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NATURE = f(NURTURE): A REVIEW OF OYAMA'S THE ONTOGENY OF INFORMATION: DEVELOPMENTAL SYSTEMS AND EVOLUTION[1]

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The nature-nurture dichotomy is among the most central distinctions in the life sciences. It has preoccupied biologists (e.g., Jennings, 1924), ethologists (e.g., Lorenz, 1965), psychologists (e.g., Plomin, 1990), and sociologists (e.g., Homans, 1979) since Francis Galton (1874) first formalized the distinction—and even before (see Medawar & Medawar, 1983, pp. 194-196). In some cases, the nature-nurture dichotomy asks only that we distinguish between nature (i.e., genes) and nurture (e.g., environments) as sources of biological, behavioral, and social-cultural characteristics or activities. In other cases, the dichotomy asks that we make a choice between nature and nurture as a primary or sole cause. The seemingly more moderate position with respect to the latter is that nature and nurture interact. This, however, carries with it the implication that nature and nurture are causal *entities*—entities that are, at least in principle, independent.

Although the nature-nurture dichotomy has been a preoccupation within the life sciences in general, it has been of special and more focal concern in developmental psychology. Indeed, one way in which developmental theories often are classified is with respect to their place along a nature-nurture continuum, with the extremes represented by nativism and environmentalism (Horowitz, 1987). Some developmental theories, however, resist any such placement because, for them, the nature-nurture dichotomy is not a meaningful way to conceptualize the "causes" of development (e.g., Gottlieb, 1992; Kuo, 1967/1976; Lehrman, 1970; Oyama, 1985).

Among those approaches inclined to regard the nature-nurture dichotomy as meaningless is the behavior analysis of development (e.g., Bijou & Baer, 1961, 1965, 1978). Indeed, 25 years ago, Bijou and Baer (1967) provided an alternative to the nature-nurture dichotomy. In the prefatory material to their reprinting of Anastasi's (1958) "Heredity, Environment, and the Question 'How?'," they wrote:

> It is a mistake to ask *which* traits are hereditary and which are learned. Similarly it is a mistake even to ask *how much* heredity and environment contribute respectively to any specified pattern of development. The correct question, as always, is *how* development takes place, in detail, step by step through the causal chains found operating in a specific individual under study. (Bijou & Baer, 1967, p. 111)

Developmental though this may be, Bijou and Baer's alternative to the nature-nurture (i.e., heredity and environment) dichotomy was only a beginning, not an end.

It is in the spirit of offering a systematic, constructive alternative to the nature-nurture dichotomy that we recommend Susan Oyama's (1985) *The Ontogeny of Information: Developmental Systems and Evolution.*[2] In what follows, we (a) describe the defining characteristics of Oyama's (1985) alternative with respect to inheritance, construction, and developmental systems, (b) discuss some similarities between Oyama's views and behavior analysis, and (c) comment on the relevance of the developmental systems perspective to current and future directions in behavior analysis.

[1] Oyama, S. (1985). *The ontogeny of information: Developmental systems and evolution.* Cambridge, England: Cambridge University Press. ix + 206 pp.

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[2] For more accessible treatments of Oyama's developmental systems perspective, see Oyama (1982, 1989). For a discussion of the relationship between developmental and evolutionary processes, see Oyama (1988).

In general, we restrict our review and commentary to the content of Oyama's book and some of her other publications, omitting background material on the historical and conceptual lineages of her work. We can, however, put her perspective in historical context by noting that it has much in common with (a) classic critiques of the nature–nurture dichotomy (e.g., Lehrman, 1953, 1970; Verplanck, 1955), (b) prior alternatives to "genetic imperialism" (e.g., Jennings, 1924; Weiss, 1971; see Oyama, 1989, p. 10), and (c) earlier emphases on life-span development (e.g., Beach, 1955; Kantor & Smith, 1975; Kuo, 1967/1976; Schneirla, 1966).[3] Contemporary syntheses and extensions of this earlier work may be found under the rubrics of developmental interactionism, probabilistic epigenesis, an interactionist approach, dialectical materialism, and the inheritance of niches (see, e.g., Delprato, 1987; Gottlieb, 1983, 1992; Johnston, 1988; Levins & Lewontin, 1985; Miller, 1988a; West, King, & Arberg, 1988). Oyama herself acknowledges much of this classical and contemporary work and more, noting parallels between it and her own efforts.

