

our understanding of geodynamic forces that drive the plates? The suggestions^{3,5} that continental lithosphere has a greater resistance to motion and hence moves more slowly than oceanic lithosphere owing to asthenospheric drag are not supported by our data. The suggestion³ that the velocity of a plate is controlled by the length of subduction zones 'pulling' the plate cannot yet be tested, as we have no indication of the length of subduction zones bordering the Laurentia and Gondwana plates during their intervals of rapid motion.

We have yet to find an explanation for these periods of fast motion, but note that the duration of rapid drift for each of our examples does not exceed 50 Myr. There could have been intervals of faster motion, especially since we cannot determine longitudinal motion. Forsyth and Uyeda³ analysed only the most recent few million years of plate motions, perhaps giving rates biased by a period of mantle quiescence. Long-term fluctuations in mantle dynamics (for example superplume activity) could alter the balance of forces driving plate motions and allow continental plates to move at rates comparable to the fastest oceanic plates. Finally, true polar wander can always be invoked to explain the fast rates calculated for Laurentia and Gondwana. However, true polar wander is not significant for the past 80 Myr and, because there are currently no compelling data to indicate amounts of true polar wander for earlier times, we conclude that our rates closely approximate true minima.

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Fluctuating asymmetry

SIR — Sullivan *et al.* suggested in Scientific Correspondence¹ that the use of fluctuating asymmetry as an indicator of selective pressures on ornamental characters in animals is statistically flawed (see refs 2–5). The use of relative asymmetry, calculated as the absolute difference in the lengths of paired morphological characters divided by the mean length of the character, rather than absolute asymmetry dates back to 1986 (ref. 6). Relative asymmetry allows comparison of the asymmetry of the same trait in different species, such as the leg of a mouse and an elephant, or different traits in the same species, such as a leg and a tooth. Without controlling for the size of a trait, comparison between species will be uninformative; the elephant or the leg will always have larger asymmetry. Relativization should be with respect to the allometric relationship between characters, and that need not be linear. We used a linear relativization because the allometric relationship demonstrated isometry⁵. Regression of relative asymmetry on character size has only been used once⁴, and the conclusions of this analysis did not differ from those based on regression of absolute asymmetry on character size.

Sullivan *et al.*¹ suggest that a negative relationship between asymmetry and mean size of a character can arise simply because of consistent measurement errors. But this explanation does not apply to our previous results^{2–5}, because measurements of asymmetries were highly repeatable and measurement errors therefore relatively small. If Sullivan *et al.*¹ were correct, a spurious negative correlation between relative asymmetry and character size should arise more frequently in characters with relatively large measurement errors. However, the negative relationship between absolute asymmetry and mean character size is more often negative for secondary sexual characters with large asymmetries and relatively small measurement errors than for ordinary morphological characters with relatively large errors^{2–5}. This result invalidates the explanation of Sullivan *et al.*

Sullivan *et al.* also suggest that differences in character length may be due to unfinished growth, injury or damage, and that this effect may affect estimates of asymmetry. They suggest that the only rigorous approach is to use maximum rather than mean length of characters as the independent variable in statistical analyses. A more rigorous and straightforward approach is directly to

examine specimens for growth, injury or damage rather than basing the approach on untested assumptions. Exclusion of individuals with unfinished growth (birds with feather quills) or damaged characters (broken and worn feathers) has routinely been adopted in previous studies^{2,4,5}. The conclusions drawn from such studies are therefore less biased than would be the case if the approach of Sullivan *et al.*, with its untested assumptions about growth, damage and wear, had been adopted.

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SIR — Sullivan *et al.*¹ rightly point to the dangers of statistical regression analysis where "the same measurement . . . occurs as a component of both the dependent and independent variables, which can lead to spurious correlations". They claim that measurement error incorporated into the measurement in question can produce a correlation when none exists. They then go on to recommend a procedure where the absolute difference between two measurements is regressed on the larger of the two measurements. They have fallen into their own trap.

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SIR — Fluctuating asymmetry describes the symmetrical distribution of random deviations from the population mean of a bilaterally symmetrical trait, presumed to arise from failure of homeostatic mechanisms in the face of developmental stress^{7–10}. As individuals vary in their ability to resist disruption of symmetrical growth, the relationship between trait asymmetry and trait length can give valuable insights into how selection acts on trait length¹⁰. Traits under stabilizing selection often show U-shaped relationships between asymmetry and mean trait length¹⁰, with extreme individuals poorly adapted to prevailing conditions. It is thus significant that recent studies indicate that many secondary sexual characters show negative relationships between asymmetry and size^{2,4,5,10–12}, indicating that sexual selection is directional and that individuals with large display traits are of 'high quality' (better adapted to prevailing conditions)¹⁰. Sullivan *et al.*¹ cast doubt on this evidence by suggesting two reasons for such negative correlations being artefacts. Their first criticism, of the use of relative asymmetry,

- Ullrich, L. & Van der Voo, R. *Tectonophysics* **74**, 17–29 (1981).
- Gordon, R. G., McWilliams, M. O. & Cox, A. J. *geophys. Res.* **84**, 5480–5486 (1979).
- Forsyth, D. W. & Uyeda, S. *Geophys. J. R. astr. Soc.* **43**, 163–200 (1975).
- Harper, J. F. *Geophys. J. Int.* **100**, 423–433 (1990).
- Ricard, Y. & Wuming, B. *Geophys. J. Int.* **105**, 561–573 (1991).
- Klootwijk, C. T. *et al.* *Geology* **20**, 395–398 (1992).
- Tarduno, J. A., McWilliams, M. O. & Sleep, N. *J. geophys. Res.* **95**, 15503–15527 (1990).
- Gordon, R. G. *Nature* **349**, 16–17 (1991).
- Meert, J. G., Van der Voo, R. & Payne, T. *J. geophys. Res.* (submitted).
- Symons, D. T. A. & Chiasson, A. D. *Can. J. Earth Sci.* **28**, 355–363 (1991).
- Chen, Z. *et al.* *Geophys. J. Int.* (in the press).
- Chen, Z., Li, Z.-X., Powell, C. McA. & Balme, B. E. *J. geophys. Res.* (submitted).
- Murthy, G., Gower, C., Tubrett, M. & Patzgold, R. *Can. J. Earth Sci.* **24**, 1431–1438 (1992).
- Van der Voo, R. *Rev. Geophys.* **28**, 167–206 (1990).