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Psychology is a Developmental Science

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In this paper we argue that psychology should be understood as a developmental science, and we place the discipline squarely in the realm of the natural sciences. The case is made that scientific progress in psychology has been (and still is) impeded by prolonged misadventures down conceptual dead ends such as biological reductionism, the nature/nurture debate, evolutionary psychology, and the persistent insistence on emphasizing dependent variables that defy observation and measurement, such as "mind" and cognitive modules. We take issue with the behavior geneticist's approach to psychology while making the case that many psychologists and biologists today seem wholly unaware of many of the most recent experimental results in the area of molecular genetics, especially as they relate to development. We propose that such results, as well as those in the area of nonlinear dynamics, support a developmental systems perspective of psychology emphasizing the epigenetic nature of development as well as the importance and reality of emergent properties in psychology in particular and science in general. Whereas we do not dismiss the significance of biological processes for a full appreciation of behavioral origins, we understand biology to merely be one of many participating factors for psychology.

Scientific psychology was born around 1879 in either Wilhelm Wundt's laboratory in Leipzig or in William James's at Harvard, depending on which history one reads. The early years of the scientific approach to psychology proved to be fruitful, resulting in a variety of different "schools" of thought. These competing approaches were each driven by vastly different ideological underpinnings. Nevertheless, they provided psychology with a bedrock foundation of facts with which the new science was able to navigate through the 20th century. At first this manifested itself in the use of the atomistic metaphor of structuralism, the identification with positivism, and the reliance on Western science's materialism and clock-work universe. Psychology of the 20th century was materialistic, positivistic, and reductionistic. Though coming from different perspectives, the essential facts of Gestalt psychology, Behaviorism and neo-Behaviorism, New Look Psychology, and so forth have done much to prepare our now firmly established science to enter the 21st century. But just as science in general and physics and biology in particular have adopted new models (e.g., dynamic systems, non-linear dynamics, complexity theory) at the beginning of the 21st century, so too is psychology beginning to see merit in these new approaches.

This new perspective, and its extremely broad application, can be summarized as follows:

...since the 1960s, an increasing amount of experimental data ...imposes a new attitude concerning the description of nature. Such ordinary systems as a layer of fluid or a mixture of chemical products can generate, under appropriate conditions, a multitude of self-organization phenomena on a macroscopic scale—a scale orders of magnitude larger than the range of fundamental interactions—in the form of spatial patterns or temporal rhythms.... [Such states of matter] provide the natural archetypes for understanding a large body of phenomena in branches which traditionally were outside the realm of physics, such as turbulence, the circulation of the atmosphere and the oceans, plate tectonics, glaciations, and other forces that shape our natural environment; or, even, the emergence of self-replicating systems capable of storing and generating information, embryonic development, the electrical activity of the brain, or the behavior of populations in an ecosystem or in economic development (Nicolis, 1989, p. 316).

As we show in this article, such ideas equally apply to psychology.

Of course, as with other developments in science, these ideas applied to psychology did not spring up de novo, but rather have their own history. We see seeds of this line of thinking in Morgan's (1923) emergent evolution, Kantor's interbehaviorism (1959; Pronko, 1980), and Schneirla's (1949) behavioral levels hypothesis. Contemporary biologists such as Goodwin (1994) and Kauffman (1993, 1995) have elucidated the linkages between developmental psychobiology and newly emerging concepts of complex adaptive systems and self organization (Prigogine & Stengers, 1984).

These somewhat diverse positions are linked by three crucial ideas: the important organizing principle of integrative levels, the idea that there is a tendency towards increased complexity with evolutionary advance, and the contextual nature of behavioral events. This results in a synthesis which leads to a developmental perspective in which behavior is seen to be the result of the fusion of biological and psychosocial factors, by probabilistic epigenetic events rather than by preprogrammed genetic or other biochemical ones (Gottlieb, 1992, 1997; Kuo, 1967).

Nonlinear dynamics provides an abundance of concepts pertaining to change processes over time that cannot be found in any other known theoretical system. Dynamical models allow us to compare and contrast seemingly unrelated phenomena that often share common dynamical structures. Though relatively new to mainstream psychology, the notion of dynamic systems theory is gaining momentum (Boker, 2001; Damon & Lerner, 2001; Ford & Lerner, 1992; Newell & Molenaar, 1998; Sulis & Trofimova, 2000). Nonlinear dynamics and complex systems analysis are helping to revolutionize our understanding in many of the life sciences. As summarized by Kauffman (1993, p. 173):

Eighteenth-century science, following the Newtonian revolution, has been characterized as developing the sciences of organized simplicity, nineteenth-century science, via statistical mechanics, as focusing on disorganized complexity, and twentieth and twenty-first-century as confronting organized complexity.

Complexity science involves the study of the nonlinear dynamics of complex adaptive systems (Lewin, 1992). Applying nonlinear dynamic systems theory and emergence in their study of children, Thelen and her colleagues suggested that development is better understood as “the emergent product of many decentralized and local interactions that occur in real time” (Smith & Thelen, 2003, p. 343). She later advanced the notion that development should be conceptualized as “a changing landscape of patterns, whose stability depends not only on the organic status of the child, but also on its experiential history, and how these interact with the particular task at hand” (Thelen, 2004, p. 16).

