OEB 258

Contingency versus Determinism: Is Evolution Predictable?

Instructor: Jonathan Losos
Meeting Time: Tuesdays, 2:30-5:00
Meeting Place: MCZ Labs 213

Course Catalog Description:

In his 1989 Pulitzer-Prize winning book Wonderful Life, Stephen Jay Gould asked what would happen if we could replay the tape of life. That is, if somehow we could go back in time and re-start evolution from a previous point, would the evolutionary outcome be the same? Or would events—minor or major—perturb the evolutionary trajectory such that the world today would be a very different place? Presented as a thought experiment, Gould's metaphor has attracted widespread attention; twenty-five years on, approaches as disparate as molecular phylogenetics and experimental field studies of evolution have provided a wealth of data on the relative importance of contingency and determinism in evolutionary diversification. In this seminar class, we will discuss Gould's ideas, how they have been developed and transformed over the last quarter century, and what the data say.

Course Format:

OEB 258 will be a discussion seminar course. Each week, we will read 3-4 papers (or, for the first two weeks, Stephen Jay Gould's *Wonderful Life: the Burgess Shale and the Nature of History*) and will discuss the issues raised by these reading assignments. Students will be expected to read the papers carefully and thoughtfully and to come to class prepared to discuss them. One or more researchers in the field may meet with us either in person or via Skype to discuss their work, and we will spend part of at least one class visiting MCZ collections to examine specimens about which we've read. A 10-page term paper on a topic relevant to the course will be due at the end of the semester.

Course Rationale:

The topic of contingency vs. determinism has been of interest to Professor Losos throughout his career, and some of his early empirical research is commonly used as an example in general discussions of the topic. For the last two years, he has been working on a book for a popular audience on this topic, which has been submitted for review. In addition, he is currently preparing a short review on the topic for a scientific audience, which will be submitted for publication early next year.

Course Schedule

Sept. 6 Introduction

Sept. 13 *Wonderful Life* I

S.J. Gould. 1989.*Wonderful Life: the Burgess Shale and the Nature of History* (Norton: New York). Read up to page 239.

Briggs, D.E.G., R.A. Fortey, R.A., and M.A. Wills, M.A. 1992. Morphological disparity in the Cambrian. *Science* 256: 1670-1673.

Foote, M., and S.J. Gould. 1992. Cambrian and recent morphological disparity. *Science* 258: 1816.

Briggs, D.E.G., R.A. Fortey, R.A., and M.A. Wills, M.A. 1992. Response. *Science* 258: 1817-1818.

This set contains a paper attempting to empirically test one of the core ideas presented by Gould in Wonderful Life*, Gould's response, and the authors' rebuttal.*

Sept. 20 *Wonderful Life* II

S.J. Gould. 1989.*Wonderful Life: the Burgess Shale and the Nature of History* (Norton: New York). Finish the book.

Erwin, D.H. 2016. *Wonderful Life* revisited: Chance and contingency in the Ediacaran-Cambrian radiation. In: G. Ramsey and C.H. Pence, Eds., *Chance in Evolution*. University of Chicago Press: Chicago. (in press)

Our very own Andrew Berry provides a nice review of Simon Conway Morris' critique of Gould's ideas, or you can read the two contestants battling it out directly. I recommend you read one of these:

Berry, A. 1998. Wonderful Crucible. *Evolution* 52:1528-1532.

Conway Morris, S., and S.J. Gould. 1998. Showdown on the Burgess Shale. *Natural History* Dec-Jan 1998-1999, pp. 48-55.

Sept. 27 The Meaning of Contingency

Beatty, J.H. 2006. 2006. Replaying Life's Tape. *Journal of Philosophy* 103: 336-362.

Beatty, J. and E.C. Desjardins. 2009. Natural selection and history. *Biology and Philosophy* 24: 231-246.

Turner, D.D. 2011. Gould's replay revisited. *Biology and Philosophy* 26: 65-79.

Inkpen, R., and D. Turner, D. 2012. The topography of historical contingency. *Journal of the Philosophy of History* 6: 1-19.

The philosophy of science can make pretty dense reading. Don't get too hung up on the philosobabble, but try to get the gist of the arguments they are making. And fear not: there won't be many more papers like this moving forward.

In addition, the following are two papers which evolutionary biologist should have read. If you haven't, you might consider reading them now, as they are relevant, or at some time.

Jacob, F. 1977. Evolution and tinkering. *Science* 196: 1161–66.

Gould, S.J., and R.C. Lewontin. 1979. The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptionist program. *Proceedings of the Royal Society of London B* 205: 581-598.

Oct.4 Convergent Evolution

Conway Morris, S. 2009. The predictability of evolution: glimpses into a post-Darwinian world. *Naturwissenschaften* 96: 1313-1327.

Sterelny, K. 2005. Another view of life. *Studies in History and Philosophy of Biological and Biomedical Sciences* 36: 585–93.

Currie, A.M. 2012. Convergence, contingency & morphospace. *Biology & Philosophy* 27: 583–93.

Coyne, J.A. https://whyevolutionistrue.wordpress.com/2015/02/08/simon-conway-morriss-new-book-on-evolutionary-convergence-does-it-give-evidence-for-god/

I include three book reviews as critiques of the convergence approach. Note that Currie's critique is a bit too in-depth about the theoretical framework of George McGhee, but it does give a good sense of the functional arguments underlying both McGhee's and Conway Morris' ideas about convergence. The latter half of the Currie review covers a number of important points including: the distinction between parallelism vs. convergence, the importance of scale and grain in recognizing convergence, and the role of development in shaping convergence, and thus whether convergent taxa sharing developmental systems are a fair test of the contingency hypothesis.

