray Gell Mann (a paladin of quarks) by calling the constituents of protons 'partons', and refusing to acknowledge that partons are quarks. As it turns out, each rival had part of the truth. Some of the partons are quarks, but many are gluons. The quarks carry all the electric charge, but most of the energy is in the colour gluons.

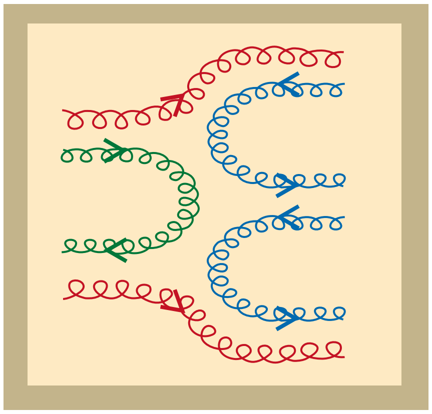

Figure 2 **Recombination of gluons. In Fig. 1, a single smudgy gluon was resolved into two sharp ones. If gluon seas were always dilute, then two separate smudgy gluons should be resolved into four sharp ones. But when gluons are more densely packed (as shown), two could be resolved into three, suggesting recombination has taken place.**

So what's new? The latest and greatest accelerators allow us to take snapshots with ever shorter time exposures. We can thereby resolve in ever finer detail the dynamical processes going on inside protons. When this is done, a remarkable result emerges. In the shorter-exposure pictures, one finds that the balance of energy tilts more and more toward gluons. What previously appeared as a blurry quark is on sharper examination revealed as part quark, part gluon. Nor is the concept of gluons free from challenge. They, too, on sharper examination, are revealed to be composites of several lower-energy gluons (Fig. 1). The closer we look, the more a proton (or neutron) appears as a bundle of soft glue[1].

This remarkable phenomenon — the gluonization of the proton — was predicted theoretically[3]. Indeed, it reflects quite directly one of the most profound features of the fundamental theory of quarks and gluons. According to QCD, the very powerful, complicated forces that confine quarks, preventing them from drifting away over long periods of time, are due to the accumulated effect of a surrounding cloud of short-lived virtual