

28 July 2017

Dear editors,

Please find attached our manuscript “Punctuated non-equilibrium and niche conservatism explain biodiversity fluctuations through the Phanerozoic” that we wish to submit for publication as an Article in *Nature Ecology and Evolution*.

Our study is the first to demonstrate that complex, previously unexplained patterns in diversity fluctuations in the fossil record are the result of a simple underlying process emerging from non-equilibrium evolution on an adaptive landscape^{1,2}. Our theory provides a novel explanation for deep time diversity dynamics invoking emergence of lineage-level traits as the drivers of complexity via the same mechanisms by which complexity emerges in large physical³ and social systems⁴. In the context of fossil diversity we show how this complexity arises naturally from the uniquely biological mechanisms of punctuated adaptive radiation^{1,2,5} followed by long durations of niche conservatism^{5–7} and thus identify these mechanisms as sufficient and necessary to produce observed patterns in the fossil record.

Using two seminal fossil datasets^{8,9} we show that fluctuations in marine biodiversity over the past 550 million years results from the superposition of many independently fluctuating subsystems whose fluctuations are Gaussian but give rise to non-Gaussian patterns when combined. These independent subsystems correspond to lineages of closely related animal taxa, implying that diversification within lineages is driven by random additive interactions with the environment. Our findings thus challenge the idea that changes in origination and extinction through deep geologic time are the result of complicated evolutionary interactions among organisms and between organisms and their environment^{10–12}. However, we demonstrate that the evolutionary process responsible for generating new lineages varies slowly through time, possibly driven by non-random evolutionary innovations in the physiology and demography of new lineages. This slow change between lineages produces patterns of apparent complexity earlier ascribed to unnecessarily complicated mechanisms. We further show, using permutational null models, that our findings are not an artifact of how fossils are taxonomically classified but rather capture true underlying biological processes.

This work has not been published or accepted for publication, and is not under consideration for publication elsewhere. Thank you very much for your consideration.

Sincerely,

Andy Rominger
Santa Fe Institute
1399 Hyde Park Road
Santa Fe, New Mexico 87501, USA
rominger@santafe.edu

References

1. Eldredge, N. & Gould, S. J. Punctuated equilibria: an alternative to phyletic gradualism. *Models in paleobiology* **82**, 115 (1972).
2. Newman, C., Cohen, J. & Kipnis, C. Neo-darwinian evolution implies punctuated equilibria. *Nature* **315**, 400–401 (1985).
3. Beck, C. Superstatistics in hydrodynamic turbulence. *Physica D: Nonlinear Phenomena* **193**, 195–207 (2004).
4. Fuentes, M. A., Gerig, A. & Vicente, J. Universal Behavior of Extreme Price Movements in Stock Markets. *PLoS ONE* **4**, e8243 (2009).
5. Hopkins, M. J., Simpson, C. & Kiessling, W. Differential niche dynamics among major marine invertebrate clades. *Ecology letters* **17**, 314–323 (2014).
6. Ackerly, D. D. Community assembly, niche conservatism, and adaptive evolution in changing environments. *International Journal of Plant Sciences* **164**, S165–S184 (2003).
7. Roy, K., Hunt, G., Jablonski, D., Krug, A. Z. & Valentine, J. W. A macroevolutionary perspective on species range limits. *Proceedings of the Royal Society B: Biological Sciences* **276**, 1485–1493 (2009).
8. Sepkoski, J. J. *A compendium of fossil marine animal families* (Milwaukee Public Museum, Milwaukee, WI, 1992).
9. Alroy, J. *et al.* Phanerozoic Trends in the Global Diversity of Marine Invertebrates. *Science* **321**, 97–100 (2008).
10. Bak, P. & Sneppen, K. Punctuated equilibrium and criticality in a simple model of evolution. *Phys. Rev. Lett.* **71**, 4083–4086 (1993).
11. Solé, R. V., Manrubia, S. C., Benton, M. & Bak, P. Self-similarity of extinction statistics in the fossil record. *Nature* **388**, 764–767 (1997).
12. Newman, M. E. J. & Roberts, B. W. Mass Extinction: Evolution and the Effects of External Influences on Unfit Species. *Proceedings of the Royal Society of London B* **260**, 31–37 (1995).