THE ONTOGENY OF INFORMATION

The Ontogeny of Information consists of nine chapters: an introduction; a chapter apiece on biological and behavioral constancy, change, and variability; a chapter on prevalent metaphors used to describe the actions of genes and environments; a chapter on philosophical issues; a chapter that presents an explicit statement of Oyama's perspective; and two final chapters—reprise and prospects.

Three propositions are central to Oyama's developmental systems perspective. First, what is inherited extends beyond the genes to include other physical, chemical, biological, environmental, and behavioral "interactants"—Oyama's generic term for all developmentally relevant factors or participants. Second, many biological and behavioral structures and functions are not themselves inherited, but are "constructed." And third, the "developmental system" is an empirical and conceptual biobehavioral unit of analysis that treats nature and nurture not as independent causes (even if interacting and weighted), but as *product* and *process*, respectively. That is, nature is the product of the process of nurture. We elaborate on these points in the following.

Inheritance

The first of Oyama's three propositions concerns what is inherited. Everyone, including Oyama, agrees that genes are inherited. The problem is that most everyone also agrees that *only* genes are inherited. For Oyama, what is inherited needs to be broadened beyond mere "naked DNA strands" (Oyama, 1982, p. 118). As she notes, "[Inheritance] is not limited to genes, or even to germ cells, but includes developmentally relevant aspects of the surround" (Oyama, 1989, p. 26). For Oyama, inheritance includes all factors—physical, chemical, biological, environmental, or behavioral—that participate in prenatal and postnatal development. Among the factors she cites as inherited, other than genes, are "cell structure," "intracellular chemicals," "extracellular environment," "parental reproductive system," "self-stimulation by the organism itself," "immediate physical environment," "conspecifics and members of other species," and "climate, food sources, [and] other aspects of the external environment" (Oyama, 1989, pp. 27–28).

Oyama's point is that genes never function in isolation and that we therefore need to look to factors that serve as their contexts. These factors are frequently held constant, either methodologically or statistically (as they should be for certain purposes) but they are often then unfortunately taken for granted or ignored (e.g., Oyama, 1985, pp. 68–69). For these and other reasons, we know less about how nongenetic factors operate in development than we know about how genes operate—or about how we *think* genes operate given that their functioning is easily thought of as "context-free." If we were to examine these nongenetic factors, we would discover that they are relevant to gene functioning, and hence developmentally relevant in their own right. In support, Oyama (1985) cites Raff and Kaufman (1983):

> In describing the three information systems in a fertilized egg (nuclear DNA, regionalized cytoplasmic macromolecules, and the "cytoskeletal matrix" or cellular structure), they show

[3] We would not want to leave the reader supposing that these individuals addressed only these associated issues. These scholars, and others, have contributed to a broad range of topics and issues related to nature, nurture, and development.

> that the initial developmental system includes (but, I would argue, is not limited to) the organism's genome, complex cell structures and messenger ribonucleic acid (mRNA) that derives from the mother's genome, not the embryo's own. In sea urchin embryos, the latter two parts of the system can bring development a surprising distance. Changes in cell shape, assembly of cilia and synthesis of hatching enzymes will proceed all the way to the blastula stage, without any transcription of the embryo's own genes. Again and again these authors cite research showing the regulation of gene activity by temperature, cytoplasmic constitution and a host of other factors. (Oyama, 1985, pp. 128–129)

Oyama's broadened definition of *inheritance* may appear unusual or even trivial to those accustomed to thinking only of genetic inheritance. In actuality, though, it comports well with an older use of the term, a use derived from property inheritance:

> A systems view brings biological inheritance into closer correspondence with the model of property inheritance in human societies than has generally been recognized. A family usually passes on its wealth and the means for its maintenance and exploitation, including education, social position and connections, and an appropriate ethic as well. Alternatively, one might say that all those things together constitute the family's wealth. Offspring receiving only part of the complex do not as reliably perpetuate the family fortunes. (Oyama, 1985, p. 131; cf. Smith, 1985)

In other words, although money is what is most obviously bequeathed to an heir, much else is passed along as well. The "much else" not only influences how the inherited money is used (i.e., how it functions), but also the subsequent financial (and other) life history of the heir. Does he or she, for instance, become a tycoon or a bum—or both? Genes, then, function in different ways and contribute to different developmental outcomes depending on what else is inherited, that is, depending on their context. Given that "culture" and "ecological niche," for instance, refer to the interdependence of developmental interactants during an individual's life history, it is appropriate to consider them, as well as genes, as inherited (Oyama, 1989; West et al., 1988). Genes are but one inherited class of interactants among many.

