either roots or shoots in a manner consonant with what we know about the effect of these hormones on normal tissue cultured *in vitro*. The products of these genes could either themselves catalyze some step in hormone synthesis, or derange control of the plant's own synthetic or degradative pathways. These possibilities can now profitably be investigated.

The answers to these fundamental questions will probably have profound implications for the use of Ti plasmids as vectors. Important candidates for improvement are the grass crops, but monocotyledenous plants lie outside the normal host range of *Agrobacterium*, which includes most dicotyledons and some gymnosperms. This could be because Ti plasmid DNA cannot enter the cell, or because it fails to be integrated into plant DNA, or simply because the morphogenetic restraints on cell division are not disrupted by the oncogenic genes in monocotyledons as they are in dicotyledons.

The ironic possibility that Ti plasmids are already 'disarmed' with respect to grass crops causes one to wonder if their strategem of inserting DNA into another organism is unique. It has only been detected in the case of the Ti plasmids because of its oncogenic effect, which is not an essential part of the strategem. And is this bizzare transfer of genetic material unidirectional, or could the Ti plasmid have picked up its T-DNA sequences from a plant in the first place?

Ten years ago work on crown gall was the poor relation of cancer research. Now as a vector for crop improvement and as a research tool, as a system for studying the biochemical genetics of hormone action, and as an extraordinary phenomenon in its own right it holds a central place in the new discipline of plant molecular biology. Those who study it enjoy a rare opportunity to do basic research with immediate and far-reaching practical implications. □

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High-energy physics

Structure in electrons?

from Frank Close

ARE electrons and quarks the ultimate frontier of matter or are they perhaps built from more fundamental particles so far undetected? What hope is there of answering this question in the near future? In a recent paper (*Phys. Rev. Lett.* **50**, 811; 1983), Eichten, Lane and Peskin point out that prospects are perhaps more exciting than has been generally realized.

When we say that electrons (or quarks) are pointlike, we implicitly add the caveat "subject to the limits of resolution currently available". A plane appears pointlike to a radar beam, as does an atom to visible light. As wavelength of the probe decreases, resolution improves and new structure appears.

The uncertainty principle places an inherent limit on resolution, of course. To resolve submicroscopic distances requires high-momentum high-energy probes. This is the domain of the high-energy or particle physicist. As the power of particle accelerators has increased so have the resolvable distances been reduced. The pointlike atom of the late nineteenth century became a structure with a pointlike nucleus; by the 1950s nuclear structures were resolved; and by 1970 the proton itself was seen to contain quarks. At the best resolution now available — distances of order 10^{-18} m can be probed — no inner structure has been detected for quarks or for electrons and their associates. For all practical purposes they are structureless.

Even so, there are some tantilizing problems. Long before atomic structure was discerned, Mendeleev drew up his periodic table of the elements. With hindsight we can see here the first hint of the 'non-elementarity' of atoms. More recently the eightfold-way patterns that were noticed in the subnuclear particles (proton, neutron, pion and so on) gave the clue that deeper structure might be responsible for this regularity. And indeed it was; a decade later the quarks were seen within the 'elementary' particles.

Today we know six particles like the electron ('leptons') and five (probably six) quarks. They appear elementary to the experimentalist — just as protons and atoms once did. But there are intriguing regularities in their behaviour. 'Generation' patterns have been discerned (*Nature* **271**, 406; 1978), and even the families of quarks and those of the leptons seem to be related.

It is possible that this is a profound and direct consequence of grand unified theories of matter and forces; on the other hand it might be a consequence of a deeper structure that is common to quarks and leptons. Some of the versions of grand unified theories require substructure for some of the particles. Theorists estimate that substructure and/or new phenomena could occur at energies of the order of 1–10 TeV (= 1,000 GeV), slightly above present accelerator energies, and might already have been manifested in some cosmic ray anomalies.

What can we say quantitatively about substructure?

If electrons contain constituents, these will manifest themselves in scattering experiments between electrons and positrons. As the collision energy approaches that corresponding to the size of the electron, Λ, the scattering cross-section will deviate significantly from the standard value predicted by quantum electrodynamics (QED) for an elementary electron.

Tests for substructure can be made by comparing data with QED predictions. QED is so well established that these tests are referred to as 'model-independent'. Eichten, Lane and Peskin (*Phys. Rev. Lett.* **51**, 811; 1983) have now shown that we can improve upon these if we are prepared to make model-dependent assumptions.

Without commitment to any specific model of substructure, they note that some general features are rather well accepted. In particular, the electron and positron, being composite, can interact by exchanging their constituents (analogous to covalent atomic forces). Eichten and his colleagues argue that the best way to search for electron substructure is to study the angular distribution of the scattered electrons and they show that if $\Lambda \sim 700$ GeV, even today's 'low-energy' experiments at PETRA Hamburg would yield a 5 per cent deviation in the angular distribution of the scattered particles relative to the standard expectations. Such an effect is not seen. To convert this into a limit on Λ requires knowledge of the nature of the constituent's interactions.

The authors consider a general class of models where the constituents have spin ½. There are two ways in which they can interact: like standard electromagnetic interactions — 'vector interaction', or like neutrinos with a handedness — 'left handed' or 'right handed'. The forms of the angular distortions are different for the two types of interaction and the limit on Λ is stronger in the former case (>1,500 GeV compared with >750 GeV for the latter).

These results are interesting because some theorists believe, for quite different reasons, that a new physical scale Λ could occur between 1 and 10 TeV. An electron–positron facility that could copiously produce the Z° at 90 GeV should set limits for Λ >5 TeV (the event rate at Z° resonance is high, so good statistics can be readily obtained). The coming generation of multi-TeV colliders should be able to detect substructure up to $\Lambda \simeq 10$–50 TeV. One may indeed hope for significant effects at energies well below Λ. If $\Lambda \simeq 1$–5 TeV then deviations from the standard model will soon be observable. If the W and Z bosons are confirmed this year at CERN (*Nature* **302**, 478; 1983) then these ideas will begin to loom larger in everyone's mind. □

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