Actual studies of children contradict Chomskian dicta:

> [D]escriptions of mothers' speech to young children were undertaken in the late sixties in order to refute the prevailing view that language acquisition was largely innate and occurred almost independently of the language environment. The results of those mother's speech studies may have contributed to the widespread abandonment of this hypothesis about language acquisition but a general shift from syntactic to semantic-cognitive aspects of language acquisition would probably have caused it to lose its central place as a tenet of research in any case. (Snow 1977, p. 31)

Again according to evolutionary biologist Lewontin (1991),

> The trouble with the general scheme of explanation contained in the metaphor of [genetic program] is that it is bad biology. If we had the complete DNA sequence of an organism and unlimited computational power, we could not compute the organism, because the organism does not compute itself from its genes. Any computer that did as poor a job of computation as an organism does from its genetic "program" would be immediately thrown into the trash and its manufacturer would be sued by the purchaser. (p. 17)

L&B emphasize lengthy human development from infancy to adolescence. A human child develops by interacting and experiencing rather than by incubating and unfolding like a flower in a pot. In behavioral biology, cross-fostering – parents of one genetic strain rearing infants of another genetic strain – is a tool for studying the critical interaction between genetic endowment and developmental environment (Goodenough et al. 1993; Stamps 2003). Cross-fostered gulls adopt species-specific migratory habits of their adoptive parents (Harris 1970). Cross-fostered cockatoos adopt species-specific flying and feeding habits of their adoptive parents (Rowley & Chapman 1986). Cross-fostered voles adopt species-specific maternal habits of their adoptive parents (McGuire 1988). B. T. Gardner and Gardner (1989) cross-fostered infant chimpanzees in nearly human households to study the effect of a human developmental environment on a closely related species.

In Gardner and Gardner (1980) early sign language vocabularies of chimpanzees Moja, Pili, Tatu, and Dar overlapped with early vocabularies of human children as much as child vocabularies overlap with each other. L&B's lengthy developmental road to language implies a gradual, stage-by-stage process. In B. T. Gardner and Gardner (1998) semantic relations, that appeared in the early phrases of Moja, Tatu, and Dar, appeared in the same developmental sequence reported for human children. Nominative and action phrases appeared first, attributives second, and experience/notice latest in developmental samples of children and cross-fostered chimpanzees.

L&B emphasize pragmatic development. In studies of casual conversation (Bodamer & Gardner 2002; Jensvold & Gardner 2000), cross-fostered chimpanzees used expansion, reiteration, and incorporation to maintain the topic of a conversation as human adults and human children do. Contingencies of chimpanzee rejoinders to probes were comparable to contingencies reported for human children and, in adult cross-fosterlings, more comparable to older children than to younger children.

In Shaw (2000), adult cross-fosterlings integrated gaze direction and turn-taking into conversation the way human speakers and signers integrate gaze direction and turn-taking into their conversation with a pattern of development from infant to adult that resembles human development. Both directional modulation to indicate person, place, and instrument, and quantitative modulation to indicate intensity are essential pragmatic features of human sign language. In Rimpau et al. (1989) and Chalcraft and Gardner (2005), directional modulation to indicate person, place, and instrument appeared in conversational samples of Dar and Tatu as infant cross-fosterlings. In Chalcraft and Gardner (2005), quantitative modulations observed in human sign language also appeared in Tatu's infant conversation.

This article by L&B moves squarely in the path away from doctrinaire theory and points forward to open-ended discovery as expressed so well by Bruner (1978):

> bridging of gaps that before were not so much empty as they were filled with corrosive dogmatism. The gaps between prelinguistic communication and language proper as the child develops, the gap between gesture and word, between holophrases and sentences, between chimps signing and man talking, between sign languages and spoken ones, between the structure of action and the structure of language. I think that the renewal of interest in language as an interactive, communicative system has made these "gaps" less like battle grounds where one fights and dies for the uniqueness of man and more like unknown seas to be mapped. (p. viii)

Dynamic systems and the evolution of language

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Abstract: Locke & Bogin (L&B) suggest that theoretical principles of ontogenetic development apply to language evolution. If this is the case, then evolutionary theory should utilize epigenetic theories of development to theorize, model, and elucidate the evolution of language wherever possible. In this commentary, I evoke principles of dynamic systems theory to evaluate the evolutionary phenomena presented in the target article.