By itself, Oyama's revised definition of inheritance does not resolve the nature–nurture dichotomy. Identifying all developmental interactants as inherited does not necessarily change how we conceptualize the emergence of biology and behavior. For Oyama, a further move away from traditional notions is needed. We need to adopt a perspective that not only recognizes the context-dependent functioning of genes but also takes developmental processes seriously as well. Such a perspective—Oyama's perspective—argues that although some biological and behavioral structures and functions are inherited, many others are constructed.

Construction

For Oyama, asserting (a) that particular biological and behavioral structures[4] and functions develop largely because of certain genes or (b) that certain genes are "for" particular structures and functions (e.g., Oyama, 1989, p. 28) is not far from asserting that the structures and functions are "in the genes" (cf. Lewontin, Rose, & Kamin, 1984). For Oyama, structures and functions are not preformed, nor is their development preprogrammed. She uniformly rejects metaphors couched in the language of "genetic blueprints," "symbols," "instructions," "programs," and the like (see Chapter 5, "Variations on a Theme: Cognitive Metaphors and the Homunculoid Gene," pp. 46–72). Such explanations amount to preformationism (e.g., Oyama, 1985, pp. 24–25).

In rejecting preformationist metaphors, however, Oyama is not advocating the other extreme—that cells are nothing but unstructured bio-chemical stuff waiting to be shaped by some external agent (e.g., the environment). That would affirm the nature–nurture dichotomy, which is being denied. More subtly, as Oyama (1985) notes:

> There is really nothing problematic about this idea [of "preformed structure"]. What is misguided, not only about the preformationist belief, but the modern version as well, is the assumption of correspondence between initial and final structure. The chromosomes are indeed highly structured, as are the cell organelles, the

[4] By "behavioral structure" we mean "the organization of behavior and its products" (S. W. Bijou, personal communication, October 9, 1991) (e.g., Ray & Delprato, 1989). We are referring neither to mental (e.g., in a Piagetian-structuralist sense) nor to physiological structures.

chemical substrates and the extracellular environment. (p. 25)

In contrast to encoded genetic blueprints and unorganized passive masses of physiology, Oyama distinguishes between what is inherited and what is constructed.

As to inheritance, many "things" are inherited in the sense that they are literally "passed on" intact to the developing organism, both pre- and postnatally. Included among these inherited factors are interactants we would otherwise classify as biological and behavioral[5] structures and functions (e.g., the zygote, an intrauterine environment, conspecifics). As to construction, inherited structures and functions have to be distinguished from biological and behavioral structures and functions that emerge from interactions between inherited interactants and the organism (i.e., the organism as the product of a developmental process at any one point). In other words, although some biological and behavioral structures and functions are inherited (see our preceding section on inheritance), phenotypic outcomes (both biological and behavioral) develop. They are constructed.

Oyama's distinction between what is inherited and what is constructed is independent of the traditional dichotomy of "innate" versus "acquired." That is, characteristics that are typically thought of as "innate" or "unlearned" may be just as much a function of an individual organism's developmental history as those characteristics typically thought of as "acquired" or "learned." For Oyama, then, those structures and functions we usually describe as "innate" or as "acquired" actually have a history of development within the lifespan of the organism (see Gottlieb on Kuo, 1976, p. xv). In Oyama's (1985) words:

> Since all aspects of the phenotype are products of ontogenesis, they are in some sense acquired. Means (developmental interactants) are inherited, results ("natures") are acquired by construction. (p. 125)

Although we may have seemingly belabored this point, we have not done so without reason. Oyama's distinction between what is inherited and what is constructed is one of the most important points of the developmental systems perspective. Although many readers might, at first, think her point to be penetratingly obvious, it is too often overlooked in favor of traditional conceptualizations of inheritance that speak of preformationist metaphors and the transmission of characteristics, via the genes, across generations. In this traditional view, development is seemingly guided in an almost automatic or mechanical fashion (Oyama, 1982). For Oyama (1985), who sees development as "the conditional transformation of prior structure," these traditional accounts come close to denying the importance of developmental processes altogether (p. 4). They simply do not take development seriously (Oyama, 1989, p. 24). Descriptions of development based on the metaphors of encoding, transmission, and retrieval (akin to cognitive metaphors in psychology) are actually contrary to a thoroughgoing developmental perspective. As Oyama (1989) succinctly notes, "The transmission metaphor denies development" (p. 24). By delineating the distinction between the inherited and the constructed, Oyama's perspective is one that *does* take development seriously.

