taxa. The specific constitution of the forest has been dynamic in both time and space, most recently because of human disturbance and clearance for agriculture. The same seems to be true of tropical forest.

Biodiversity hotspots in the tropics are unlikely to be explained simply on the basis of refugium theory. But survival history has undoubtedly played an important part in their current richness. The range of opportunities presented in the Holocene development of ecosystems — both in terms of microhabitat diversity and disturbance features — must also have contributed to the variety of species combinations that can be achieved and maintained in these areas. Such is the essence of a biodiverse hotspot. □

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1. Jolly, D. *et al. J. Biogeogr.* **24,** 495–512 (1997).
2. Hamilton, A. *Environmental History of East Africa* (Academic, London, 1982).
3. Becker, B., Kromer, B. & Trimborn, P. *Nature* **353,** 647–649 (1991).
4. Jacobson, G. L., Webb, T. & Grimm, E. C. in *The Geology of North America* Vol. K-3 (eds Ruddiman, W. F. & Wright, H. E.) 277–288 (Geol. Soc. Am., New York, 1987).

Extrasolar planets

Back in focus

Geoffrey Marcy

Last year a conflagration of controversy engulfed the first planet ever claimed around a Sun-like star; now it has suddenly been extinguished, leaving the new world unscathed. The original suggestion[1] that a planet exists around the star 51 Pegasi was based on periodic variations in Doppler shifts of the light from the star — presumably caused by wobbling because of the gravitational pull of the planet. But criticism of this interpretation came from David Gray[2], who reported spectral-line variations that could be caused only by an undulating, pulsating stellar surface, not an orbiting planet. This interpretation called into question the reality of not just the 51 Peg planet, but also the other five detected extrasolar planets, as highlighted by the cover of *Nature* (27 February 1997): "Extrasolar planets: Fading from view". But now, three papers[3–5] (including those on page 153 and page 154 of this issue) report that the spectral evidence of pulsations is absent, after all. The empirical case for oscillations has vanished, leaving planets as the only plausible interpretation.

The discovery of the planet around 51 Pegasi by Michel Mayor and Didier Queloz[1] caught the scientific world off guard, not only because it was the first planet found around a Sun-like star, but because the orbital period of 4.2 days implied that it is 20 times closer to its star than the Earth is to the Sun. Such extreme proximity for a Jupiter-mass planet (or any planet) was unanticipated by conventional theories of planet formation.

Scorched by its close star, the planet around 51 Peg was further charred by four phenomenal controversies. First, on the US news programme *Nightline,* David Latham announced the discovery of a second planet orbiting 51 Peg. This detection has proved difficult to confirm. Then David Black wrote[6] that it was no planet but instead a failed star, a 'brown dwarf'. His twofold reasoning was that its mass "could well be ten times greater than the 0.6-Jupiter lower limit" and that inward orbital migration by planets was an "extreme mechanism" for transporting Jupiters from the outskirts of a planetary system, where they would form. Xiaopei Pan reported interferometric evidence for a star orbiting 51 Peg, not a planet at all. Finally, David Gray and Artie Hatzes[7] reported evidence that the spectral lines were changing shape with the 4.2-day period, with only "one chance in about 300 of this alignment occurring by chance".

This plethora of interpretations represents science at its healthiest. But some of them can be rejected by astrophysical reasoning. For example, the brown dwarf would raise tides on the primary star, and so exert a torque that would spin-up 51 Peg to a 4-day rotation period. Instead, we can tell that the star rotates roughly once every 30 days, based on its weak magnetic field — not much different from that of the Sun. But all of the above threats to the planet interpretation lose strength in the face of the seven additional planetary companions since discovered around other stars (see Table 1). Their number and variety provide a powerful argument against quirky explanations for any individual detection. Further, the planet discovered around 47 Ursae Majoris[8] seems quite 'normal', having a minimum mass of 2.5 Jupiter masses and orbiting at 2.1 Earth–Sun distances in a nearly circular orbit. The Doppler velocities of 16 Cygni B have the clear signature of an oval orbit, precisely consistent (and predictable) from newtonian physics. By far the simplest explanation for these last two is that they are Jupiter-mass objects at Solar-System-like distances.

The arguments for Gray's pulsation hypothesis can be subjected to *a posteriori* review. Some people have already expressed dissatisfaction that the original paper was not thorough in its statistical treatment (citing no error estimates, for example), and used less than equivocal language about the spectral-line variations ("the chance of their being caused by a planet is vanishingly small"). But these critics, including the present author, may occasionally forget that competition and human emotion have always provided fuel for the vigorous pursuit of alternative theories. It was right that the planet interpretation should not go unchallenged.

The scrutiny of 51 Peg is reminiscent of that surrounding the erroneous discovery by Andrew Lyne and collaborators of the "First planet outside our Solar System", orbiting a pulsar[9]. Lyne subsequently realized that the signal was simply an artefact of the elliptical orbit of the Earth. His honest retraction highlighted the scientific process at its finest. As Lyne did, in withdrawing that apparent detection, Gray[4] has quickly resolved this controversy by reporting new, more plentiful data that do not show pulsations. In the end we should be impressed by the exquisite care with which Mayor and Queloz examined every alternative interpretation right from the start — the absurd hypothesis of a Jupiter-mass companion in a 4.2-day orbit faced its most severe inquisition from the discoverers themselves.

Apparently, a question posed by Epicurus and Aristotle in 400 BC now has an empirical answer: other worlds — large ones at least — are common. □

Table 1 Planets around other stars

Star	Distance from Earth (parsecs)	Mass × sin(inclination*) (Jupiter masses)	Semi-major axis (AU)	Period (days)	Eccentricity
51 Pegasi	15.4	0.44	0.051	4.2308	0.01
Upsilon Andromedae	16.5	0.63	0.053	4.621	0.03
Rho1 55 Cancri	13.4	0.85	0.12	14.656	0.03
Rho Corona Borealis	16.7	1.1	0.23	39.6	0.05
16 Cygni B	~22	1.74	1.70	802.8	0.68
47 Ursae Majoris	14.1	2.42	2.08	1,093	0.09
Tau Bootis	~15	3.64	0.042	3.3126	0.0
70 Virginis	18.1	6.84	0.47	116.7	0.40

*The orbital inclination to our line of sight is unknown.

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1. Mayor, M. & Queloz, D. *Nature* **378,** 355–359 (1995).
2. Gray, D. F. *Nature* **385,** 795–796 (1997).
3. Brown, T. *et al. Astrophys. J.* (in the press).
4. Gray, D. F. *Nature* **391,** 153–154 (1998).
5. Hatzes, A. P., Cochran, W. D. & Bakker, E. J. *Nature* **391,** 154–156 (1998).
6. Black, D. *Sky Telescope* **92,** 20–24 (1996).
7. Gray, D. F. & Hatzes, A. *Astrophys. J.* **490,** 412–424 (1997).
8. Butler, R. P. & Marcy, G. *Astrophys. J.* **464,** L153–L154 (1996).
9. Bailes, M., Lyne, A. G. & Shemar, S. L. *Nature* **352,** 311–313 (1991).