SCIENCE

Published by the **American Association for the Advancement of Science (AAAS),** *Science* serves its readers as a forum for the presentation and discussion of important issues related to the advancement of science, including the presentation of minority or conflicting points of view, rather than by publishing only material on which a consensus has been reached. Accordingly, all articles published in *Science*—including editorials, news and comment, and book reviews—are signed and reflect the individual views of the authors and not official points of view adopted by the AAAS or the institutions with which the authors are affiliated.

The American Association for the Advancement of Science was founded in 1848 and incorporated in 1874. Its objectives are to further the work of scientists, to facilitate cooperation among them, to foster scientific freedom and responsibility, to improve the effectiveness of science in the promotion of human welfare, to advance education in science, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress.

Membership/Circulation

Director: Michael Spinella
Deputy Director: Marlene Zendell
Member Services: Rebecca Dickerson, *Manager*; Mary Curry, *Supervisor*; Pat Butler, Helen Williams, Laurie Baker, *Representatives*
Marketing: Dee Valencia, *Manager*; Jane Pennington, *Europe Manager*; Hilary Baar, *Associate*; Angela Mumeka, *Coordinator*
Research: Renuka Chander, *Manager*
Business and Finance: Jacquelyn Roberts, *Manager*
Administrative Assistant: Nina Araujo de Kobes
***Science* Member Services**
Marion, Ohio: 800-347-6969;
Washington, DC: 202-326-6417
Other AAAS Programs: 202-326-6400

Advertising and Finance

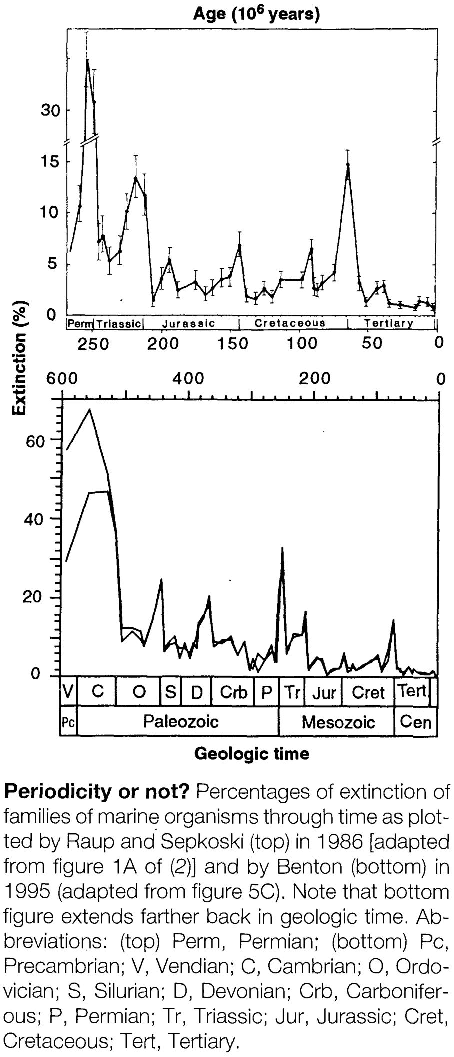
Associate Publisher: Beth Rosner
Advertising Sales Manager: Susan A. Meredith
Recruitment Advertising Manager: Janis Crowley
Business Manager: Deborah Rivera-Wienhold
Finance: Randy Yi, *Senior Analyst;* Shawn Williams, *Analyst*
Marketing: John Meyers, *Manager;* Allison Pritchard, *Associate*
Traffic: Carol Maddox, *Manager*; Christine Pierpoint, *Associate*
Recruitment: Terri Seiter Azie, *Assistant Manager*; Pamela Sams, *Production Associate*; Celeste Miller, Bethany Ritchey, Rachael Wilson, *Sales*; Debbie Cummings, *European Sales*
Reprints: Corrine Harris
Permissions: Lincoln Richman
Exhibits Coordinator: Arlene Ennis
Administrative Assistant: Nyana Gollopp de King
PRODUCT ADVERTISING SALES: East Coast/E. Canada: Richard Teeling, 201-904-9774, FAX 201-904-9701 • **Midwest/Southeast:** Elizabeth Mosko, 312-665-1150, FAX 312-665-2129 • **West Coast/W. Canada:** Neil Boylan, 415-673-9265, FAX 415-673-9267 • **UK, Scandinavia, France, Italy, Belgium, Netherlands:** Andrew Davies, (44) 1-457-838-519, FAX (44) 1-457-838-898 • **Germany/Switzerland/Austria:** Tracey Peers, (44) 1-270-760-108, FAX (44) 1-270-759-597 • **Japan:** Mashy Yoshikawa, (3) 3235-5961, FAX (3) 3235-5852
RECRUITMENT ADVERTISING SALES: US: 202-326-6555, FAX 202-682-0816 • **Europe:** Gordon Clark, (44) 1-81539-5211, FAX (44) 1223-302068 • **Australia/New Zealand:** Keith Sandell, (61) 02-922-2977, FAX (61) 02-922-1100
Send materials to *Science* Advertising, 1333 H Street, NW, Washington, DC 20005.

