precisely the kind to drive the cycle. In particular, no morph was fitter than all others when it was common, so no pure ESS exists.

There is a special pleasure when a curious piece of natural history fits a theoretical prediction. The observation of three distinct male strategies is not new. Gross and Charnov² described three kinds of males in bluegill sunfish: territorial males,

sneakers and female mimics. But it turned out that there are only two lifetime strategies: grow big, and hold a mating territory, or sneak when young, and then, when too big to hide, pretend to be a female and enter the mating territory that way. This is an example of a two-strategy mixed ESS, or, more probably, a genetic polymorphism. In stoats³, there are also three male strategies: territory holders, sneakers

and 'roamers'. However, the strategies again turn out to be in part dependent on age. Young males either hold territories, or sneak copulations. Older males are dominant in interactions, even with territory holders, and roam around acquiring copulations. In neither of these cases is there any reason, in theory or observation, to suspect cycling.

The mere fact that, in the lizard case, no morph is uninvadable is not sufficient to ensure a frequency cycle: there might be a stable polymorphism. Analysis of the rock-scissors-paper game suggests that the cause of cycling, as opposed to polymorphism, may be subtle and hard to measure. However, a simulation incorporating the measured fitnesses of the three lizard morphs did in fact cycle.

Are there other games that cycle? If only two pure strategies are available, cycles will not happen for plausible pay-off values. But if there is a single variable, size for example, that can vary continuously, there may be no ESS. Instead, there can be a sawtooth oscillation: for example, size may increase gradually until a threshold is reached, when the population can be invaded by very much smaller individuals. Myself and Brown⁴ tentatively suggested that such a game might account for the apparently anomalous observation that 90 per cent of mammalian lineages get larger with time, yet the size distribution across species does not increase. We proposed that lineages get larger because of male-male competition, but large size lowers fitness in contexts other than competition, so that large individuals can be replaced by smaller mutants, or, more plausibly, by a smaller species. This would result in a sawtooth oscillation, with gradual increases and sudden decreases in size. Roughgarden⁵ observed that a reverse type of cycle has occurred in Caribbean lizards. On islands, lizards get smaller as an ecological adaptation, but are then replaced by a larger species through interference competition. Both of these cases involve species replacement: an intraspecific cycle would require invasion by a mutant of implausibly large effect.

It seems, then, that Sinervo and Lively have reported the first example of a population cycle caused by frequency-dependent changes in fitness arising from intraspecific interactions. I suspect that it will not be the last. □

John Maynard Smith is in the School of Biological Sciences, University of Sussex, Falmer, Brighton BN1 9QG, UK.

1. Sinervo, B. & Lively, C. M. *Nature* **380**, 240-243 (1996).
2. Gross, M. R. & Charnov, E. L. *Proc. natn. Acad. Sci. U.S.A.* **77**, 6937-6940 (1980).
3. Sandell, M. *Oikos* **47**, 63-70 (1986).
4. Maynard Smith, J. & Brown, R. L. W. *Theor. pop. Biol.* **30**, 166-179 (1986).
5. Roughgarden, J. *Anolis Lizards of the Caribbean* (Oxford Univ. Press, 1995).

EXTRASOLAR PLANETS

Silhouettes of future worlds

A HOPEFUL assumption among many astronomers, science-fiction readers and those who are pessimistic about the human race is that planetary systems are commonplace. Unfortunately there has been little evidence for extrasolar planets until the past few years, with tentative detections of a few massive planets (*Nature* 378, 355-359; 1995 and 379, 397-398; 1996) and increasingly strong indications of the existence of protoplanetary systems, in the form of disks of gas and dust around young stars. But now six disks have been imaged directly by the Hubble Space Telescope, and an analysis of their properties by Mark J. McCaughrean and C. Robert O'Dell (to appear in the *Astronomical Journal* in May) hints that more than half of all stars may form planetary systems.

Four of the six are shown here, seen in silhouette against the bright background of the Orion nebula. Their appearances indicate a common disk-like shape seen at different angles, with the uppermost nearly edge-on, hiding its central star. The stars are between 0.8 and 3 million years old and similar to the Sun in size, from 0.3 to 1.5 solar masses.

Contrary to theorists' expectations, McCaughrean and O'Dell find that the disks have sharp edges. Encounters with other stars may be responsible for trimming the disks, in which case the implied rate of encounters is consistent with their being able to survive for about ten million years, which should be long enough to form planets.

The authors also note the significance of similarly dark components in many of the small ionized circumstellar clouds in Orion, and of an infrared 'excess' in the spectrum of 60 to 80 per cent of all the stars in the cluster. It seems that disks are indeed common. But is there enough material in them to make planets?

McCaughrean and O'Dell can only put lower limits on the mass of dust, because it is likely that the disks are opaque at optical wavelengths, and so the space telescope can't 'see inside' them. The lower-limit masses are not enough to form planetary systems like ours. A better estimate can be made using millimetre wavelengths, where the disks are almost transparent. Until those results come in — perhaps within the next few months — we can all be much more justifiably hopeful, if not yet quite convinced.

Stephen Battersby

M. J. McCaughrean, C. R. O'Dell & NASA