The charge of "environmentalism." Ironically, in taking this perspective, Oyama and her colleagues have sometimes been misunderstood as advocating one side of the nature–nurture dichotomy—the side of environmentalism (see, e.g., Oyama, 1989, p. 19). This misunderstanding may have arisen, in part, for two reasons. First, as Oyama (1991) notes:

> One of the legacies of the nature–nurture dichotomy is that anyone criticizing one of the opposing positions will tend to be seen as advocating the other. If one voices skepticism about some "biological" interpretation, it is often assumed one must automatically be an environmentalist, and vice versa. (p. 29)

A second reason for the charge of environmentalism may be that some of the early empirical research inspired by a developmental systems perspective (albeit not then known by that name) was concerned with environmental alterations that contributed to the development of non-species-typical behavior (see, e.g., Kuo, 1930, on cats who became "attached" to rats;

[5] Our distinction between "biological" and "behavioral" is not meant to perpetuate the innate–acquired dichotomy, appearances notwithstanding. We "identify [biological] . . . with a level of analysis roughly equivalent to 'physiological-morphological' " (Oyama, 1985, p. 148), and behavioral "with the interaction of an individual with stimulus objects, under definite immediate conditions and on the basis of the previous contacts of the organism and the stimulating objects" (Kantor, 1946, p. 252).

cf. Kuo, 1967/1976, pp. 63–64). This research demonstrated that behavior thought to be in some way innate, and thus immutable, was actually susceptible to modification by changes in an organism's environment (see Johnston, 1988, on Lehrman's selective rearing experiment, p. 622).

This charge of environmentalism is akin to related misunderstandings about all behavior being learned (see, e.g., Oyama, 1982, p. 119). As Lorenz (1965), for example, said of some of Kuo's early work (e.g., Kuo, 1932a, 1932b), as that work was discussed by Lehrman (1953):

> If Lehrman (1953) gives serious consideration to the assumption that a chick could *learn, within the egg,* considerable portions of the pecking behavior by having its head moved rhythmically up and down through the beating of its own heart, he totally fails to explain why the motor pattern thus individually acquired should fit the requirements of eating in an environmental situation which demands adaptedness to innumerable single givens as exactly as it does. (p. 23, emphasis added)

But Lehrman (1953) said nothing about such behavior being *learned* (Lehrman, 1970). He and Kuo were simply stressing that prenatal events influence postnatal events. As Kuo (1967/1976) replied:

> Just as the prenatal visual responses and leg movements are historical antecedents of postnatal food-getting behavior, the prenatal movements of the beak, the head, and, in fact, the whole visceral system are part and parcel of innumerable gradient patterns of postnatal behavior such as "courtship," "threat," "preening," "running," "attacking," and innumerable other patterns of social behavior. Indeed, Lorenz has left his humorous remarks about my work on the chick embryo unfinished. Instead of merely, "The heart teaches the chick to peck," he should have said, "The heart teaches the chick to peck, to fight, to crow, to make love calls, to sound alarm, etc." (p. 114)[6]

Oyama and her colleagues may at least take comfort in having descended from a long line of distinguished—even if misunderstood—psychologists. (For a somewhat personal account of the conflict between comparative psychologists and ethologists in these regards, mostly between Lehrman and Lorenz, see Beer, 1975.)

To summarize Oyama's position thus far: The factors that enter into developmental processes are inherited. The outcomes of these processes are acquired—they are constructed.

Developmental Systems

Oyama's conceptualization of inheritance and construction culminates in what she calls the "developmental system"—the integration and organization of all the factors or interactants relevant to the development of particular biological and behavioral structures and functions. For readers familiar with Kantor's interbehavioral psychology (Kantor, 1959, 1970; see Midgley & Morris, 1988; Morris, 1982; Mountjoy, 1976; Pronko & Herman, 1982), his "integrated field" is analogous to Oyama's developmental system. The integrated field and the developmental system are simply abstractions, not reifications, from the ever-evolving stream of behavioral and biological processes, respectively (Kantor, 1938; Oyama, 1985). Biological and behavioral structures and functions emerge from or are constructed through the interaction of numerous and varied factors at their own level (see Midgley & Morris, 1988).

