demonstrate that the present can provide a useful framework for understanding the past.

My own perspective on "Language and life history" is conditioned by an extended period of familiarity with the writings of one of the authors. For more than a decade I have used two editions of Barry Bogin's *Patterns of Human Growth* (1988; 1999) as main texts in an upper-level undergraduate course titled Human Growth and Development. On first reading the target article against this background, I recalled the critical comment once offered by Samuel Johnson with ungentle pithiness: "Your work, Sir, is both new and good, but what's new is not good and what's good is not new." However, the work by Locke & Bogin (L&B) merits a much more positive assessment: What is not new (elucidation of the stages, shared and unique, in human life history) remains as good as it ever was, and what is new (the extension of this perspective to furthering our knowledge about the evolution of human language) is even better.

Most readers of *Behavioral and Brain Sciences* are likely to be specialists in functional rather than evolutionary biology; however, as is the case with the authors of the target article, my scientific work overlaps both domains. As a help toward relating these contrasting perspectives, I will paraphrase here part of a keynote address by Bruce Latimer that was delivered to the 2005 joint meeting of the American Society of Biomechanics and the International Society of Biomechanics: Scientists who work with living subjects (from elite athletes endeavoring to set new records to stroke victims and other patients undergoing rehabilitation work) have problems for which solutions must be found. But those of us who study the fossil record of past human evolution can see the adaptive solutions that nature has evolved; it is our challenge to reconstruct the problems that required these solutions in the first place.

The work of L&B is particularly fascinating because it begins with a set of problems, the so-called "obstetrical dilemma" triggered by the assumption of upright posture and bipedal locomotion, that has been the focus of much recent work by my own research group and our close colleagues in several other countries (e.g., Galik et al. 2004). This research has enabled us to establish the origin of bipedalism at about 6 million years before the present, thus bounding the earliest temporal limits of the human lineage that uniquely evolved language. The synthesizing work by L&B goes beyond the limitations of human fossil evidence by using developmental clues still perceivable in human ontogeny to attempt to tease out the stages that must have existed between the rudimentary forms of communication in living chimpanzees and those characteristic of our own species. This sort of approach, escaping the confines of so-called hard evidence by reasoning from soft tissue features and behaviors existing in present populations to comparable attributes in ancestral groups, holds much promise (Eckhardt 2000). It therefore is no criticism to characterize this target article more as a step in the right direction than an ultimate formulation of some end point in our understanding of the evolution of those aspects of brain and behavior science concerned with human language – or even to note that a few of its more unusual ideas have been anticipated (Livingstone 1973).

I suspect that some paleoanthropological colleagues may feel that the approach taken by L&B departs too much from traditional reliance on the hard evidence. But recently the new species *Homo floresiensis* has been hypothesized on the basis of a single skull with a chimp-sized brain of about 400 cc, yet with the supposed behavioral capacity to have manufactured stone microblades as part of complex tools heretofore found associated only with large-brained humans capable of speech. This is a dubious proposition for which there is a better alternative explanation in terms of human biology (Henneberg & Thorne 2004). Appropriate use of developmental clues inferred from living populations promises to provide an approach to behavioral inference in which broadly based theory trumps a narrow evidential base.

Enduring excitement in the brain and behavior sciences will be found in the solid advance of knowledge through hypothesis generation and testing of the sort offered by L&B, rather than through journalistic sensationalism.

Road to language: Longer, more believable, more relevant

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Abstract: A realistic developmental view of language acquisition recognizes vocabulary and pragmatics as well as grammar with a lengthy period of growth in a favorable environment. Cross-fostering is a tool of behavioral biology for studying the interaction between genetic endowment and developmental environment. Sign language studies of cross-fostered chimpanzees measure development in a nearly human environment.

Theoretical linguists of the last century seemed to deny human development.

> We are presenting an "instantaneous model" of language acquisition which is surely false in detail, but can very well be accepted as a reasonable first approximation. (Chomsky 1967, pp. 441–42)

Early followers of Chomsky supported his instantaneous model.

> Children all over the world learn to speak their native language at approximately the same time – 3 to 4 years of age. Within a relatively brief period, the child appears to learn a complicated and abstract system of rules . . . without teaching or training, [they] acquire their native language at about the same time – regardless of just about any variable one cares to look at, short of deafness or severe retardation. (Moore 1973, p. 4)

Chomsky's instantaneous model flattened the landscape of development from toddler to college student. Repeatedly, loyal Chomskians found virtually complete grammar in the speech of the same four-year-olds who cannot yet tie their own shoelaces or use a knife to spread jam on a cracker (Cohen & Gross 1979).

Locke & Bogin (L&B) recognize vocabulary and pragmatics, as well as grammar, and emphasize human development from infancy through adolescence. Their road to language is longer, more believable, and more relevant. They relate detailed aspects of linguistic skill to human development, doing justice to linguistic development as a biological phenomenon. Immature humans hardly spend their lengthened childhood vegetating, they spend it interacting with their parents and their culture.

Evolutionary biologist, Lewontin puts it this way:

> We are not determined by our genes, although surely we are influenced by them. Development depends not only on the materials that have been inherited from parents – that is, the genes and other materials in the sperm and egg – but also on the particular temperature, humidity, nutrition, smells, sights, and sounds (including what we call education) that impinge on the developing organism. (Lewontin 1991, p. 26)

Genetic advances in agriculture produce new breeds that are dramatically different from parent stocks. Under contrasting conditions, seeds that are virtual clones mature into dramatically different plants, often so different that they are hardly recognizable as the same species. Animal agriculture reveals equally dramatic interactions between genes and environment. Behavioral development should be more sensitive to environment, and advanced behavior, such as language, should be still more sensitive.

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.