the form of a simple indicator of longitudinal polarity, or a continuous gradient of information or a series of discrete markers.

Other observations have suggested the cellular landmark hypothesis favoured by Ho and Goodman. Before the peripheral pioneers axons appear, glia-like cells are found in the lumen of the appendage and in contact with the inner surface ofthe epithelium. These cells are found at regular intervals along the presumptive path of the pioneers[3-5] and could provide a series of stepping stones between the tip of the appendage and its base[3]. Later the glia ensheath the pioneers to form a proper nerve bundle. Ho and Goodman observed several other conspicuously located cells which could act as landmarks for the pioneers. Furthermore, the monoclonal antibody which they used for many of their observations stains growth cone filopodia very clearly and shows that they extend for some 50 μm. Thus, at no time need an axon be navigating without being in 'filopodial grasp' of a landmark cell.

The three proposed substrates for guiding pioneer axon growth now need to be tested by experimental manipulation, such as selective ablation of putative landmark cells. Ultimately these studies must lead on the one hand to an investigations of the molecular mechanisms underlying the preferential growth of pioneers over their chosen substrates and on the other hand to a study of the principles of spatial organization which generate these substrates at their appropriate locations — the fundamental unanswered question of developmental biology. □

1. Harrison, R.G. *J. exp. Zool.* **9**, 787 (1910).
2. Bate, C.M. & Grunewald, E.B. *J. Embryol. exp. Morph.* **61**, 317 (1981).
3. Bate, C.M. *Nature* **260**, 54 (1976).
4. Edwards, J.S. in *Identified Neurons and Behavior of Arthropods* (ed. Hoyle, G.) 483 (Plenum, New York, 1977).
5. Edwards, J.S. & Chen, S.-W. *Wilhelm Roux's Arch. dev. Biol.* **186**, 151 (1979).
6. Keshishian, H. *Devl. Bio.* **80**, 388 (1980).

Discovery of pre-galactic lithium

from Bernard Pagel

THE reality of the hot big bang is attested by galaxy redshifts, the 2.9K microwave background and evidence for evolution in the statistical properties of distant quasars. Indeed, if grand unified theories fulfill all their promises, then such basic facts as the existence of matter (rather than antimatter) and electric charge can also be taken as consequences of the big bang. These fundamental effects were imprinted on the Universe less than 10^{-35} seconds after it was born, while the last scattering of the microwave background took place about a million years later when protons combined with electrons and space became transparent. Galaxies and stars were presumably formed later still.

In an intermediate phase, when the Universe was about one second old and its temperature around 10^{10}K, neutrinos decoupled leaving an excess of protons over neutrons. During the next two minutes or so these combined in nuclear reactions to make deuterium, helium-3, helium-4 and lithium-7, production of heavier elements being aborted by the absence of stable nuclei at mass numbers 5 and 8. The resulting pre-galactic composition of cosmic matter, consisting chiefly of hydrogen and helium-4 in proportions of about 3:1 by mass, has since been modified by cycling of some of the material through stars. This has affected material in our neighbourhood by adding a mass fraction of 1 or 2 per cent of carbon and heavier elements and a similar amount of additional helium-4. Deuterium, on the other hand, is totally destroyed in matter cycled through stars, and helium-3 and lithium-7 can be both created and destroyed, so that the net effect of stellar evolution on these two species is rather uncertain.

A remarkable claim by Monique and Francois Spite, of the Meudon Observaory near Paris, that something at least very close to the pregalactic lithium abundance can be measured directly (see this issue of *Nature*, p.483), may now provide additional constraints on this view of the early Universe.

The pregalactic composition of cosmic matter depends on a number of parameters of cosmology and particle physics, notably the ratio of baryons to photons (or, equivalently, the present mean density of ordinary baryonic matter) and the number of lepton flavours, together with the net charge number and various lepton numbers that are believed to be zero or negligibly small. As a result, the determination of pregalactic abundance provides interesting constraints on these parameters and tests the consistency of the entire picture. For example, the presence of observable deuterium in the interstellar medium implies that the Universe cannot contain a sufficient density of ordinary matter to 'close' it, that is, eventually to halt the expansion by gravity, although it could be closed by non-baryonic matter such as massive neutrinos, if these exist. A still more severe upper limit to the density is provided by the observation that the mass-fraction of helium in emission-line galaxies of low oxygen abundance (in which the gas has accordingly undergone little recycling through stars) is below 25 per cent, which implies that the baryon/photon ratio (resulting from the primordial excess of matter over anti-matter) is below 4×10^{-10} or $\Omega_b < 0.03$ (assuming three neutrino flavours and a Hubble constant of 75 km s^{-1} Mpc^{-1}) where Ω_b is the fraction of the closure density supplied by ordinary baryonic matter. If, however, the density were less than about ⅓ of this upper limit, corresponding to a helium abundance of under 23 per cent, then the expected pregalactic abundances of deuterium and helium-3 would become embarrassingly large. Thus a really accurate determination of the pregalactic helium abundance would provide a very severe test of the consistency of canonical big bang models, if only it could be carried out. Unfortunately, the prospects of finding the pregalactic helium abundance to better than 5 per cent are not very good.

What about lithium in all this? The 'cosmic' mass fraction of lithium-7, deduced from meteorites, is 5×10^{-9} and a similar amount is found in the atmospheres of the youngest stars. In older stars, however, and notably in the Sun itself, lithium is depleted because the surface layers are mixed in the course of time with

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100 years ago

THE mines opened a short time since in China in the province of Chihli, with the special support and patronage of Li Hung Chang, have recently become the subject of much adventitious interest in Europe. It was believed that, with sufficient transport, one thousand tons a day could be raised for many years from the present pits, while it was said that fifty collieries of an equal size to the present one could be opened in or near Kaiping. The information, therefore, telegraphed by Reuter's agent in Shanghai that the further working of the mines had been peremptorily stopped by the Government, came with a shock to many interested in progress in China. It was stated that a censor in a memorial to the throne complained that the long galleries in the mines, and the smoke of the foreign machinery, disturbed the earth dragon, who in his turn disturbed the spirit of the Empress, who died some months ago, and who was buried about a hundred miles off. The irate spirit of the departed lady promptly took vengeance by afflicting the denizens of the palace in Peking with measles. The latter were, the censor is reported to have said, distintly traceable to the Kaiping mines, which interfered with the *fêng-shui*. The conclusion was obvious: the mines must be stopped. Such was the story told by the Tientsin correspondent of a Shanghai newspaper. The latest information from the East enables us to say that the mines are still working as usual, and there is not the slightest evidence that there is or has been any intention of interfering with them. It is even denied that such a memorial as that mentioned above has had any existence except in the imagination of a *gobemouche* at Tientsin. However this may be, it must be confessed that the petition has a Chinese ring about it, and that the method of argument is one sufficiently familiar to readers of the *Peking Gazette*.

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