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Can high energy physics be too easy?

THE Harvard physicist Sheldon Glashow, who with 'BJ' Bjorken invented charm, remarked to a visiting *Nature* reporter last week that we were in danger of losing a whole generation of high energy physicists. Not, for once, for lack of jobs or money but because students were turning to mere calculation, and not tackling the 'real problems' of physics. His students, said Glashow, want to play with the equations of 'gauge theory', developing new solutions and thus investigating the properties of the equations, rather than investigating the properties of matter. Gauge theories appear to have made life too easy. But what exactly are the 'real problems' that the students should tackle?

Gauge theories, with a useful addendum known as 'spontaneous symmetry breaking', have become the predominant theory of particle physics in the last few years. By them, most of the threads of the subject can be hustled into a fairly respectable shape, with only a few loose ends. The loose ends can encompass a great deal. For example, one of the major problems on which physicists cracked their heads in the 60s—what happens when one hadron, such as a proton, hits another—can now be seen as little more than a technicality. The complications are caused by throwing a bunch of quarks at another bunch, rather than single quarks at single quarks.

The quark-quark interaction seems now to be explicable by the gauge theory known as 'quantum chromodynamics' (QCD); the rest of hadron dynamics is complication. Even confinement—the means by which quarks are retained in the hadron—may be seen as an effect ultimately derivable from QCD. It may be that high energy physics is spawning a sub-group of 'hadron physicists', who will be left to deal with the complications of hadrons, just as the subject spawned nuclear physicists at an earlier date. In this view, the 'real physics' comes in explaining the properties of the quarks (and the leptons, like the electron and the neutrino, which come with them).

For Glashow, the deep problem is why nature chooses to repeat itself. The everyday, low energy world can be explained with two quarks (up and down) and two leptons (electron and electron neutrino). But then comes another set—more massive, but mirroring the properties of the first. These are the strange and charmed quarks, the muon and muon neutrino. Experiment appears to be revealing a third set, and there seems little reason why there should not be more. Why this repetition? Glashow has been working on it, but has been unable to make much progress. He has turned to the history of physics to see if such a problem has faced physics before; he has concluded that it is unique.

For Steven Weinberg, one of the creators of the gauge theory paradigm and himself a Harvard physicist, the great challenge is to incorporate gravity into the gauge theory unification of forces. Judging by the activity of the CalTech physicist Murray Gell Mann, he agrees with Weinberg. Both have been working on 'supersymmetry', the invention of CERN theorists, which offers hope of unification. But, Weinberg told our reporter, two years of great technical progress have brought little contact with experiment.

On the experimental side, the next great leap will probably be the testing of the gauge theories, and the discovery of precisely which gauge model fits nature. Many experimenters are by nature iconoclasts and will be happiest if they defeat gauge theory; but the majority expect it to survive. The experiments will probably reveal more quarks and leptons, and the plethora of particles that gauge theory predicts: intermediate vector bosons, Higgs particles and the like. And perhaps the unexpected that will lead us forward.

Experiment is ultimately the source of all physical knowledge, but among theorists Glashow's students, and others interested in the apparently purely mathematical properties of gauge theories, may yet be tackling the 'real problems'. In the past, mathematical juggling yielded Lagrangian and Hamiltonian mechanics from Newton's theory; both were a necessary precursor to an understanding of quantum mechanics. Newton had no concept of energy, nor of the principle of least action, both extremely fruitful concepts which derive from the original Newtonian equations.

Rutherford is said to have remarked "one should no more let the mathematicians take over physics than let the military take over power". But there should be an exception to his maxim: when the mathematicians are creating new physical concepts with the equations at their disposal.

Many of the properties of gauge theories can only be investigated in the 'classical' approximation—that is, ignoring quantum effects and treating the equations just like those of Maxwell's equations of electromagnetism; quantisation comes later. This is attractive to students, who find themselves facing problems not unlike the ones they solved as undergraduates, with the exciting difference that they are at the frontier of physics. The calculations are very sophisticated, and require the development of great skills and ingenuity. Should they be discouraged?

Particle physics has been moving too fast; it needs time for reflection. Gauge theories with spontaneous symmetry breaking are strange mixtures of ideas; it is not at all clear that their significance has been thoroughly absorbed yet, or that they have been cast in anything like their most illuminating form. So let the mathematicians play—provided that ultimately, they come up not with mathematics, but with ideas. □