In this context, complexity is a developmental consequence of emergence. Goldstein (1999, p. 49) provided a useful definition of emergence: “[Emergence]...refers to the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems.” Emergence is an irresistible attraction for a system to develop to its highest potential, free to ascend to new levels of self-organization, self-reference, and self-iteration (Fitzgerald, 2002). Here, an overall system behavior becomes evident among variable interactions amid multiple participants; and this behavior could not be predicted by understanding what each element of the system does in isolation (Lissack, 1999).

From a developmental perspective, emergence holds promise in explaining certain processes of development. However, we would be remiss if we failed to mention misinterpretations of the concept of emergence. In the past, emergence has been dismissed as a “new-age” concept with mystical overtones, that is, the idea that consciousness emerges from complex neural functioning is understood by some to invoke a “vital” force that is somehow added to the mix. Another misconception of emergence is when the concept has been oversimplified to mean “that a whole is different from the sum of its parts.” Although essentially true, this statement contributes to the misunderstanding about the concept of emergence.

Goldstein (1999) provided a detailed explanation of interrelated and common properties pertaining to emergent phenomena. Emergent phenomena can be identified by several criteria: (1) they display radical novelty, that is, they possess features not present in the underlying complex system; (2) they display coherence or correlation, meaning that they have a unity over time; (3) they exist at the global or macro level and not at all at the underlying micro level; (4) they are dynamical, arising as a result of the dynamic interplay of underlying micro events; and (5) they are ostensive—they really exist and are observable (Goldstein, 1999). The emergent property is not a feature at the level of individual components of a system. Rather, it is a property of the entire system. In the absence of the system, there is no emergent property. This is to say that emergent properties such as language, social and motor behavior, symbolic thought, and so on are not entities in themselves; more accurately, they are processes of collections of entities.

Whereas the behavior of individual components within the system is mutable, the overall structure of the system as a whole is stable. This property of global stability and internal instability is what Kauffman (1993, 2000) refers to as being poised at the edge of chaos. Being poised at the edge of chaos allows these systems to be quite adaptable to changing environmental pressures and contingencies, which positions these systems to flourish under principles of natural selection.

There are thresholds of organizational complexity at which small quantitative increases produce qualitative discontinuities (i.e., levels) resulting in the development of new levels. We contend that the principles of emergence are inherent in dynamic developmental systems where small changes in one or more components can lead to new levels of organization; and in terms of behavior, these small changes can lead to large individual and collective differences.

For our purposes it is important to emphasize that complexity is so pervasive a phenomenon (e.g., Simon, 1999) that some have likened it to a second of law of evolution after natural selection (Saunders & Ho, 1976, 1981, 1984). Many evolutionists have adopted this line of thinking, including Stebbins (1969), who suggested that we can recognize at least eight major levels of complexity in the evolution of life (and behavior), and Smith (Smith & Szathmáry, 1995), who at different times has identified five or eight levels of complexity, though he associated each with degrees of organization of genetic material. The important point to be made here is that there is a hierarchy of levels of increasing complexity and organization in the evolution of life, and not that there are five or eight such levels. This was recognized earlier by Pringle (1951, p. 175), who noted that, "The characteristic of living systems which distinguishes them most clearly from the non-living is their property of progressing by the process which is called evolution from less to more complex states of organization."

Let us avoid at the outset the highly charged and controversial idea in evolutionary thinking of "progress" by adopting Gould's (1988, p. 321) approach, that "...we can preserve the deep (and essential) theme of direction in history, while abandoning the intractable notion of progress." It is now undeniable from the fossil record that organismic complexity has increased with time. Stated another way, we note that, with few exceptions, more recently evolved forms are more complex in their behavior than are earlier evolved forms. As evolution has continued it has preserved many simple forms, perhaps unchanged over millennia, but the *new* forms produced have tended strongly in the direction of increasing complexity. We have addressed criticisms of these ideas elsewhere and see no need to reiterate them here (Greenberg, 1995; Greenberg, Partridge, Weiss, & Pisula, 2004). For a thorough treatment of complexity in nature see Chaisson (2001). With respect to the application of complexity to development in psychology the following statement by Arthur (1993, p. 144) is telling: "The writer Peter Matthiessen once said, 'The secret of well-being is simplicity.' True. Yet the secret of evolution is the continual emergence of complexity. Simplicity brings a spareness, a grit; it cuts the fat. Yet complexity makes organisms like us possible in the first place."

Of course we recognize that this is not only a controversial issue, it is as well a contentious one, debate frequently occurring from ideological perspectives (Lewin, 1992). We find the statement by Bonner (1988, pp. 5-6) to reflect our position best:

There is an interesting blind spot among biologists. While we readily admit that the first organisms were bacteria-like and that the most complex organism of all is our kind, it is considered bad form to take this as any kind of progression..... It is quite permissible for the paleontologist to refer to strata as upper and lower, for they are literally above and below each

other...But these fossil organisms in the lower strata will, in general, be more primitive in structure as well as belong to a fauna and flora of earlier times, so in this sense "lower" and "higher" are quite acceptable terms....But one is flirting with sin if one says a worm is a lower animal and a vertebrate a higher animal, even though their fossil origins will be found in lower and higher strata.

