interfered with normal cellular contact mechanisms such as intercellular communication or adhesion; this interpretation is supported by the observation that the neural epithelium subsequently develops a looser structural organisation than normal[18].

Morphogenetic patterns and mechanisms in postimplantation embryos present serious problems of analysis because of their enormous complexity. However, we must come to terms with these difficulties if we are to improve our ability to interpret and predict causes and origins of human malformations, and to be able to extrapolate from the results of experimental work on laboratory animals to man. □

Speckle interferometry of Pluto

from David W. Hughes

THIRTY years ago Kuiper used the 200-inch Mount Palomar telescope and a 'disk meter' to measure the diameter of Pluto, the ninth planet of the Solar System. He found a value of about 5,900 km but was considerably worried by possible systematic errors. The disk meter produces an artificial image of variable angular diameter, brightness and colour. These quantities are then adjusted until the artificial image and the image of Pluto look similar. The angular diameter of the planet can then simply be read off. Times change and in March 1978 S. J. Arnold and A. Boksenberg of University College, London and W. L. W. Sargent of the California Institute of Technology used the same telescope and observed the same planet but this time with a speckle interferometer at the Cassegrain focus. The value obtained for the diameter was 3,600 ± 400 km, this value however depending on the assumption that the planet disk was limb darkened. Their results have been published in a recent edition of *The Astrophysical Journal* (**234**, L159; 1979).

Speckle interferometry is a fascinating technique which has been developed extensively in the past 10 years and has been used to measure the diameters of stars, the separation of binaries and to study fine structure on the Sun and on the surfaces of supergiant stars. Atmospheric turbulence distorts the plane radiation wavefront from the astronomical object, a wavefront which has travelled more or less undisturbed through space. This corrugation serves to make a single large telescope mirror act as a multitude of smaller ones with individual sizes of around 10 cm. Small erratic movements are produced in the image position and the overall image is blurred, distorted and considerably enlarged. Turbulence is the main limitation to the resolving power of the telescope and the resulting image can be up to 80 times larger than the diffraction-limited image (the so-called Airy disk).

The speckle interferometric technique relies on taking many short exposure pictures of the object. This freezes the effects of turbulence such that the 'speckles' that make up each individual image are in essence distortion free. Each image is analysed statistically, the end result being a nearly diffraction-limited image of the original object. Arnold, Boksenberg and Sargent took 170,000 'pictures' of Pluto, each having a 20 millisecond exposure. Each picture was produced by an image photon counting system consisting of a 256 × 256 element array which could find electronically the centre of each photon event. The information was recorded onto digital magnetic tape. Observations were centred on a wavelength of 5,000 Å with a bandwidth of 350 Å. There were about three photon events in each picture and each picture element was roughly equivalent to an angular extent of 4×10^{-3} arc s on the sky.

The image of Pluto was compared with two stellar images, one being Alpha Herculis A which had a known diameter and the other GC24617 which should be unresolved. The authors found a systematic error of 0 .035 ± 0 .010 arc s in their results which they thought might be due to an incomplete compensation for atmospheric dispersion and to the possibility that the speckles were not completely stationary over a period of 20 ms.

They conclude that the best fit to the profiles would be obtained if the disk of Pluto subtended an angle of 0 .17 ± 0 .02 arc s at the telescope and was limb darkened. The presence of limb darkening was deduced by Renschen (*Astronomische Nachrichten* **298**, 179; 1977) from observations of Pluto's light variation as a function of time. The authors assume that this limb darkening follows a simple cosine law rather like that of the solar limb darkening. Titan, the 2,440 km radius satellite of Saturn, is also limb darkened like this. Arnold, Boksenberg and Sargent also found marginal evidence for an asymmetry in their data suggesting the presence of Pluto's moon. Also the surface of Pluto seems to have a variable albedo — half of it being covered with high albedo (0.5) methane frost and the remainder being of albedo about 0.13.

Combining the results with other recent observations leads to the conclusion that Pluto has mean opposition visual magnitude of 15.12, Pluto's moon being about 10.8^{m}. The mass is $(1.9 \pm 0.3) \times 10^{-3}$ Earth masses, the diameter is 3,600 ± 400 km and the mean density 0.5 (+0.3,-0.2) g cm^{-3}. The low value for the mean density suggests that Pluto is made up predominantly of frozen volatiles. The authors are obviously not too convinced about their limb darkening assumption and they carefully quote another set of results for the non limb darkened case. The mass obviously stays the same but the diameter and density change to 3,000 km and 0.8 (+0.6,-0.3) g cm^{-3} respectively.

As time progresses Pluto is looking less and less like a planet and more and more like an escaped planetary satellite. □

David Hughes is a lecturer in the Department of Physics, University of Sheffield.

Soil seed banks

from Peter D. Moore

As any gardener knows, the soil seems to be full of seeds of a variety of species, some needing only warmth and water to germinate and others whose dormancy is not so easily broken. Harper (*Population Biology of Plants,* Academic Press, 1977) likens these respectively to a current and deposit account in a bank and the term 'seedbank' is one that is frequently used for this latent plant community.

A striking feature of the seed bank is the general disparity between the species contained in it and the present-day vegetation. Many examples could be quoted, such as the work of Kellman (*Can. J. Bot.* **48**, 1383; 1970) who found that 70% of the seeds which germinated from soils beneath a century-old *Pseudotsuga* and *Tsuga* forest in British Columbia were *Alnus rubra*, many of the remainder being weeds. The possibility that the seeds had come in from other areas could not be excluded, but it was also considered conceivable that the seed population belonged to an early successional stage following a fire which had taken place a hundred years before.

Besides the disparity between present-day vegetation and seed bank, the seed bank itself can be extremely heterogeneous throughout the site. Van der Valk and Davis (*Can. J. Bot.* **54**, 1832; 1976) used a Sorensen similarity index to compare the viable seed flora of mud samples from fresh water marshes in Iowa. Within marshes their indices varied from 2 to 68% and between marshes (eight were studied), indices fell between 24 and 28%. They account for the variability in terms of the time over which any given seed bank has accumulated and the local variation in

Peter D. Moore is a Senior Lecturer in the Department of Plant Sciences, King's College London.

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