In essence, what Oyama and Kantor have done is to create generic "recipes" for biobehavioral processes. Interestingly, Miller (1988b) has actually argued that genes and other developmental factors can be represented by different ingredients of a recipe, and that different "experiential factors" can be likened to different types of cooking (e.g., baking vs. frying) (Miller, 1988b, p. 148). As he explains by way of example:

> In the first case, FLOUR + SALT + WATER fried in shortening "develop" into a FLOUR TORTILLA. In the second case, we take precisely the same ingredients and provide them with a "baking" experience (without shortening). . . . [N]ow these ingredients yield a MATZO. In the third case, we keep these three ingredients and add YEAST to them. While baking, these develop into BREAD. Finally, we retain the FLOUR and SALT, but add to them BUTTER, COCOA, and SUGAR. Again, bake them, and the result is a BROWNIE. (Miller, 1988b, p. 148)

Miller's metaphor, however, is not without difficulties, for example, as Oyama notes (personal communication, December, 11, 1991):

[6] To the extent that Kuo thought it necessary to "exchange" comments with Lorenz, we are tempted to quip, "Quid pro Kuo."

> Experience is not placed in the same category as other influences, and although cooking is important, it is easy to read it as a modifier of the essential elements, but not an essential element itself. This fits too easily with ideas of a "biological base" that is differently expressed in different environments.

Oyama's objection notwithstanding (and with which we agree), we may still appreciate Miller's recipe metaphor for what it *does* appropriately convey: the distinction between product and process. That is, the recipe is a description encompassing all relevant developmental factors. From Oyama's view, the interaction of all the factors (i.e., the ingredients *and* the cooking) would be described as "nurture"; their product would be described as "nature." Nature and nurture are not opposed to one another, as in weighted causes, but are product and process, respectively. As noted before: "Nature and nurture are . . . not alternative sources of . . . causal power. Rather, nature is the *product* of the *process* of the developmental interactions we call nurture" (Oyama, 1989, p. 5). In other words, nature is a function of nurture.

To this point, we have described Oyama's treatment of inheritance, construction, and developmental systems. We now turn to some similarities between her perspective and contemporary behavior analysis, and then to the possible relevance of her system to current and future directions in that discipline.

ABOUT AND BEYOND BEHAVIORISM

About Behaviorism

Response–stimulus interactions. Oyama does not identify herself as a behavior analyst. Even so, she has a behavior-analytic outlook on behavior as a subject matter—that is, on responding and its relationship to environmental stimuli—as her following observations exemplify. With respect to the definition of stimulus functions and the form–function distinction, she observes:

> The impact of sensory stimuli is a joint function of the stimuli and the sensing organism; the "effective stimulus" is defined by the organism that is affected by it. That one creature's sensory meat is another's poison, or that the same stimulus may have different effects on the same organism at different times, does not render stimulation causally irrelevant or merely permissive. (Oyama, 1985, p. 33; cf. Kantor, 1942)

With respect to reciprocal interactions between experimenter and subject, she writes:

> To shape an animal's behavior with conditioning methods, a trainer needs to be observant and sensitive to his subject. He needs to be under its precise control in order to control it. To control is not to stand outside the causal world; it is to rearrange oneself in it. (Oyama, 1985, pp. 167–168; cf. Skinner, 1956)

Oyama's appreciation for the reciprocal interactions between organism and environment demonstrates that she "takes the environment seriously," albeit without advocating an environmentalism (see our previous section on "the charge of 'environmentalism' "). Indeed, a developmental systems perspective, with its broadened definition of inheritance and its emphasis on the construction of developmental systems, recognizes the importance of environmental factors in a way often overlooked by perspectives that speak in terms of preformationist metaphors. That is, from a developmental systems perspective,

> *All* behavior, and indeed all phenotypic characters, arises in development as the result of an interaction between the animal and its environment. The genes play a role in this interaction, one that is still hard to specify in any detail, but they do not directly determine any aspect of the phenotype. (Johnston & Gottlieb, 1990, p. 475)

Direct (nonmediated) development. The developmental systems perspective is markedly different from other perspectives wherein genes are said to encode, transmit, or retrieve relationships between organism and environment (see Oyama, 1985, pp. 46–72). From a developmental systems perspective, genes no more mediate the effects of the environment than other interactants mediate the effects of any other interactant. Genes are not mediators, but rather are a class of developmental interactants. As such, the developmental systems perspective is a theory of direct (nonmediated) development, just as behavior analysis is a theory of "direct behavior" (i.e., nonmediated behavioral relations) (Morris, in press-a; cf. Skinner, 1931, 1935).