Bonner's book is an exposition on the evolution of biological complexity, a phenomenon he likens to a "law" of evolution.

Why Psychology is not a Biological Science

Twentieth century psychology amassed a great many facts in seemingly intractable debates between cognitive nativists and behaviorist environmentalists. It became quite clear in the latter half of the 20th century that these debates were intractable, in part because these various schools of thought were examining their own small part of the same integrated biopsychosocial system. A central task of scientific psychology in the 21st century is to articulate a set of principles which can fruitfully organize the set of factors ranging from genetic, to neural, to intrapersonal, to micro- and macro-ecological. Our take on the evidence at hand is that development is among the most significant of those organizing principles, specifically the meta-theoretical perspective of developmental systems. The developmental systems perspective builds on the empirical properties of dynamic complex adaptive systems. These systems have been shown across a wide array of mathematical abstractions and biological, behavioral, and sociological instantiations to display the patterns of coherence and variability, plasticity and canalization, and complex integration so pervasive in psychology. Further, the organization of these systems is not reliant on an organizing agent, but rather is inherent in the dynamic transactions of the genetic and epigenetic aspects of the biopsychosocial ecology in which behavior is embedded.

We entered the 21st century on the heels of two expensive and popular scientific efforts, The Decade of the Brain and the Human Genome Project. Both purported to put to rest the search for the origins of behavior. The former endeavor sought to put the entire burden of behavior on the brain, the latter on the human genome. Both, of course, came down on the nature side of the nature/nurture equation; both failed to "take development seriously" (Robert, 2004).

Psychology and the Brain

One of us (Greenberg, 1983) once reviewed a textbook for undergraduate Physiological Psychology courses that began with a fantastic story. The authors told beginning students that if their brains were removed and transplanted into their neighbor's heads, and vice-versa, they would each have the other's memories and personalities and would, in fact, "be" the other person! Of course, this is not only pure fiction, it is poor fiction. Not only have brain transplants never been carried out (nor could they), it is unlikely that the transplantee would have the transplantor's memories any more than do heart or liver recipients.

Despite the tenaciously held belief that “mind” is a product of brain (e.g., Gold & Stoljar, 1999), in our present stage of understanding the brain this is still merely conjecture. Indeed, a strong case can be made that the mind-brain problem may never be solved (Uttal, 2005). And, of course, it is hardly conjecture that a person and his or her personality is much more than merely his or her brain. “Mind,” whatever it is, or even if it actually is, is built up over the course of a person’s lifetime -- a result of development, if you will. Brains are certainly involved in the development of one’s personality, but as participating factors and not causative ones (Kantor, 1947; Pronko, 1980; Skinner, 1974). In fact, the almost unbelievable discoveries of John Lorber of young normal adults with virtually no brains at all (Lewin, 1980) is to this day not only unexplained, but virtually ignored by the neuroscience community. In various searches, we have come upon only two references to this amazing finding -- the first only a one or two sentence passing reference in a textbook of developmental psychobiology (Michel & Moore, 1995), the second a website discussion simply stating that this could not possibly be true, offering no empirical evidence of support (McCrone, 2004). Of course, it should not surprise us that scientific findings which challenge the status quo (especially when it comes to the brain or the genes) tend to be ignored and often treated as a nuisance (e.g., Barber, 1961; Barnes, Bloor & Henry, 1996).

A discussion of schizophrenia in the flagship journal of the American Psychological Association, *American Psychologist*, ignored an enormous body of evidence regarding the developmental nature of that serious disorder by stating, “...it is difficult to quarrel with the general proposition that schizophrenia is a kind of brain disease that should be approached as a problem in neuroscience. There are no viable alternatives” (Heinrichs, 1993, p. 221). The prominent psychiatrist and schizophrenia specialist Torrey (1983, p. 2) echoed this point in equally unequivocal terms:

Schizophrenia is a brain disease, now definitely known to be such. It is a real scientific and biological entity as clearly as diabetes, multiple sclerosis, and cancer are scientific and biological entities. It exhibits symptoms of brain disease, symptoms which include impairment in thinking, delusions, hallucinations, changes in emotions, and changes in behavior. And, like cancer, it probably has more than one cause. Thus, though we speak of schizophrenia and cancer in the singular, we really understand them as being in the plural; there are probably several kinds of schizophrenia of the brain just as there are several different kinds of cancer of the brain.

We don’t deny that the brain is an essential structure. We argue only that too much of a burden has been placed on it as the organ of behavior. We have, in fact, discussed the important role played by the evolution of the brain in the evolution and development of complex behavior (Greenberg, Partridge, Weiss, & Hara-way, 1998). With respect to schizophrenia and other psychological disorders, psychological and developmental accounts are not only preferable, they serve as true explanations (e.g., Pronko, 1963) rather than making appeals to as yet unknown biological mechanisms such as genes or brain processes as causes of this class of disorders (e.g., Utall, 2001, 2005; Valenstein, 1973, 1998).