Locke & Bogin (L&B) underscore the role of ontogeny in evolution, to set it apart from several recent language evolution proposals that have ascribed a less significant role to ontogeny (e.g., Christiansen & Kirby 2003a; but see Johansson 2005, p. 31; also Oyama et al. 2001 for a general theory). L&B's account is comprehensive, with recent, much-needed research constituting its foundation. Specifically, they illustrate an important connection between evolving increases in the duration spanning childhood, culminating in a unique developmental phase in humans – adolescence – and evolving language abilities. The general perspective adopted in this article, however, is not entirely new. It echoes Oyama's (2001) general idea that processes of evolution and development bear striking similarities (Studdert-Kennedy [1991] provides a similar view on language; also see Haeckel 1899).

Throughout the target article, by adopting the life-history framework, the authors advocate that theoretical principles and phenomena of ontogenetic development are applicable to language evolution. For example, articulation and phonology were likely precursors to syntax in language evolution as in ontogeny. If indeed ontogeny and phylogeny are closely related in this manner, then evolutionary theory could benefit exponentially from adopting epigenetic theories of ontogenetic development to theorize, model, and elucidate, wherever possible, aspects of the evolution of language in humans. In this commentary, therefore, I draw upon three principles of epigenetic theories of development, in particular *dynamic systems theory* (henceforth DST; Thelen & Smith 1994; 1998; cf. Lickliter, in press; Oyama et. al. 2001), to evaluate and highlight some evolutionary phenomena elaborated upon by L&B. The primary purpose of this exercise is to integrate the principles underlying, and draw parallels between, changing systems of lifespan and species-specific development. After all, the forces that drive species to evolve can be explained only within a framework that makes explicit (a) the principles underlying the dynamics of complex biological systems, and (b) the multiple causes that drive dynamical systems to change over numerous time scales, within and beyond the lifespan.

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According to DST (Thelen & Smith 1998; cf. Lickliter, in press; Oyama 2001), form is a product of process: *Changes in developing systems are not predetermined by a grand design*. To the contrary, they are shaped at the local level during the process of an organism's interaction with its immediate environment. Similarly, the evolution of language did not take place in a vacuum (Johannson 2005). Evolutionary changes culminating in language were the result of selectional pressures at the local level, always shaped by interactions between members of the species and their immediate environment. L&B provide rich examples of these local-level selectional pressures that resulted in key changes that, in turn, facilitated the onset of language in evolving humans. For example, extension of the period of brain volume increase into postnatal life, to ease the obstetric problem of cephalo-pelvic disproportion in human females (caused by bipedalism), likely caused increased dependency of infants on adults, requiring extensive postnatal care. Greater physical handling by human caregivers, in turn, resulted in greater social stimulation and infant-caregiver interaction, and greater neurological development, eventually facilitating language in humans.

The preceding example also highlights a second tenet of DST: *multiple causality in emerging systems*. According to this tenet, changes occurring in a system – neurological, physiological, or behavioral – are the complex product of interaction between many factors at multiple levels (Lickliter, in press). Therefore, attributing primary causal status to any one factor or level is inadequate. This tenet, also applicable to language evolution, is well represented in Oyama's idea that change occurs via interactive co-construction: "The idea of construction through interaction of many different factors is applicable to evolution as well as development, and it highlights striking similarities between the two processes" (Oyama 2001, p.6).

Third, according to DST (Thelen & Smith 1998), *stability or lack of variability is inimical to change*. Changes in an emerging system are driven by instability or perturbations (at the local level) during ongoing organism-environment interactions (Kelso 1997). Therefore, a few collective variables, if accurately identified, and the collective organism's ability to self-organize in response to the changes in these variables (or control parameters) can explain change at any given point in time. To identify these control parameters, evolutionary theory must turn to robust empirical findings from life-span development, as prescribed and practiced in the target article.