Information for Contributors appears on pages 112–114 of the 6 January 1995 issue. Editorial correspondence, including requests for permission to reprint and reprint orders, should be sent to 1333 H Street, NW, Washington, DC 20005.
***Science* World Wide Web address:** http://www.aaas.org
Other Internet addresses: science_editors@aaas.org (for general editorial queries); science_letters@aaas.org (for letters to the editor); science_reviews@aaas.org (for returning manuscript reviews); membership@aaas.org (for member services); science_classifieds@aaas.org (for submitting classified advertisements); science_advertising@aaas.org (for product advertising)

LETTERS

Mass Extinctions and Periodicity

The recent article by Michael J. Benton tracking "Diversification and extinction in the history of life" (7 Apr., p. 52) concludes that periodicity in the mass extinction record is not supported, as echoed in "This Week in *Science*" (p. 9). Benton's article, however, contains no quantitative statistical analyses designed to test the extinction record for periodic components, and may lack the resolution to identify all of the significant species-level extinction events on which such an analysis should be based.



Periodicity or not? Percentages of extinction of families of marine organisms through time as plotted by Raup and Sepkoski (top) in 1986 [adapted from figure 1A of (2)] and by Benton (bottom) in 1995 (adapted from figure 5C). Note that bottom figure extends farther back in geologic time. Abbreviations: (top) Perm, Permian; (bottom) Pc, Precambrian; V, Vendian; C, Cambrian; O, Ordovician; S, Silurian; D, Devonian; Crb, Carboniferous; P, Permian; Tr, Triassic; Jur, Jurassic; Cret, Cretaceous; Tert, Tertiary.

Benton used compilations of unculled family-level data to estimate the magnitude of extinction events, whereas previous analyses (*1, 2*) have used familial data from Raup and Sepkoski (*3*) culled to enhance the extinction signal by eliminating extant families, those known only from strata with exceptional preservation (Lagerstätten), and families with extinctions not resolved to the geologic stage level. Benton was able to identify the three major events of the last 250 million years (the Late Permian, end-Triassic, and end-Cretaceous events), but only four other less severe events, the end-Jurassic (Tithonian), Aptian, Cenomanian, and Late Eocene (Priabonian) extinctions, in contrast to the earlier studies that had identified a total of from 8 to 12 extinction events in culled, family-level and more detailed genus-level data for the same interval (*1, 2*).

The apparent lack of resolution in Benton's study is not unexpected, as Sepkoski (*4*) has shown that the use of unculled familial data in extinction analysis is problematic, and has determined that genus-level data are best suited for detecting second-order extinction events. First, as the standard error in any frequency count (n) is approximately $n^{1/2}$, the smaller number of familial extinctions as opposed to those of genera is thus subject to considerable random variation, making detection of signal above noise more difficult (*4*).

Because all species in a family or genus must disappear in order to produce an extinction on those levels, and as species extinctions are independent of family or genus membership, the higher-level data should significantly dampen the severity of species-level extinctions in a manner predictable through rarefaction relationships (*4*). Raup (*5*) has determined that the rarefaction curve for families shows a shallow slope over low levels of species extinction, where even a 50% loss of species results in only a 10% family extinction, whereas a similar loss of species results in a 25% extinction of genera. On the basis of these two factors, one can predict that one's use of family-level data will present difficulty in resolving extinction events involving loss of less than or equal to 40% of species, which is the range of the additional peaks identified in the genus-level data (*4*).