In behavior analysis, behavior is the interrelationship of response function and stimulus function—in context. Biology and cognition do not mediate this relationship (e.g., as the O in S-O-R psychology; see Morris, in press-a). Rather, biology is both an interactant within and a product of development; it contributes to both the historical and current context of behavior. Cognition, in turn, is a vernacular term describing behavior in context; that is, cognition is a behavioral product of behavioral processes, not a process unto its own (see Skinner, 1974).

Cast this way, the behavior-analytic perspective is similar to Gibson's (1979) theory of "direct perception" (see Costall, 1984) and to Watkins' (1990) theory of "direct memory." It is likewise related to the contextual and ecological approaches to cognition (see Neisser, 1985; Wilcox & Katz, 1981; cf. Leahey, 1991, p. 377), as well as perhaps to the PDP neural network theory as a theory of "direct adaptation" (see Donahoe & Palmer, 1989). These are all perspectives that "take the environment seriously" (cf. Neisser, 1985, p. 30).

Dualism. Like behavior analysts, Oyama also sees the deleterious effects of dualism in the life sciences. Her concern, however, is not so much with psychophysical (i.e., mind-body) dualism as with gene-environment dualism (but see Oyama, 1991). For Oyama, viewing genes as "self-actional" agents of "innate" behavior or maturation (see Oyama, 1982) is comparable to viewing minds as self-actional agents of action (see Dewey & Bentley, 1949; cf. Pronko & Herman, 1982). Here, Oyama borrows and extends Ryle's (1949) metaphor of the "ghost in the machine" to describe the ways in which genes are usually believed to function in developmental processes. For Ryle (1949), the ghost in the machine is a self-actional mind. For Oyama (1985), "the ghosts in the ghost-in-the-machine" (p. 73) are self-actional genes. In her words:

> There are no ghosts in machines, only persons in the world, thinking, feeling, intuiting and sensing, deciding, acting and creating. And there are therefore no ghosts in these ghosts, no programs in the operators of the machines, making them feel as their ancestors felt, making them act or want to act as gorillas or chimps act. But there *are* many ghosts in the psychological, social and cultural machine that creates and recreates the body-machine, the ghost in it, and the ghost in *it*. (Oyama, 1985, p. 113, footnote number omitted)

Beyond Behaviorism

Moving beyond similarities, the developmental systems perspective has, we think, some constructive implications for the future of behavior analysis. First, by explicitly treating *both* the "innate" and "acquired" characteristics of development as the product of an ontogenetic biological and behavioral process, the developmental systems perspective makes ontogenesis central to developmental outcome. Behavior analysis, in contrast, has seemingly overlooked biological ontogenesis, which suggests that we do not always "take development seriously" and, as a consequence, maintain a dichotomy between nature and nurture.

Second, the developmental systems perspective suggests that we might consider behavior analysis a "developmental" psychology in its own right. Moreover, by extending what we see as behavior analysis's implicit (and Oyama's explicit) developmental perspective to all bio-behavioral phenomena, behavior analysis may also achieve a more thoroughgoing developmental orientation, joining other bio-behavioral sciences in studying and elucidating the dynamics and complexities of all developmental processes (see, e.g., Bertenthal, 1991).

In the remainder of this review, we turn first to the neglect of biological ontogenesis by behavior analysis. Second, we turn to the characteristics that make behavior analysis, in part, an inherently developmental psychology.

Ontogenesis. That behavior analysis does not always take development seriously is exemplified in its distinction between phylogenic and ontogenic contingencies. That is, behavior analysis has parsed selection by consequences into two broad classes—phylogenic and ontogenic (e.g., Skinner, 1966, 1981). Phylogenic contingencies are said to account for "behavioral relations" acquired during the evolution of species (Michael, 1985, pp. 101–103), that is, for behavioral relations that are commonly labeled "innate" or "unlearned." Ontogenic contingencies, in turn, are said to account for behavioral relations acquired during an individual's lifetime, that is, for behavioral relations that are commonly labeled "acquired" or "learned." Behavior analysis thereby includes both (a) species-typical behavioral development via natural selection and (b) individual behavioral development via contingencies of reinforcement, but it does not seemingly include individual pre- and postnatal biological ontogenesis. Overlooking biological ontogenesis has had two unfortunate and related consequences.

