Rumours of the February 17 event spread rapidly, and two explanations for understanding it within the framework of the popular model of merging pairs of neutron stars in distant galaxies were quickly forthcoming. Assuming that the initial GRB occurs during a merger between two neutron stars, a second burst might occur when the highly relativistic ejected material strikes a dense ring of material that was thrown off much earlier in the evolution of the merging binary[4]. Alternatively, the delayed emission might occur when the merger ejecta slams into interstellar matter located far from the merger site[5]. However, the production of photons with energy greater than 10 GeV remains a challenge in both cases.

The February 17 event might also be interpreted as a gravitationally lensed GRB at a cosmological distance. In this case, the two bursts of photons observed would have followed paths that differed in length by more than one light hour. This hypothesis sidesteps the issue of the physics of GRB sources at cosmological distances, and appears unlikely, as gravitational lensing does not alter the spectrum of the source, whereas the 'second' event here had a much more energetic spectrum than the first. In fact, it was not seen at all by BATSE or the GRB detector on board the Ulysses spacecraft.

Many astrophysicists still find it desirable to have the GRB sources within our Galaxy as opposed to lying at cosmological distances, as the physics behind their non-thermal, non-monotonic properties would be far easier to imagine. At present, the main hope for a Galactic distribution of sources is a very extended halo. Recently considered are GRB sources that are ejected from our Galaxy at high speeds, continue to burst for at least 10^9 years, and are gravitationally perturbed by the galaxy M31 (ref. 6). These conditions result in a very extended and well mixed distribution of sources that mimic the observed isotropy and radial cut-off.

To my mind, the high energies and long duration of the burst on February 17 might be explained by the accretion of an asteroid onto a high-speed Galactic neutron star[7]. In this model, the neutron star has a magnetic dipole of typical strength (10^{12} to 10^{13} gauss), and is rotating too slowly to be observable as a pulsar. The angular momentum of the infalling asteroid twists the magnetic field lines so much that their eventual reconnection accelerates electrons and ions to high energies[8]. The electrons radiate their energy promptly as a GRB. It is plausible that the ions stored in the neutron star's magnetosphere reach far higher energies than the electrons, and ultimately produce gigaelectronvolt photons long after the initial event.

Observations of other GRBs like the February 17 event would help to narrow down the theory. With luck, the next such GRB will occur near one of the poles of CGRO's orbit, so that the Earth will not get in the way, and we might find out whether the emission of gigaelectronvolt photons was continuous during the missing hour. Also, the discovery of such an event in progress might provide time enough for Earth-based teraelectronvolt detectors to turn towards the source to search for unattenuated γ-rays. Teraelectronvolt photons from cosmological sources are unlikely to reach the Earth, as they have a high probability of interacting with the cosmic microwave background, whereas such γ-rays from Galactic sources would not experience this attenuation. If teraelectronvolt photons are detected, this would suggest that GRB sources do not lie at cosmological distances.

There are at least three additional observations that would help to resolve the GRB controversy. First, if the repetition of GRBs[9,10] turns out to be genuine, then it would argue against the theory of a neutron-star merger, as such events cannot repeat. Better BATSE positions are required to rule on this[11]. Second, measuring the column densities to GRBs at soft X-ray wavelengths may reveal the relevant distance scale[12]. Afterglows from GRBs have been detected at such wavelengths[13]. Third, if GRB sources lie at cosmological distances, then a dipole anisotropy will eventually show up in their distribution on the sky, just as is the case for the cosmic microwave background. It is estimated that about 10^4 BATSE bursts will be required to reveal this[14]. Of course, some hint of an excess of sources towards the Galactic Centre or the galaxy M31 may show up first, which would argue in favour of extended-halo models for the bursts. ☐

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CATALYSIS

What promise for dendrimers?