It is, in fact, possible to make the case that abnormal behaviors such as schizophrenia are the result of the same sorts of developmental dynamics as are all behaviors (e.g., Koopmans, 2001). In this approach, complex behaviors are understood to be the result of development, including emergent learning factors (Rumbaugh & Washburn, 2004, discussed below). Indeed, the entire “self” has been conceptualized as an emergent phenomenon, the result of developmental dynamics (Marks-Tarlow, 1999; O’Conner & Jacobs, 2003). Nonlinear dynamic systems theory provides a theoretically consistent language with which to describe and analyze behavioral development (Michel & Moore, 1995). For example, Thelen and her associates have examined the applicability of the principles of nonlinear dynamic systems in certain behavior change conditions, including stepping and walking behaviors in infants (Thelen, 1989), and the Piagetian “A-not-B” error (Spencer, Smith, & Thelen, 2001; Smith & Thelen 2003).

Psychology and Genes

A similar situation exists today with respect to the role attributed to genetics and behavior. One must surely marvel at the staying power of the nature/nurture controversy, something seemingly put to rest by Hebb (1953) who understood behavior to be 100 percent determined by biology (nature) and 100 percent determined by psychology and development (nurture). However, as Oyama, Griffiths, and Gray (2001, p. 1) noted,

The nature/nurture debate is not dead. Open a book, read a newspaper, turn on the TV, read Science or Nature and you will find yourself bombarded with claims and counterclaims. Are there ‘genius’ genes? If not those, then surely the ‘gay’ ones? Is aggression the consequence of social and economic conditions, or is it a product of evolution? Are cognitive differences between men and women due to genetics or upbringing?

Bouchard (2004, p. 148) went so far as to claim that, “Among knowledgeable researchers, discussions regarding genetic influences on psychological traits are not about whether there is genetic influence, but rather about how much influence there is, and how genes work to shape the mind.” And, as Rutter (2002, p.2) noted, “Any dispassionate reading of the evidence leads to the inescapable conclusion that genetic factors play a substantial role in the origins of individual differences with respect to all psychological traits, both normal and abnormal.” Of course, much of this is driven more by ideology than by pure science, as reflected in Lewontin’s (1991) criticism of the issue which he titled, *Biology as ideology*.

The most interesting thing about the attribution of behavior to genetics is the absence of discussion as to how the genetic influence manifests itself. Behavior geneticists do not describe pathways, though we of course now understand the pathway from genes to even biological structure to be extremely indirect and enormously complex. Skinner’s (1966, 1988) discussion of the genetic basis of behavior reflects our understanding as well: To the extent that we behave with structures we inherit, it may be possible to speak of the genetic or otherwise biological foundations of behavior. But despite the inheritance of two hands with a

full complement of fingers piano playing does come automatically. Slowly and gradually, out of a rich experience of the world, one builds a behavioral repertoire, including piano playing.

There is no explanation in attributing a trait, behavioral or structural, to genetics in light of what converging current research from several disciplines indicates (Moss, 2003). Many behavioral scientists, behavior geneticists, and evolutionary psychologists seem to be unaware of these recent developments in our understanding of genetics (Gottlieb, 2004; Lickliter & Honeycutt, 2003). It turns out that there is no information in the genome to be triggered or nurtured by the environment, though this is the current consensus in the behavioral and much of the biological sciences. This has been demonstrated in data from hundreds of studies which give us a new picture of the role of genes in development in general. "For instance, genes are not informational in the way supposed, nor do they initiate or direct ontogeny, there is no such thing as a genetic programme, and there is no straightforward 'unfolding' relation from genotype to phenotype" (Robert, 2004, p. 39). Hubbard and Wald (1999) pointed out that having a gene for breast cancer, for example, means that one may or may not develop breast cancer; similarly, one may or may not develop breast cancer even without that gene. Diet, lifestyle, and other factors underlie the development of that disorder and of other biological and behavioral traits.

This view is the central theme of a powerful heuristic in developmental psychology, that of developmental systems theory (Ford & Lerner, 1992) which "views both development and evolution as processes of construction and reconstruction in which heterogeneous resources are contingently but more or less reliably reassembled for each life cycle" (Oyama et al., 2001, p. 1). In other words, epigenetic, rather than simply genetic, processes are at work in development (Robert, 2004). Of course, there are excellent examples of the role of epigenesis in behavior, none more powerful than reflected in the work of the now almost forgotten Chinese comparative psychologist Kuo (1967) whose painstaking pre- and post-natal studies of behavior stand as exemplars of this perspective. Benno (1990) has recently discussed the development of the nervous system from an epigenetic perspective.

Epigenesis has been described in a variety of ways, but none so well put as that by Moltz (1965, p. 44):

An epigenetic approach holds that all response systems are synthesized during ontogeny and that this synthesis involves the integrative influence of both intraorganic processes and extrinsic stimulative conditions. It considers gene effects to be contingent on environmental conditions and regards the genotype as capable of entering into different classes of relationships depending on the prevailing environmental context. In the epigeneticist's view, the environment is not benignly supportive, but actively implicated in determining the very structure and organization of each response system.