Finally, because much theorizing about how language evolved depends on post hoc evidence from ontogeny or life-history, as the authors suggest, predicting changes along extended timescales might be possible by turning to the newly emerging field of *epigenetic robotics*. In this field, computational modeling of human development and its dynamics over multiple time scales is feasible. It involves the design and construction of artificial systems with adaptive, developmental algorithms, using key parameters that constitute specific behaviors of developing natural systems (Blank et al. 2005; see review by Prince et al. 2005). Future epigenetic models of language evolution would require architecture that is not fully specified. Fully specified systems are by nature predetermined by a grand design (e.g., see Hurford 2002; Kirby 1999b). These systems neither *develop* nor *evolve* by adapting to their local environment, and therefore are not accurate models of natural evolutionary processes. An alternative approach to modeling evolutionary changes in biological systems would require designing artificial systems to simulate self-organizing behavior and ongoing environmental interactions over extended time scales. These systems would adapt to perturbations at a local level (or levels).

In conclusion, future models of language evolution would need to include key parameters that do not fall strictly within the language domain. For example, consistent with developmental theory (e.g., Gogate et al. 2001; 2006), models of language evolution should find it useful to include the sensory and intersensory precursors to language development, to accurately model the process of language evolution from basic perceptual processes (Dominey & Boucher [2005] model syntactic acquisition using auditory and visual inputs; Prince & Hollich [2005] model infant auditory-visual perception and word-mapping). This domain-general approach to modeling language evolution would complement the multi-domain perspective embraced by L&B in their life-history approach to language evolution.

Why don't chimps talk and humans sing like canaries?

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Abstract: We focus on two problems with the evolutionary scenario proposed: (1) It bypasses the question of the origins of the communicative and semiotic features that make language distinct from, say, pleasant but meaningless sounds. (2) It does little to explain the *absence* of language in, for example, chimpanzees: Most of the selection pressures invoked apply just as strongly to chimps. We suggest how these problems could possibly be amended.

We agree with Locke & Bogin (L&B) on the importance of considering ontogeny in evolutionary studies. The unusual human developmental pattern may indeed provide insights concerning language origins. The emphasis of L&B on functional and pragmatic aspects of language is likewise commendable. However, these need to be integrated within an account of the origins of the semantic and grammatical aspects that make language a unique semiotic system allowing the communication of *detached representations* (Gärdenfors 2003) and the construction of narrative (Donald 1991). Since this is not the case, there are at least two major problems with the specific selective scenarios proposed by L&B.

Why not just sing? A major feature of language distinguishing it from all animal vocalizations is its ability to express an endless number of *thoughts* in various complex *combinations*. A plausible scenario of language origins needs to explain this enormous expansion of semiotic functionality. But Bickerton's argument against Dunbar's (1993) verbal-grooming hypothesis, about which he writes "a similar result could have been achieved simply by using pleasant but meaningless noises" (Bickerton 2003, p. 79), applies to a considerable extent against L&B's scenario as well. Or as an informant of Folb (1980), quoted by L&B, puts it: "Don' hafta make whole buncha sense, long sounds pretty" (sect. 7 of the target article).

The first stage in L&B's two-stage scenario concerns parental-care elicitation during infancy and childhood. There are certainly strong selective pressures at work here, but, as noted by L&B, the interests of parents and offspring do not coincide. This would more likely drive the evolution of manipulative signals rather than cooperative interaction and communication, as it has, for example, among many birds.

The second stage concerns sexual selection among adolescents and young adults. The common theme in L&B's lengthy discussion of oral societies is the importance of form and presentation over content. One would reasonably expect this to drive the evolution of ever more elaborate form – but why would it drive the evolution of content? Isn't it more likely that a scenario driven by sexual selection and status competition would result in something more resembling birdsong than language? Invoking sex and

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