With regard to periodicity, Benton finds that the seven extinction peaks detected in his unculled familial data over the last 250 million years are spaced 20 to 60 million years apart and uses this as evidence against the reality of about 26-million-year periodicity in the record. Here, he seems to conclude that detection of periodicity in the record of extinctions requires that all recognized extinction events be part of a regular periodic time series, even though some relevant events could have been missed in his analysis. A periodic component in the extinction record can be detected by time-series analysis if the extinction events show relatively small random fluctuations about a periodic pacemaker, if the extinction time series contains a mixture of periodic and stochastic events, and even if some events are missing (6).

We analyzed the seven events identified by Benton, with dates taken from the most recent widely used geologic time scale (7), using standard Fourier analysis and treating each event as a delta function (6). This analysis reveals the highest spectral peak at a period of about 27 million years, similar to that found in previous time-series analyses of family- and genus-level extinction data (1, 2). Although use of Monte Carlo techniques suggests that the apparent periodic component falls well below statistical significance, this is not unexpected for a record of only seven events. The appearance of the peak, however, is consistent with the detection of a similar and significant spectral peak either by analysis of the continuous record of extinction intensity of the past 250 million years, or by use of the 8 to 12 above-background extinction peaks found in culled, family-level and genus-level data (1, 2).

Thus, analysis of Benton's data in no way rules out a 26- to 30-million-year periodic component in the mass extinctions. Furthermore, contrary to Benton's concluding statement, impacts could provide a single cause for mass extinctions (8), as the impact record may contain both periodic (possibly derived from periodic comet showers) and stochastic components (from nonshower comets and earth crossing asteroids) (9).

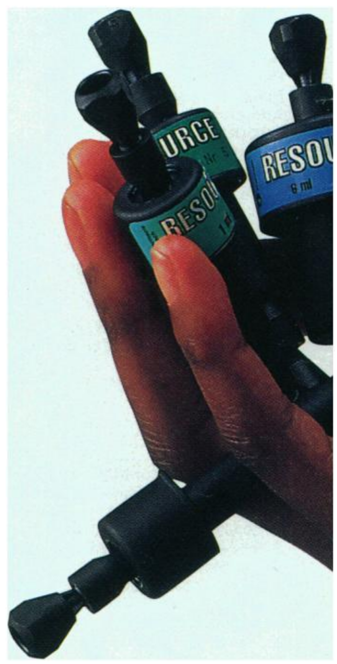
Michael R. Rampino
Bruce M. Haggerty
Earth Systems Group,
Department of Biology,
New York University,
New York, NY 10003, USA

References

1. D. M. Raup and J. J. Sepkoski Jr., *Proc. Natl. Acad. Sci. U.S.A.* **81**, 801 (1984); M. R. Rampino and R. B. Stothers, *Nature* **308**, 709 (1984); W. T. Fox, *Paleobiol.* **13**, 257 (1987); R. B. Stothers, *Geophys. Res. Lett.* **16**, 119 (1989); J. J. Sepkoski Jr., *Paleobiology* **19**, 43 (1993).
2. D. M. Raup and J. J. Sepkoski Jr., *Science* **231**, 833 (1986).
3. J. J. Sepkoski Jr., *Mil. Public Mus. Contrib. Biol. Geol.* **51** (1982); J. J. Sepkoski Jr., *Milw. Public Mus. Contrib. Biol. Geol.* **83**, 1 (1992).
4. J. J. Sepkoski Jr., *J. Geol. Soc. London* **146**, 7 (1989).
5. D. M. Raup, *Science* **206**, 217 (1979).
6. M. R. Rampino and K. Caldeira, *Earth Planet Sci. Lett.* **114**, 215 (1993).
7. W. B. Harland *et al.*, *A Geologic Time Scale 1989* (Cambridge Univ. Press, Cambridge, UK, 1990).
8. M. R. Rampino and B. M. Haggerty, in *Hazards Due to Comets and Asteroids*, T. Gehrels, Ed. (Univ. of Arizona, Tucson, 1994), p. 827.
9. M. J. Fogg, *Icarus* **79**, 382 (1989); J. S. Trefil and D. M. Raup, *Earth Planet Sci. Lett.* **82**, 159 (1987); S. Yabushita, *Earth, Moon, Planets* **58**, 57 (1992).