In other words, DNA is not the primary cause of anything, structural or behavioral. DNA is an inert molecule incapable of any action on its own. It is present in the

nucleus and thus can be acted on by other molecules. DNA does not even “self-replicate, but is rather replicated by other molecules involved in metabolism” (Mahner & Bunge, 1997, p. 285). At the cellular level, the level of genes and DNA, the system is akin to a chemical soup and functions in much the way we were taught in inorganic chemistry. If the proper chemicals are added in the proper amounts, and at the proper rates, and heated to the proper temperatures, then the green precipitate will collect at the bottom of the test-tube. In the test-tube of the cell, however, these cascading events are probabilistic and not at all guaranteed; epigenesis is thus a probabilistic set of processes and events (Gottlieb, 2001, 2004).

There is, as well, something insidious and unsaid about behavior-genetic analyses of human behavior, especially as they may impact social policy (Hirsch, 2004). Wahlsten (2003) made the point that behavior geneticists airbrush this point out of their discussions. He reminded us that there were sterilization laws in many states until recently and that successful educational programs such as Head Start have been jeopardized by genetic thinking. Dickens and Cohen (2004, p. 51) have openly discussed the social implications and ramifications of behavior genetic analysis. “The most pernicious application of arguments for genetic influences on behavior has been the rationalization of unequal treatment of different groups – sometimes as horrific as slavery or extermination.” All of these authors caution against the misapplication of genetics to the understanding of the development of behavior. These are all prominent behavior geneticists themselves, Hirsch, of course, being one of the preeminent behavior geneticists of the 20th century. Indeed, there has been a serious and longstanding sidestepping of the idea of development by biologists as well as psychologists. “Despite the existence of what has come to be known as the ‘interactionist consensus,’ according to which everyone agrees that both genes and environments ‘interact’ in the generation (and explanation) of organismal traits, it is my claim that those swept up in genomania have nevertheless failed to take development seriously” (Robert, 2004, p. xiii).

With respect to this issue, it is time for us to put it aside and move on. Are we any further along in the fruits of the nature/nurture debate than we were when Anastasi (1958, p. 197) said:

Perhaps we have simply been asking the wrong questions. The traditional questions about heredity and environment may be intrinsically unanswerable. Psychologists began by asking which type of factor, heredity or environmental, is responsible for individual differences. Later they tried to discover how much of the variance was attributable to heredity and how much to environment. It is [my] primary contention... that a more fruitful approach is to be found in the question ‘How?’ ?

Future genetic research should emphasize the transactional role between gene expression and developmental regulation across genetic and supragenetic levels of gene expression. For instance, one approach to gene-environment transactions would be to examine the manner in which concentrated conditions of poverty impact intrauterine environments and pre- and post-natal nutrition and, further, how these factors might influence the expression of key neurotransmitter receptors in

the limbic system. The gene-expression / neural function relationship then might be associated with increased probabilities of internalizing disorders which in turn place strains on parent-child relationships. This system would also include feedback loops in which the breakdown of the parent child-relationship results in poorer child behavioral and emotional regulation. This breakdown then impacts multiple socioemotional developmental outcomes increasing the likelihood of remaining in an environment of concentrated poverty. This set of hypotheses provides a broad framework for organizing developmental data from multiple and integrated levels of analysis and represents a set of gene-environment-behavior hypotheses that would be substantively meaningful and consistent with the transactional dynamic manner in which genes and environments are fused over the course of ontogeny. Forty-eight years later and one Human Genome Project behind us, we are not much closer to answering Anastasi's question.

Psychology is a unique science

We believe it is time for psychology to shake free of the label "social science," or any other descriptor which identifies the discipline as a "soft" science. True, there are no formulae yet in psychology—we are one of the modern sciences that don't lend themselves to math. "Biology, for example, deals with large systems of interactive cells that defy a numerical approach....[N]umbers, while useful, ultimately cannot be used to explain evolution. There are no biological equivalents of Maxwell's equations that explain the platypus or the giraffe" (Teresi, 2002, p. 27). Yet no one would deny that biology is a "hard" science. It is time for us to recognize finally that psychology, that is behavior, is as natural a phenomenon as rolling balls down inclined planes was for Galileo.

A crucial idea for our analysis is the view that the universe is ordered in a family of hierarchies in which natural phenomena exist in levels of increasing organization and complexity. This is one important implication of the idea of integrative levels which in its general form is a broad organizing principle regarding the temporal organization of matter as a series of discontinuous increases in complexity of organization. Indeed, the sciences themselves have been divided into areas of study based on these qualitative changes in complexity of organization, with physics and chemistry addressing the lower levels of complexity and biology, psychology, and sociology addressing higher levels of complexity, an idea seemingly originated by Auguste Comte in the late 1800s (see Boorstein, 1998, p. 223) and later developed by others such as Novikoff (1945) and Feibleman (1954). This is summarized by Aronson (1984, p. 66) in the following way:

[The levels concept]... is a view of the universe as a family of hierarchies in which natural phenomena exist in levels of increasing organization and complexity. Associated with this concept is the important corollary that these successions of levels are the products of evolution. Herein lies the parallel with anagenesis.

