

Sandpile Criticality, Speciation, Mass Extinctions and Cambrian Explosion

M. Ayhan Murtaza Baloch*

Department of Bio-Sciences, Nishtar Medical University, Multan, Pakistan

Abstract

The abelian sandpile model is used to explain in a new way-the Cambrian explosion, continuous speciation, speciation bursts, mass Extinctions and extinction bursts. The sandpile model explains why continuous speciation exist however speciation bursts seem more common a pattern. Moreover, it explains how Cambrian explosion may have been a result of a small environmental change.

Keywords: Sandpile criticality • Speciation • Mass extinctions

Introduction

The abelian sandpile model is actually a cellular automation model. The model was introduced by Per Bak, Chao Tang, and Kurt Wiesenfeld. The theme of this article is to explore the diverse and significant implications of the sandpile model in the evolutionary biology. The model can be explained as follows; when sand is dropped on a sandpile grain by grain, a critical state is reached [1-4]. Afterwards, each falling grain may have no effect at all or may cause an avalanche. The particular model using which I seek a way to explain Cambrian explosion is theory of punctuated equilibrium in light of concept of evolution as a self-organized critical phenomenon as initially presented by K Sneppen, P Bak, H Flyvbjerg, M H Jensen [5-8].

Punctuated equilibrium

It has been established many times that extinctions within families have occurred as "extinction bursts". Recent evidence from molecular phylogenetics has suggested the process of speciation to have also occurred in similar bursts. Model for such bursts of evolution was also presented by Venditti and Pagel.

However, we can also consider a novel mechanism based on same sand pile criticality and Gould's concept of punctuated equilibrium [9-12]. If we consider following axioms:

- The Sand grains falling on the sandpile are actually the environmental factors that induce so called selection pressure. For now, we'd call them stress factors.
- The grains reaching the ground are the result of selection pressure (our stress factors) i.e. species. The whole process from

grain falling to reaching the ground is speciation i.e. the change of specie to a better fitness peak as defined by Gould. This can also be justified by the fact that the group(s) of grains at the ground is having less potential energy which would imply in case of evolution a better fitness or adaptability.

Explanation of continuous speciation

- If we consider these axioms, we can now consider why punctuated evolution pattern is more followed and yet the continuous evolution exists too. Since some of the grains of sand may land at the points from where they singularly fall to ground i.e. stress factor resulting in specie exploring some new environmental resources and thus entering a new niche thereby becomes a new specie. However, such happening would be less common as once the critical state is established it would either have no effect or cause an avalanche. The latter is discussed in the later section.
- Molecular data according to Venditti suggested that punctuational changes were more common in plants (57%) and fungi (71%) than in animals (21%).
- However, one is left astounded how the authors of that study reached a conclusion that such punctuational divergence is a minor contributor in animal kingdom while the Cambrian explosion is the best, biggest and the most drastic example of such a change in which between 20-35 i.e. all major phyla of animal kingdom evolved in a mere 13-25 Million years' time.
- Continuous extinctions if any can also be explained using this very approach.

*Address to correspondence: Dr. M. Ayhan Murtaza Baloch, Department of Medical Sciences, Nishtar Medical University, Multan, Pakistan; E-mail: m.ayhan.baloch@gmail.com

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Explanation for speciation bursts

If we consider the grains of sand-falling after pile reaches the critical state- that bring an avalanche we can easily expect that small "trigger stress factors" can bring a large sum of grains from the sand pile on the ground i.e. a small trigger stress factor causes a lot of species to change their niches i.e. become new species in an amount of time greatly lesser than would be expected. Such model is supported by the fossil record as well.

Cambrian explosion

The event has been introduced earlier. In the light of this model, we can expect that if the critical state of the sandpile is large enough even a small grain would cause a gigantic avalanche and thus a lot of species. Cambrian Explosion maybe one such case merely. A large sum of stress had built upon the animal kingdom. And then any even a small new stress factor would have caused this avalanche called Cambrian radiation causing emergence of a very large and diverse amount of animal species and thus 20-35 phyla. Therefore, I propose Cambrian explosion as a case of mere speciation bursts. Interestingly enough such changes have been proposed as well. However, they aren't concerned with this research article. With that being said we can assume that the whole Cambrian radiation may have been a result of small environmental change instead of a drastic one. As at critical state in a sufficiently big sandpile even a small grain of sand would cause a huge avalanche.

Mass extinctions

Mass Extinctions and extinction bursts can also be explained in the same manner. If we assume that each grain reaching on ground is specie becoming extinct. Then avalanches would represent mass extinctions. For example, dinosaur mass extinction by possible asteroid hit.

Conclusion

The sandpile model explains why continuous speciation exist i.e. because of some grains falling (some stress factors) settling down (i.e. resulting in a specie). However, many grains of critical state sandpile cause avalanches of various magnitude and thus after

summed up stress i.e. selection pressure even small amount of stress causes speciation bursts. Cambrian explosion may very well be such a case of a big avalanche. Mass Extinctions and extinction bursts have been correlated the same way earlier researchers.

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