If you want to read more about the relationship between convergent evolution and adaptation, see:

Losos, J.B. 2011. Convergence, adaptation, and constraint. *Evolution* 65:1827-1840.

Oct. 11 Guest Visitor: Doug Erwin

Topic TBD

Erwin will be giving a talk sponsored by The Initiative for the Science of the Human Past at Harvard and OEB, followed by a panel discussion, at 5:30 p.m. in Robinson Hall. This should be well worth attending.

Oct. 18 The Long-Term Evolution Experiment (LTEE)

Blount, Z.D. 2016. A case study in evolutionary contingency. *Studies in History and Philosophy of Biological and Biomedical Sciences* 58: 82e92.

Read Rich Lenski's recap of the LTEE. Follow links to read all five posts (he says there will be 10, but I think they ended at 5):

https://telliamedrevisited.wordpress.com/2014/01/20/recap-what-weve-learned-about-evolution-from-the-ltee-numbers-1-5/

and this recent interview:

https://evolution-institute.org/article/evolutionary-biologys-master-craftsman-an-interview-with-richard-lenski/

Travisano, M., J.A. Mongold, A.F. Bennett, and R.E. Lenski. 1995. Experimental tests of the role of adaptation, chance and history in evolution. *Science* 267: 87-90.

Oct. 25 Microbial Evolution Experiments II

Blount, Z.D. 2016. History's windings in a flask: Microbial experiments into evolutionary contingency. In: G. Ramsey and C.H. Pence, Eds., *Chance in Evolution*. University of Chicago Press: Chicago. (in press)

Bailey, S.F., N. Rodrigue, and R. Kassen. 2015. The effect of selection environment on the probability of parallel evolution. *Molecular Biology and Evolution* 32: 1436-1448.

1-2 papers from the Desai Lab.

Nov. 1 Convergence at the molecular level

Conte, G.L., M.E. Arnegard, C.L. Peichel, and D. Schluter. 2012. The probability of genetic parallelism and convergence in natural populations. *Proceedings of the Royal Society of London B: Biological Sciences* 279: 5039–47.

Orgozozo, V. 2015. Replaying the tape of life in the twenty-first century. *Interface Focus* 5: 20150057.

Marvig, R.L., L.M. Sommer, S. Molin and H.K. Johansen. 2015. Convergent evolution and adaptation of *Pseudomonas aeruginosa* within patients with cystic fibrosis. *Nature Genetics* 47:57-64.

Manceau, M., V.S. Domingues, C.R. Linnen, E.B. Rosenblum and H.E. Hoekstra. 2010. Convergence in pigmentation at multiple levels: mutations, genes and function. *Philosophical Transactions of the Royal Society B*: 365: 2439–2450.

Nov. 8 Recreating ancestral phenotypes

Brigham, J.T, Ortlund, E.A., Thornton J.W. 2009. An epistatic ratchet constrains the direction of glucocorticoid receptor evolution *Nature* 461:515-9.

Thornton J.W. 2004. Resurrecting ancient genes: experimental analysis of extinct molecules *Nature Reviews Genetics* 5:366-375.

Kacar, B. 2016. Rolling the Dice Twice: Evolving Reconstructed Ancient Proteins in Extant Organisms. In: G. Ramsey and C.H. Pence, Eds., *Chance in Evolution*. University of Chicago Press: Chicago. (in press)

Joy, J.B., R.H. Liang, R.M. McCloskey, T. Nguyen and A.F.T. Poon. 2016. Ancestral Reconstruction. *PLoS Computational Biology* 12(7): e1004763.

(More) fun read:

Science news: Scientists dig up proteins from the past
https://www.sciencenews.org/article/scientists-dig-proteins-past

Quanta: Biologists Invoke the Past in Modern Bacteria
https://www.quantamagazine.org/20150618-genetic-time-travel-bacteria/

Nov. 15 The Predictability of Evolution and Estimating the Adaptive Landscape

Lobkovsky, A.E., and E.V. Koonin. 2012. Replaying the Tape of Life: Quantification of the predictability of evolution." *Frontiers in Genetics* 3: 246.

De Visser, J.A.G.M., and J. Krug. 2014. Empirical fitness landscapes and the predictability of evolution. *Nature Genetics* 15:480-490.

Weinreich, D.M., N.F. Delaney, M.A. DePristo, and D.L. Hartl. 2006. Darwinian evolution can follow only very few mutational paths to fitter proteins." *Science* 312: 111–14.

Achaz, G., A. Rodriguez-Verdugo, B.S. Gaut, and O. Tenaillon. 2014. The reproducibility of adaptation in the light of experimental evolution with whole genome sequencing." Pp. 211-231 in C.R. Landry and N. Aubin-Horth, Eds., *Ecological Genomics.* Dordrecht: Springer Netherlands.

C. Pál, B. Papp, M. J. Lercher, P. Csermely, S. G. Oliver, L. D. Hurst 2006 Chance and necessity in the evolution of minimal metabolic networks. *Nature* 440:667-670.

Nov. 29 Contingency and determinism at the origins of life and at the planetary scale

Readings TBD