First, behavior analysis seemingly overlooks the effects that *biological* ontogenesis has on *behavioral* ontogenesis[7] (see, e.g., Smotherman & Robinson, 1990), as well as the effects that behavioral ontogenesis has on biological ontogenesis (see, e.g., Greenough, 1975; Rosenzweig, 1984). We are not saying that these relationships have been entirely neglected, of course (see, e.g., Fantino & Logan, 1979). Indeed, Skinner's (1931, 1935, 1938) early work involved, in part, conceptual and experimental analyses of how "third variables" such as maturation, disease, and injury affect response–environment interactions (e.g., rate of responding). What we *are* saying is that behavior analysis has not systematically incorporated individual biological ontogenesis into its general conceptual system (see Morris, in press-b).

Where behavior analysis has included biological ontogenesis, however, it is treated as a relatively "automatic" process governed by the genes. Oyama, of course, would object to such gene-driven notions because biological ontogenesis is an *individual* developmental process. It is this individual process, along with behavioral ontogenesis, that gives rise to all biological and behavioral characteristics, whether typically described as "innate" or as "acquired." That is, for Oyama, interactants may be inherited, but they enter into developmental processes that are responsible for the construction of phenotypic characteristics, whether those characteristics are biological or behavioral.

Second, overlooking biological ontogenesis perpetuates the dichotomy between innate and acquired. By dividing environmental contingencies into the phylogenic and the ontogenic (not discounting the fact that they are said to interact, e.g., Skinner, 1969), we have put ourselves in the position of maintaining—not rejecting—the nature–nurture dichotomy. In assuming that organisms have inherited some behavioral relations from their ancestors via phylogenic contingencies and that they have acquired others via ontogenic contingencies, we have simply fashioned our own version of a dichotomy in which some determinants of behavior are genetic or due to nature (i.e., phylogenic) and others are environmental or due to nurture (i.e., ontogenic), even if all the determinants are said "ultimately" to be environmental (Michael, 1985, p. 101).

In contrast to the phylogeny–ontogeny distinction, a developmental systems perspective maintains that *all* bio-behavioral phenomena—"innate" and "acquired"—are the products of "a continuous developmental process from fertilization through birth to death" (Kuo, 1967/1976, p. 11). Again, nature is the product of the process of nurture. This is a constructive implication for the future of behavior analysis.

Development. As noted at the beginning of this review, Bijou and Baer (1967) once wrote of the nature–nurture dichotomy in a way congruent with Oyama's developmental systems perspective, but within the discipline this aspect of their position never was elaborated much further (e.g., Skinner, 1966, 1974, 1975, 1981, 1984, 1988). As a result, behavior analysis overlooked an opportunity to extend what we take to be its inherently developmental perspective.

What makes behavior analysis developmental—that is, a historical science—has nothing to do with its application to particular content areas (e.g., to child development; see Bijou & Baer, 1978; Gewirtz & Pelaez-Nogueras, 1991; Patterson, DeBaryshe, & Ramsey, 1989). Rather, behavior analysis is developmental because of (a) its approach to behavioral history (e.g., conditioning history) in the explanation of current behavior and (b) its inherently contextualistic world view.

As for behavioral history, behavior analysts have long recognized, at least conceptually, that explanations of behavior lie not only in current circumstances but also in the history of past organism–environment interactions (e.g., Lee, 1988, pp. 161–162; Skinner, 1953, p. 31; Wanchisen, 1990). That is, they typically invoke inferences about behavioral histories in accounting for behavior that is not readily attributable to immediate circumstances. Much of the rest of psychology, of course, invokes entities such as mind, cognition, and perception as accounting for such cases. Inferences about behavioral histories are germane to a natural science of psychology (albeit sometimes too facile) because they are themselves based on knowledge of the extant behavioral principles (e.g., Palmer, 1991; Skinner, 1974, pp. 251–253): They are, in principle, empirically testable (e.g., Weiner, 1970); they can

[7] At this point, it seems desirable to speak of biological and behavioral *ontogenesis* to emphasize that we see the two processes as comparable in many respects (e.g., neither is encoded in genes).

be, in practice, demonstrated (e.g., Johnson, Bickel, Higgins, & Morris, 1991; Wanchisen & Tatham, 1991); and they do not appeal to nonspatiotemporal (i.e., nonnatural) entities (e.g., Kantor, 1959, pp. 47–48).