Anagenesis recognizes the role played in psychology by the evolution of increasing complex biological forms, especially nervous systems (Greenberg, 1995;

Greenberg et al., 1998). Anagenesis is the idea in evolutionary biology that there are directional trends in evolution, trends we understand to reflect change from the simple to the complex, where newly evolved grades represent an ascending series of evolutionary changes. It is important that we clarify this. We are proposing here merely directional change—continuing change from simplicity toward complexity. We are not implying that such change is for the better, and we do not wish to characterize this change in that manner, one way or the other. We simply note the historical trend that as evolution has continued it has resulted in increasingly more complex forms of animal life. As we discussed above, with few exceptions, more recently evolved forms are more complex in form and behavior than are earlier forms.

The levels concept has a relatively long intellectual history in both biology (Brücke, 1861; Woodger, 1929) and functional psychology (Dewey, 1886; Morgan, 1901). The impetus for this line of thinking, which was common to these early theorists, was that processes in both biology and psychology were qualitatively different from the structures and functions of less complex systems. Thus, biology needed an explanatory model distinct from physics and chemistry (e.g., Woodger, 1929) and psychology needed a model distinct from biology (Schneirla, 1949). The levels concept matured in the middle part of the twentieth century through the notable work of scientists and philosophers such as Schneirla (Aronson, Tobach, Rosenblatt, & Lehrman, 1972), Needham (1929), Novikoff (1945), and Feibleman (1954).

We thus see psychology as a unique science, separate and distinct from biology, with its own unique principles searching for its own unique laws. The study of learning, of cognition, of personality development, of species-typical behavior are subject areas that the psychologist can address from the orientation we are proposing here. Of course, as we have stressed, biology is not irrelevant nor unimportant for a full understanding of events at the level of psychology; nor are sociological principles. There are few genuine “laws” in psychology, a result we suspect of our still relatively young age and involvement with misguided intellectual efforts. Scientific progress in psychology has been hampered by our being lost and enamored in our own blind alleys of alchemy, phrenology, and reductionism. Hence we heed the admonition of Lerner (2004, p. 20) that, “We are at a point in the science of human development where we must move on to the more arduous task of understanding the integration of biological and contextual influences in terms of the developmental system of which they are a dynamic part.”

One psychological principle that we can comfortably apply the label of law to is that of reinforcement. It appears to apply universally as do laws in physics and chemistry. For several generations it was the working-horse principle in the study of learning, one of the earliest experimental efforts of psychology. The history of the study of learning has produced various formulations in which the learning of simple organisms is attributed to one set of principles and that of more complex organisms to other principles, hierarchies if you will. Razran (1971) identified eleven levels of learning; others, such as Deacon, (1990) only three. Eleven categories (levels) of learning proposed by Razran? Three proposed by Deacon? How many levels of learning are there? Do such formulations clarify our understanding of learning, or lead to greater obfuscation? With his recent formulation of “emer-

gents” as a higher-order level of learned responses, Rumbaugh (Rumbaugh & Washburn, 2004) has found a way of addressing and simplifying this issue, and especially criticism’s of Skinner’s somewhat simplistic S-R formulations. This draws on the evolutionary co-relationship of brain complexity and level of cognitive capacity in which animals functioning at the highest behavioral levels, the psychosocial (Tobach & Schneirla, 1968) levels, show the emergence of higher-order cognitive skills. With this theoretical breakthrough Rumbaugh has linked the study of cognition to the most contemporary formulations of the newly developing sciences of complexity and dynamic systems. The point is that “emergent learning” describes the long-range outcomes of a learning system that cannot be reduced to its respondent and operant elements; emergent learning thus constitutes a separate class of learning origins.

This approach is not only germane to psychological phenomena, it provides a potential explanation for the appearance of complex behavioral phenomena, such as the development of language and culture in homo sapiens (Greenberg et al., 1998; Savage-Rumbaugh & Sevcik, 1984; Savage-Rumbaugh, Murphy, Sevcik, Brakke, Williams, & Rumbaugh, 1993), childhood temperament (Partridge, 2002, 2003), and even of pathological behavior such as schizophrenia as discussed above. Rather than searching for single causes, or taking an analytic approach, we can understand the development of much complex human behavior as an emergent property of the dynamic interplay of several sets of systems: biological, physiological, psychological, and socio-cultural (i.e., ecological context), the results involving not just one possible outcome.

The issue is that in the social world, and in much of reality including biological reality, causation is complex. Outcomes are determined not by single causes but by multiple causes, and these causes may, and usually do, interact in a non-additive fashion. In other words, the combined effect is not necessarily the sum of the separate effects. It may be greater or less, because factors can reinforce or cancel out each other in non-linear ways...In essence the complexity is locked away in the interaction term” (Byrne, 1998, p. 20).

In a word, complexity is a consequence of emergence.

