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Essay Review

Mutual Bootstrapping

By James Brody.

A review of *Niche Construction: The Neglected Process in Evolution* by J. Olding-Smee, K. Laland, and M. Feldman. Princeton University Press, 2003.

Behavior geneticists have no difficulty with the idea that genes make niches and neither do most biologists; they balk, however, at the idea of manufactured niches' contributing to the further evolution of their occupants. *Niche Construction* (*NC*) pleads that evolution has two "general selective" players, natural selection and its unrecognized partner, niche construction (p. 385). A pair of equations from Richard Lewontin opens on p. 7

1) d(O)/d(t) = f (E, O),
2) d (E)/d(t) = g (E, O).

Organisms are an outcome of traits of prior organisms plus traits of environments, environments are an outcome not only of prior environments but also of the organisms that occupied them. The penultimate statement is on page 373: "...we have invited the reader to think about niche construction differently by regarding it not as just a product of evolution, but as a co-contributor, with natural selection, to the evolutionary process itself."

Olding-Smee *et al.* do the expected thing and do it very well: they show us their pony for 9 chapters and summarize clearly, in Chapter 10, why we should take it for a ride. First, some organisms cannot be understood as only the product of external selection. Worms, for example, did not adapt to top soil but preceded it, both keeping a fresh water kidney and building an extended kidney in their tunnels, one that allowed their survival on dry land (See Turner, 2000). Second, feedback exists between what the creature makes and the selection pressures for its offspring. Third, evolution is reflected in and acts upon phenotypes and phenotypes result not only from genes but also from the environments present during ontogeny. Thus, current environments have a vote in the tools that an organism acquires during its life. Fourth, environments are inherited, supplied through the accumulated contributions of prior generations and matched to offspring by parental intervention. Thus, "...explanations of standard evolutionary theory, according to which properties of organic systems are explained exclusively in terms of independent properties of environments, are insufficient..." (p. 372). Hooray!

Niche Construction takes us through the exchanges between occupants and settings as both

a problem and opportunity for evolutionists and for ecologists. The opening presents examples of environments crafted by the creatures who live in them and draws on material from Hansel (1984) and Lewontin (2000) through Turner (2000). The usual suspects...worms, coral, crickets, and humans...are accused of new crimes: stabilizing their settings so that each worldly improvement becomes a selective platform for more changes in the next generation, changes in occupants and changes in settings. Further, organisms are charged with being selective environments for other organisms. Long term residents in the neighborhood sometimes prosper or sometimes move out when new people move in. The new kids can directly influence the old timers or can do so by changing the non living materials that the old timers require.

Niche Construction criticizes the externalist view of evolution, and builds a most thorough alternative. For example, Chapter 3 considers ecological and evolutionary models and takes us into frequency- and density-dependent selection, habitat selection, coevolution, maternal inheritance, epistasis, indirect genetic effects, gene-culture coevolution, and evolution in spatially heterogeneous environments. Chapters 4-9 take us through the general traits of niche construction, its role in ecology, in human learning and cultural processes, assessing it in evolutionary biology, in ecology, and in studies of human behavior. Each chapter has algorithmic thoroughness, linear arguments, and only the most careful use of terms and examples. Nice job!

Caveats

Niche Construction will be cited and it will be included on bibliographies but it occupies a very crowded ecosystem of new viewpoints that apply to evolutionary biology. For example:

1) Network physics tells us about hubs and nodes, a statistical setting that was probably part of the EEA for even the first *Hox* sequences 500 MYA. The patterns that we now find in emergent electrical networks also occur in cellular metabolism, nervous systems, and language (Barabasi, 2002; Buchanan, 2002). (Network theory will change not only our thinking about evolution but also about much of psychology and psychiatry. It will also help us to find consciousness in a small worm.) For example, in many networks, a few dominant participants control as much as 80 percent of the action. Import: metazoans retained the same core metabolic systems but also developed a glorious variety of experiments that both adjusted their fit to existing niches and allowed them to find new ones. The mechanisms behind this decision were a recent mystery (Gerhart & Kirschner, 1997; Kirschner & Gerhart, 1998) but no longer. Biology and *NC* will, however, need decades to integrate such findings into their mainstream.

Further, "tuned oscillators" are on-off switches that automatically synchronize with each other. Tuned oscillators include the light from fireflies and chirps from crickets as well as the movement of pendulums (Strogatz, 2003). The model may fit interactions that occur between niches and occupants: bi-directional feedback lets either participant stabilize the other and such arrangements could produce very long intervals of stasis. The network people, however, don't seem to describe one oscillator as a platform for enhanced performance by its mate and mutual boot strapping. (Maybe Strogatz and friends need to look for this possibility!)

