Seminar on *The Balance of Nature*

12.S593 Spring 2021 G (2-0-4); *Instructor: Daniel H. Rothman; TA: Constantin Arnscheidt*

Overview

The natural world has long been perceived to be an expression of an exquisite equilibrium—the "balance of nature." Although the notion of balance seems obviously at odds with the episodic evolution of Earth and life, its modern cousin—the pervasive assumption of steady states in the Earth system—is alive and well, despite its likely irrelevance. Why is this so? And what are the alternatives? In the first half of this seminar, we examine the history of the idea of the balance of nature, with particular attention to changing views of mass extinction. We then consider alternative models in which the coevolution of many components results in periods of punctuated change away from equilibrium. We close with an examination of an attempt to explain coevolutionary change toward equilibrium—the Gaia hypothesis.

Organization

The initial meeting will be organizational, at 2:30 PM on Wednesday February 17. We'll meet Wednesdays from 2:30–4:00 thereafter. Interested students with scheduling conflicts should send their schedule to the instructor at dhr@mit.edu; we'll make accommodations if we can. We'll meet synchronously by Zoom; the Zoom link is available on Canvas.

Participation, format, and expectations

Each week we will discuss the assigned readings. Rather than designating discussion leaders, we will each participate in discussions on an equal basis. No one is expected to have any special expertise in any of the subjects; instead, we will all come prepared to learn from each other. Participation is open to all, including undergraduates. Interested students should register (in advance, if possible) for 12.S593, Special Seminar in EAPS. Grading is P/D/F.

Syllabus

Each week's readings are listed below. All material will be available on Canvas or obtainable electronically from the MIT Library. The syllabus is tentative; any updates will be posted on Canvas.

History

1. Notions of the balance of nature, from antiquity to the present

   Egerton, F. N. (1973). "Changing concepts of the balance of nature". *The Quarterly Review of Biology* 48, pp. 322–350.

   Simberloff, D. (2014). "The 'balance of nature'—evolution of a panchreston". *PLoS Biol* 12, e1001963.

2. Balance, extinction, and early views of diversity in science and society

   Sepkoski, D. (2020). *Catastrophic Thinking: Extinction and the Value of Diversity from Darwin to the Anthropocene*. Introduction and Chapters 1–2. University of Chicago Press.

3. Cuvier's catastrophes and the discovery of extinction

   Rudwick, M. J. (1976). *The Meaning of Fossils: Episodes in the History of Palaeontology*. Chapter 3. University of Chicago Press.

4. Misreading the fossil record: extinctions are gradual, not catastrophic

   Darwin, C. (1859). *On the Origin of Species*. Chapter 9. London: John Murray.

5. Catastrophism's revival: nuclear winter and the KT impact

   Sepkoski, D. (2020). *Catastrophic Thinking: Extinction and the Value of Diversity from Darwin to the Anthropocene*. Chapters 4–5. University of Chicago Press.

6. The sixth extinction: data and the development of the idea

   Barnosky, A. D. et al. (2011). "Has the Earth's sixth mass extinction already arrived?" *Nature* 471, pp. 51–57.
   Sepkoski, D. (2020). *Catastrophic Thinking: Extinction and the Value of Diversity from Darwin to the Anthropocene*. Chapter 6 and Epilogue. University of Chicago Press.

Models

7. Punctuated equilibria

   Gould, S. J. and N. Eldredge (1972). "Punctuated equilibria: an alternative to phyletic gradualism". *Models in Paleobiology*. Ed. by T. Schopf. Freeman, Cooper, and Co., pp. 82–115.
   Newman, C., J. Cohen, and C. Kipnis (1985). "Neo-Darwinian evolution implies punctuated equilibria". *Nature* 315, pp. 400–401.

8. Coevolution I

   Kauffman, S. and S. Levin (1987). "Towards a general theory of adaptive walks on rugged landscapes". *Journal of Theoretical Biology* 128, pp. 11–45.
   Levin, S. A. (1998). "Ecosystems and the biosphere as complex adaptive systems". *Ecosystems* 1, pp. 431–436.

9. Coevolution II

   Bak, P. and K. Sneppen (1993). "Punctuated equilibrium and criticality in a simple model of evolution". *Physical Review Letters* 71, p. 4083.
   Bak, P. (1996). *How Nature Works: the Science of Self-Organized Criticality*. Chapter 8. New York: Springer-Verlag.

10. Coevolution III

    Jensen, H. J. (2018). "Tangled Nature: a model of emergent structure and temporal mode among co-evolving agents". *European Journal of Physics* 40, p. 014005.

Gaia

11. The initial hypothesis

    Lovelock, J. E. (1972). "Gaia as seen through the atmosphere". *Atmospheric Environment* 6, pp. 579–80.
    Lovelock, J. E. and L. Margulis (1974). "Atmospheric homeostasis by and for the biosphere: the Gaia hypothesis". *Tellus* 26, pp. 2–10.

12. Gaia mathematized

    Watson, A. J. and J. E. Lovelock (1983). "Biological homeostasis of the global environment: the parable of Daisyworld". *Tellus B: Chemical and Physical Meteorology* 35, pp. 284–289.

13. Gaia today

    Lenton, T. M. et al. (2018). "Selection for Gaia across multiple scales". *Trends in Ecology & Evolution* 33, pp. 633–645.