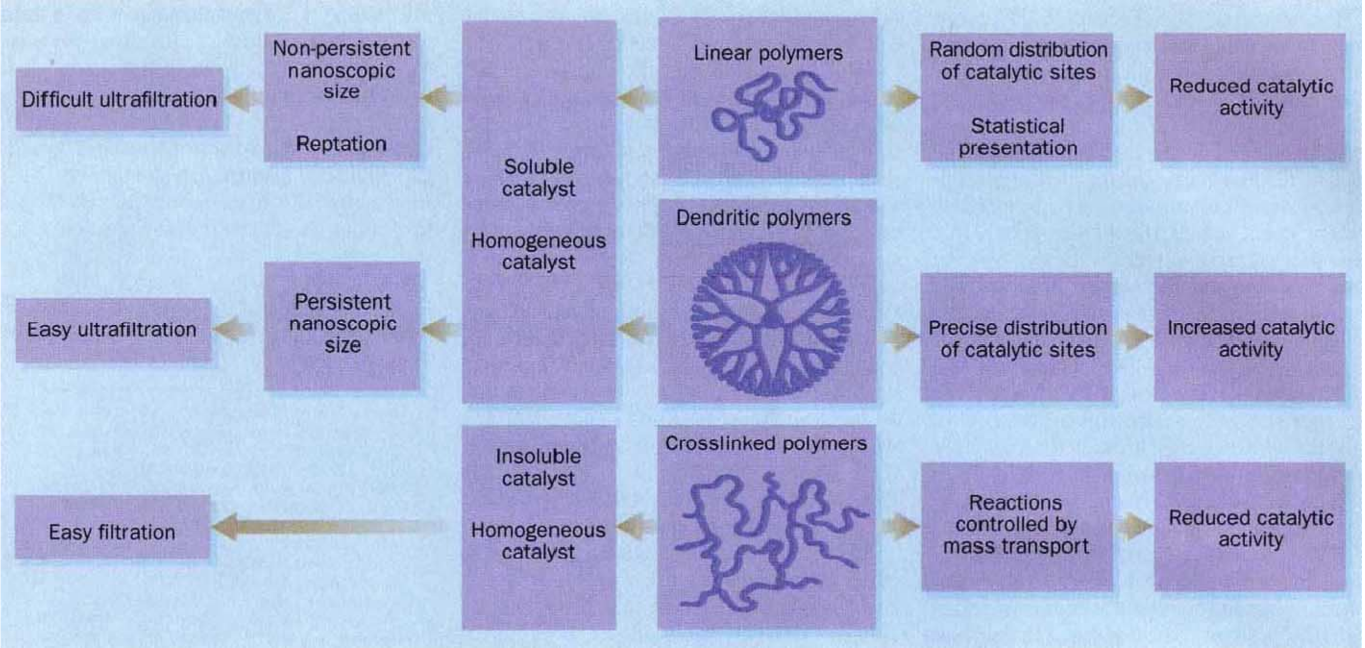
Donald A. Tomalia and Petar R. Dvornic

WHAT potential could precise macromolecular fractals[1], constructed by geometrically progressive structural branching, possibly offer to the scientific and industrial community? This is a question that has been asked many times over the past decade, since the discovery of the new class of polymeric architecture called dendrimers[2]. Would these tree-like molecules initiate new fields of application and research or would they merely be remembered as esoteric objects of symmetrical beauty? On page 659 of this issue, a group led by Gerard van Koten[3] suggests the former, by describing the first example of a catalytic dendrimer with active metal sites residing on the outer surface of the snowflake-like structures.

The species that Knapen *et al.*[3] have prepared is a well characterized, soluble polycarbosilane dendrimer[4,5] with diamino arylnickel(II) complexes presented as precisely ordered groups on the surface of this nanoscale scaffolding. As true multi-metallic species, these compounds assisted in addition reactions of polyhaloalkanes to double bonds, with catalytic activity and regiospecific formation of 1:1 addition products comparable to that observed for the monometallic complexes.