Why we are not Evolutionary Psychologists

The most recent defense of biological reductionism is that offered by evolutionary psychology, which on the surface seems a reasonable approach to understanding the origins of human behavior. What scientist in the 21st century can be opposed to the invocation of evolution and its application to psychology? However, one can recognize the enormous significance of evolutionary processes in the development of behavior and not be an evolutionary psychologist. Our views of evolutionary psychology mirror those voiced by Lickliter and Honeycutt (2003) in their critique of that flawed application of evolution to psychology. Of course we are the product of evolution, but many forces have been at work since the appearance of our species in the Pleistocene; it is an error to suggest that our behavior as *Homo sapiens* is the result of our adaptation to Pleistocene events as evolutionary

psychologists not only imply but explicitly state (e.g., Buss, 1999). For evolutionary psychologists, adaptation is perhaps the fundamental principle involved in behavioral evolution.

However, we explicitly reject the adaptationist agenda along with such notable evolution scientists such as Gould (1997), who pointed out that even Darwin suggested that mechanisms other than adaptation were at work in evolution. It is a mistake and a misunderstanding of Darwinism to suppose that there is anything approaching the consensus claimed by evolutionary psychologists. Rather, pluralism of mechanisms is the rule in the still-developing paradigm of evolution. For example, we now understand evolution to involve punctuated equilibrium, genetic drift, mutation, and other processes, as well as natural selection. In fact, evolution does not always involve changes in the genome. It is now recognized that not all genes of the human genome get expressed. Evolution can occur if different portions of the genome are expressed, the result perhaps of environmental impact. This would result in new phenotypes (see Honeycutt, 2006).

Indeed, some feel that “evolutionary psychology has recently gone too far in its epistemological agenda, as it attempts to uncover the brain ‘mechanisms’ that constitute ‘human nature’” (Panskepp & Panskepp, 2000, p. 108). We have never subscribed to the notion of innate and universal human nature, preferring instead Montagu’s (1962, p. 17) position that we are born *Homo sapiens*, but we become human beings. “The most beautiful thing about a baby” he said, “is its promise.” This too was the point of Kuo (1967) who raised the issue of whether a cat was a rat killer or a rat lover: Kittens raised with rats out of sight of cats that kill or eat rats never kill rats, even when hungry. Animal nature is a result not of biology alone, but of developmental history. Human behavior, thus, is enormously plastic (Lerner, 1984). Herein lies the significance of developmental systems theory for psychology.

One serious difficulty with evolutionary psychology is its argument from animal to human behavior. Of course, it is almost universally accepted now in psychology that there is continuity in behavioral processes from animals to humans. This is reflected in current research in cognition, studies of the origins of language, the fundamental workings of learning, and so forth. Animal models can be extremely useful in this regard, in the search for the evolutionary origins of much of human behavior. Strains of mice and the fruit fly, for example, have been the work-horses of behavior geneticists for 50 years or more. But such models have their limitations. The social climate, empowered by the enormous success of the Human Genome Project—one of the most costly scientific endeavors in history—has fostered an almost frenzied search for genes such as the “gay gene” and the “schizophrenia gene.” Nevertheless, “There is so far only one known example of male to male matings being switched on by one gene. This is the fruit fly...[However] one would be hard pressed to call a fruit fly homosexual” (Kaplan & Rogers, 2003, p. 223).

The behavioral sciences in general and evolutionary psychology in particular have tended to ignore, or perhaps are not even aware of, contemporary empirical findings in molecular biology, evolutionary biology, and genetics—a point emphasized by others (e.g., Gottlieb 2004; Kaplan & Rogers, 2003; Lickliter & Honeycutt, 2003). Thus, it is now known that genes are not directly responsible for

phenotypic expression, but rather, that the environmental context of development plays a crucial role in this process. It is now known that genes not only work from the inside out, but that behavior too can influence the expression of genes (referred to as “downward causation” by Campbell, 1990). It is now known that not all genes of a genome get expressed. It is now known that natural selection is but one of several mechanisms responsible for evolutionary change. It is now known that the path from genes to physical or behavioral traits is enormously complex and indirect.

One idea that is at the center of the evolutionary psychology program is that the human mind is constructed of innate cognitive modules, evolutionary adaptive holdovers from the Pleistocene (Pinker, 2002). About mental modules, we direct readers to discussions by Kaplan and Rogers (2003) and Uttal (2001). Not only are such modules not defined by evolutionary psychologists, but also we are never told exactly what they are, where they are in the brain, or how many there might be. “We believe that some currently fashionable versions of evolutionary psychology are treading rather close to neurologically implausible views of the human mind...there is no [convincing] evidence in support of highly resolved genetically dictated adaptations that produce socio-emotional cognitive strategies within the circuitry of the human neocortex” (Panskepp & Panskepp, 2000, p. 111).

There are other similar crucial facts of the biological sciences that are misunderstood and ignored by evolutionary psychologists. Of course, a common response of evolutionary psychologists to such criticism is that it is they who are misunderstood, and they do not suggest that behavior is genetically determined or innate. However, and unfortunately, these responses amount to little more than lip service, as reference to a recently established web site illustrates. This is the web site (University of Sheffield, 2007) of a group known as “The AHRB Project on Innateness and the Structure of the Mind,” the members of which are a veritable Who’s Who of the evolutionary psychology elite.