This last point about nonnatural entities may be the most important point of all. It emphasizes a fundamental difference between behavior analysis and mainstream psychology: Behavior analysts do not depart from a naturalistic, nondualistic conceptualization of behavioral processes when making inferences about the determinants of behavior. Pronko (1988) conveys the spirit of this point well when noting:

> Isn't an inference an inference? Aren't all inferences on the same level? Not at all. An inference about an *imaginary, unobservable* entity is not on a par with the inference ... [about] an observ*able* event, even though at the moment it is not here and now observable. It *can be* verified; "icons" and "images" have not been supported, because they are [inherently] unobservable. (pp. 206–207)

As for contextualism (a second way in which behavior analysis is developmental), this is a world view to which the behavior analysis of development seems most closely tied (Bijou, 1989; Krasner, 1977; Morris, 1988), and which has also been recognized as inherent in radical behaviorist philosophy more generally (Hayes & Brownstein, 1986; Hayes, Hayes, & Reese, 1988). From a contextualistic perspective, the root metaphor for conceptualizing behavior is "the historic event"; behavior is the ever-changing "act in its context" (Pepper, 1942, p. 232). This "historical" root metaphor of contextualism strikes us as inherently *developmental* in that it implies an integrated, temporally extended process of ongoing change.

At this point, we hasten to emphasize that "developmental" need not imply "developmentalism." Developmentalism is a quality of those psychologies that take time or chronological age as either a *marker* or *maker* of the typical onsets and offsets of behavior (see, e.g., Skinner, 1974, pp. 12–14, 71–75). That is, in developmentalism, time is either a marker that indicates when particular types of behavior are likely to emerge during the life-span or a maker that causes the behavior change. Using time as a marker is not necessarily inconsistent with behavior analysis, but such use does not constitute a functional analysis (Baer, 1970). Using time as a maker, however, is clearly pernicious because it attributes change, in part, to the realization of predetermined developmental schedules. The actual processes that lead to the emergence of behavior are thereby largely ignored (see Pronko, 1988, pp. 198–207).

In our view, "developmental" should be seen as descriptive of the behavior-analytic subject matter. It need not imply anything about the putative role of time, per se, as marker or maker. Rather, "developmental" emphasizes the temporally extended, ever-changing character of behavior. Behavior is an ongoing, durational process. As Skinner (1953) noted,

> Behavior is the coherent, continuous activity of an integral organism. Although it may be analyzed into parts for theoretical or practical purposes, we need to recognize its continuous nature in order to solve certain common problems. (p. 116)

Or, as Schoenfeld and Farmer (1970) stated,

> We take it as axiomatic that behavior is a continuous stream. . . . The continuousness of behavior means that the organism can be thought of as "always doing something." (p. 222)

Behavior analysis, then, like evolutionary biology and cosmology, is a "historical science" (see Donahoe & Palmer, 1989, pp. 399–402). It is a historical science in that its subject matter is the act in context—a "historic event" (Pepper, 1942, pp. 232–279). What remains is for behavior analysis to recognize that all biological, behavioral, and bio-behavioral phenomena are developmental processes. With this, we can avoid any tendency to perpetuate our own version of the nature–nurture dichotomy. We can expand our perspective into a developmental-contextualistic-biological-behavioral system, if not in (awkward) name, then in practice.

CONCLUSION

If behavior analysis is becoming more explicitly developmental and contextualistic, then it needs to address the nature–nurture dichotomy and other dichotomies as well. As for the latter, it will have to resolve, for instance, dichotomies between traits and situations (see Morris, 1988, pp. 307–308; Oyama, 1985, pp. 15–19), active and passive organisms (see Baer, 1976; Bijou, 1979, 1989), and possibly even structures and functions (see Woodger, 1929, pp. 326–330; contra Catania, 1973; Kantor, 1953, p. 218). In addressing these alternative conceptualizations, we might sometimes turn to the work of colleagues outside our own field. With respect to the nature–nurture dichotomy, Oyama's (1985) *The Ontogeny of Information* is a place to begin. From Oyama's perspective, we gain much and lose little—little of any consequence—by abandoning this and other dichotomies. In her words,

> I am convinced there is another way to think, and that this other way, though it requires reworking not only our ideas about genes and environment but quite a bit besides, gives us both more and less than the old way. It gives more clarity, more coherence, more consistency and a different way to interpret data; in addition it offers the means for synthesizing the concepts and methods of evolutionary biologists and developmentalists. . . . It gives less, however, in the way of metaphysical guidance on fundamental truth, fewer conclusions about what is inherently desirable, healthy, natural or inevitable, and this accounts for a good deal of the resistance it has met. (Oyama, 1985, p. 9)

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