2) *NC* is a strong proponent of "dual inheritance theory" as developed by Boyd and Richerson (See also Laland and Brown, 2002): human culture is attributed with extraordinary selective influence. "We argue that, because cultural processes typically operate faster than natural selection, cultural niche construction is likely to have more profound consequences than gene-based niche construction" (p. 377).

Such a position is apt to be popular even if suspect. After all, behavior genetics assures us that "shared environments" are effective while we are in them but often contribute only 1-10%

of the variance in long term developmental outcomes. Nonshared environment often contributes 30-40% and consists of environments that are unique to an individual (Plomin *et al*., 2000). It could well be that genes are both flexible for the short term but resilient to culture's meddling over the long term, sometimes switching on or off as a function of hormones, stage of life, and environmental circumstances: phenotype depends not just upon the genes that are carried but on the genes that are active (Ridley, 2003). Along these lines, Raff (1996) notes that ancestral genetic cascades may be intact for as long as 5 million years after their last expression. We don't see the phenotypes of such because they are inhibited by newer sequences that themselves can be disrupted by environmental extremes, in turn releasing primitive traits. A chthonic possibility: drop a few bombs and see not only *Homo erectus* once more but also their cultures!

3) Poincaré told us that three-variable nonlinear problems are beyond human solution (Strogatz, 2003). No one has corrected him but Ed Lorenz got famous when he applied Poincaré to the weather. You derive estimations, not solutions and estimations depend on the range of variation that you are willing to accept in your estimates, the amount of variation in the behavior that interests you, and how far into the past or future you want to look. Factor analysis handles multivariate *linear* effects but most of them are boring, speculative, and not very useful for people who like to manipulate things. *Nonlinear* effects, the things that we cannot compute, are far more relevant for estimating possible impacts from our finding new genotypes as well as those from population density, contagious disease, climate change, and the aftermath of war.

4) Kauffman (2000) argues, without invoking connected oscillators, that species and environments tune each other towards stability and small changes and away from catastrophes. (Kauffman relies on Per Bak's model of self-organized criticality.) Large events, whether changes in phenotypes, extinctions, or environmental catastrophes, are infrequent; many small changes are common. Large genetic changes are less apt to be adaptive not because they disrupt the economy within an organism but because such changes cannot find utility in a static setting. A larger claw not only diverts resources away from other developing systems in the lobster but becomes an even bigger problem if there is no way to put it to work. Thus, organisms pull drifting environments back to a point of stability and environments put boundaries on some drifts in phenotypes but once in a long while, one partner or the other, setting or occupant, will do something so outrageous as to cause landslides, *tsunami*, and population crashes. (Some people might call these changes "saltations").

Finally, the receptor systems and "experience producing drives" (Bouchard, *et al.*, 1996) of an organism are part of the selective environment for its mates, offspring, competitors, predators, and food. Receptors pick up small differences between options and lateral inhibition between receptors could drive sexual selection as well as niche construction and cultural evolution. The selective contributions of receptors is both more neglected than niche construction and probably more salient not only for phenotypes but also for the worlds they make. Giraffes perhaps grew tall because lady giraffes liked taller males and because taller lady giraffes gained preferential treatment for their offspring from other lady giraffes.

Bottom Lines

The "received view" (Sterelny & Griffiths, 1999) has been that environments choose between genes and changes are infrequent, small, and randomly generated. Thus, wrinkled externalists disapprove of notions that influences between genes and environments are bidirectional, that environments and organisms stabilize each other, that steps can sometimes be dramatic or reversible, and that substantial channeling is imposed by network physics and biochemistry. The kid, however, who sold me

the book at *Barnes and Noble* knew about niche construction from his college biology courses and was impressed that one of his customers also liked the idea.

Niche Construction is a landmark for us who also agree with Popper's phrase: every living creature is in search of a better world. The past "neglect" of mutual bootstrapping between organisms and their settings may arise from technology: we find it easier to manipulate environments and measure effects on creatures but more difficult, until recently, to vary creatures and measure the effects on their environments.

Environments turn genes on or off and the new sophistication that we have in molecular genetics should allow us to manipulate the bidirectional effects in such relationships. The formulae in *NC*, however, could remain a niche for purists, also known as graduate students and postdocs, helping to refine them by a process of selection and, in turn, to be refined further by purists, again by a process of selection.

James Brody, Ph.D.,
http://www.behavior.net/forums/evolutionary.
Email: JBJbrody@cs.com

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