Response: Rampino and Haggerty take exception to the implication in "This Week in *Science*" that I claimed to have disproved in my report the periodicity of mass extinctions, previously proposed (1). They are right that I did not carry out statistical tests for periodicity, and the reason is that this was not a focal purpose of my article. I merely indicated that, on the basis of a new data set (2), support for periodicity was not found.

Rampino and Haggerty argue that a better quality analysis could have been obtained from the use of a genus-level data set, instead of family-level, and by the application of various culls to the raw data. Generic-level data certainly have the advantage (3, 4) of being closer to the species level,



and hence they have the potential to reflect species-level extinctions more closely than do family-level data. Generic-level data, on the other hand, suffer larger problems in determination, both taxonomically and stratigraphically. The available generic-level data set (*4*), not yet published, is a developing assemblage of information from many sources, and it makes no claim to be complete, unlike the available family-level data sets (*2*, *5*), which are both best efforts at a complete coverage of all available paleontological data.

Culling of raw data on fossil distributions can be justified in various ways for different purposes (*4*). However, I decided to present the data in a raw form, corresponding precisely to the available published data base (*2*). The information is now widely available in printed and electronic form (*6*), and further studies, using different styles of cull, may be carried out.

Rampino and Haggerty find that the seven extinction events identified in my article give a periodic signal of about 27 million years on the basis of Fourier analysis, although the result is not statistically significant. They note also that my identification of additional events that do not fit the periodic signal in no way denies the possibility of a mix of periodic and nonperiodic extinction events. This is obviously the case (*4*), but I found seven possibly periodic, and seven nonperiodic peaks. These two classes of extinction peaks do not fall into two distinctive classes.

The proposal of periodicity in mass extinctions was based on analyses by Raup and Sepkoski in 1984 (*1*), and their subsequent work (*4*, *6*) apparently strengthened the quality of the periodic signal they found. I have no strong view either way about the existence, or not, of a periodic cause of mass extinctions, but I had expected a stronger match of timings than I found in my article. The data are improving all the time (*7*), and it is the responsibility of the proponents of periodic extinction to show that paleontological data support their view. Ten years of data analysis and of search for astronomical drivers have not produced dramatic confirmation of periodicity.

Michael J. Benton
Department of Geology,
University of Bristol,
Bristol, BS8 1RJ, United Kingdom

References

1. D. M. Raup and J. J. Sepkoski Jr., *Proc. Natl. Acad. Sci. U.S.A.* **81**, 801 (1984).
2. M. J. Benton, Ed., *The Fossil Record 2* (Chapman and Hall, London, 1993).
3. D. M. Raup, *Science* **206**, 217 (1979).
4. J. J. Sepkoski Jr., *J. Geol. Soc. London* **146**, 7 (1989).
5. _____, *Milw. Public Mus. Contrib. Biol. Geol.* **83**, 1 (1992).
6. D. M. Raup and J. J. Sepkoski Jr., *Science* **231**, 833 (1986).
7. M. J. Benton and W. G. Storrs, *Geology* **22**, 111 (1994).

■

FDA Antibody Rules

Richard Stone's article "Companies fear FDA rule on antibodies" (News & Comment, 28 Apr., p. 494) raises legitimate issues of concern in the regulation of antibodies. It does not, however, describe the complexity of the current Food and Drug Administration (FDA) review system, which allows FDA considerable latitude in performing a risk-to-benefit analysis of new products and requesting an appropriate data set based on this analysis.

Whether FDA classifies a product as Class-I, -II, or -III, it has three very different administrative review options predicated on the risk, technical features, and intended use of the product. For low-risk products, FDA can use a focused labeling review aimed at ensuring proper information is present, but without requiring a detailed