The hope is that these dendrimeric catalysts will retain the benefits of homogeneous catalysts (faster kinetics, accessibility of the metal site and so on) but that, unlike most such species, they will be readily recoverable after reaction. The large (nanoscopic) size and relative rigidity of dendrimers should allow them to be removed from solvent streams by ultrafiltration methods (see figure).

Classical polymers have exerted tremendous influence on the field of chemical reaction catalysis. Polymeric catalysts, which consist of conventional catalytic species anchored to a polymer carrier, have the advantage that they are usually considerably less corrosive and more stable, active and selective than their mononuclear counterparts. Depending on whether the polymer carrier is linear or crosslinked, the polymeric catalyst may be soluble (allowing homogeneous catalysis) or insoluble



The benefits of branching — schematic illustration of the three main types of polymer catalysts, together with their distinguishing properties and functional characteristics. The properties to the left of the structural sketches result from the physical and chemical characteristics of the polymer carrier, whereas those to the right result from the locations of catalytic sites.

(heterogeneous catalysis). The latter has the advantage that it can be easily separated by filtration from the product reaction mixture, but the disadvantage is that reactions taking place on the interior surface of a porous catalysis particle encounter resistance to mass transport through the pores.

The performance of a homogeneous polymeric catalyst is determined by the physical and chemical properties of the catalytic sites, by the distribution of these sites along that polymer backbone, and finally by the accessibility or presentation of these sites to the reacting substrates. Under given reaction conditions, these factors are usually governed by the polymer chain conformation, which in turn depends on the reaction solvent and temperature. The rate of catalysis depends on the rate of diffusion of both substrates and products to and from the catalytic sites. Therefore, the more densely coiled the catalyst-bearing polymer backbone, the less accessible are the catalytic sites, and usually the more inefficient the overall catalytic process. Consequently, an ideal polymeric catalyst should be a soluble, multifunctional macromolecule, favouring configurations in which all active sites would always be exposed towards the reaction mixture so that they were easily accessible to migrating reactants and unlikely to be hindered by catalytically inactive components of the carrier molecules.

In addition, the polymer scaffolding should show all the advantages of insoluble catalysts, particularly in ease of separation from the resulting reaction-product mixtures. For this reason, the ideal polymeric catalyst should be substantially different in size from the substrates or reaction products and be persistent in that difference — it should not, for instance, be able to change its hydrodynamic volume by reptating through a filtration barrier.

The authors have not yet directly compared the catalytic activity of these dendrimers against their linear and crosslinked counterparts, so they cannot yet set numbers on the anticipated advantages discussed above. Nonetheless, there is an impressive list of demonstrated physical and chemical properties attributed to dendrimers that clearly differentiate them from classical polymer systems. The list[6,7] includes persistent and controllable nanoscale dimensions (1 – 100 nm); controlled shape design based on the choice of core unit; precise masses (with polydispersities of $\overline{M}_w/\overline{M}_n \approx 1.0005$); chemically reactive surfaces (over 100 surface reactions and modifications have been demonstrated); interiors that could be specifically designed to be suitable for hydrolytically or thermally demanding environments (over 30 different dendrimer interior compositions are known); and designable solvent solubilizing surfaces (hydrophobic or hydrophilic types).

These properties, or some combination of them, are what make dendrimers so useful in such non-catalysis applications as nanoscale reactors[8,9], micelle mimicry[10,11], magnetic resonance imaging agents[12], immuno-diagnostics[13], gene delivery vectors[14], nano-antennae[15] and nano-scopic building blocks for more complex megamolecular structures[16].

At present, classical polymer architectures are used in a wide variety of catalytic applications such as classical organic synthesis, cracking and isomerization of hydrocarbons, nitrations, esterification hydrolysis and decarboxylations, and as supported transition-metal catalysts and polymerization initiators, to mention a few. Now Knapen *et al.*[3] have opened a new avenue by introducing these first dendrimer-supported catalysts. With the possibility of combining catalysis with other unique features of dendrimers, expectations are running high in this area. Only time and more experimentation will determine whether dendrimer catalysts will live up to their generous promises. ☐

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