Psychology is a Developmental Science

Contemporary developmental science has successfully provided a dialectical synthesis of earlier organismic and mechanistic theories by positing that behavioral development is a function of an organism interacting with an active socio-historical ecology. This family of theories includes perspectives such as the developmental ecological model (Bronfenbrenner, 1979), developmental contextualism (Lerner, 1998), the life-span perspective (Baltes, 1987), the person-oriented approach (Magnusson, 1996), and transactional models (Sameroff, 1975). The success of these theoretical formulations is indicated by the change in the scope and content of developmental psychology.

Concurrent with advances in developmental science, science in general has been revolutionized by developments in the study of nonlinear dynamic systems, as we have discussed above. Under the general rubric of nonlinear dynamics are several sub-fields: chaos theory (the study of complex behavior resulting from simple and deterministic processes), fractal geometry (the study of geometrical forms invariant across scale), and complex systems theory (the study of stable, or-

ganized behavior resulting from complex and stochastic processes). It is the latter that seems to hold the most relevance for current formulations of developmental science.

Developmental systems theory has built steadily on the ideas of such early biological and behavioral theorists as Kantor (1924, 1926), Kuo (1967), Morgan (1901), Needham (1929), Novikoff (1945), Schneirla (Aronson et al., 1972), and Woodger (1929). These early foundations provided a fertile source from which developmental systems theorists such as Bronfenbrenner (1979), Cairns (Cairns, Elder & Costello, 1996), Lerner (Ford & Lerner, 1992), Oyama (Oyama et al., 2001), and many others, have successfully drawn. A new vigor has been infused into this longstanding developmental framework through the incorporation of analytic and conceptual tools from the recent study of complex adaptive systems. Until the last decade developmental systems models were often restricted to metaphorical statements. However, advances in complex systems science have allowed for more specific and grounded assertions about how complex behavioral systems develop over time. This has the potential profoundly to impact developmental science.

The ideas of the scientists (behavioral and biological) and philosophers we have cited above have coalesced in the past 20 years or so in a form germane to psychology under the rubric of “developmental systems theory” (DST). Despite the terminology, this is not a specific theory, nor is there universal agreement among these diverse sources. It is possible, however, to identify at least seven interrelated themes among DSTists (Robert, Hall, & Olson, 2001):

(1) Contextualism: Organisms are fused with their environments, all features of which affect the developmental course of their behaviors as well as their biologies (Lerner, 1998). The idea of a genetic program becomes unnecessary. Indeed, from this perspective, the claims of geneticists and behavior geneticists can be seen as grandiose (Nelkin, 1993).

(2) Nonpreformationism: This refers to the role of probabilistic epigenesis in the course of development. The “rules” governing the developmental process are not locally encoded in some external control process, but rather are derived from the recursive mutual interactions of all the system variables as an organized whole. Thus, it is the process of development itself that drives the course that development takes by which we mean that organisms are producers of their own development (Lerner & Busch-Rossnagel, 1981).

(3) Causal co-interactionism: Developmental causes interact in complex, non-additive, ways.

(4) Causal dispersion: The many factors and processes that influence development are diffuse and fluid. Genes and brains, then, are participating and not causative factors in development.

(5) Expanded pool of interactants: Genes themselves are influenced by other genes and all the constituents of the cell, among numerous other factors.

(6) Extended inheritance: Inheritance is not the sole purview of genetics. Phylogenetic change can also be induced by environmental causes, as discussed by Honeycutt in this volume.

(7) Evolutionary developmental systems: Transmission across generations is not simply of traits, but of developmental systems themselves. A complete under-

standing of evolution requires an understanding of development (evo-devo) and vice-versa (devo-evo) (Robert, 2004).

Psychology, like biology during the early 20th century (see Woodger, 1929), has matured into an independent natural science and is poised at the threshold of a paradigmatic shift. On the one hand, there are those suggesting that our understanding of human behavior ultimately lies in the gene or the neuron and as a consequence can be fully accounted for by panselectionist evolutionary biology. In strong contrast, we argue that psychology as a discipline must be understood as a developmental science in which ontogeny itself serves to weave together biology and ecology into coherent behavioral trajectory across the life-span of the organism. This paradigmatic transition requires a fundamental shift in the meta-theoretic principles guiding psychological theory and the corresponding methodologies away from a conception of static, independent and additive relationships among biological, psychological, and social variables to an orientation that is dynamic, self-referential, and inter-dependent.

In this paper we have provided an overview of just such a meta-theoretical overview and associated methodologies. Further, while explanations of behavior from a population genetic, brain centric, or evolutionary perspective seem reasonable on the surface, when the full weight of empirical data is examined these views are left wanting. We have attempted to show the fundamental limits of each of these perspectives and how, by adopting a developmental systems perspective a more complete and coherent account of behavior can be given.

References

- Aronson, L. R. (1984). Levels of integration and organization: A re-evaluation of the evolutionary scale. In G. Greenberg & E. Tobach (Eds.). *Evolution of behavior and integrative levels* (pp. 57-81). Hillsdale, NJ: Erlbaum.
- Aronson, L. R., Tobach, E., Rosenblatt, J. R., & Lehrman, D. H. (Eds.; 1972). *Selected writings of T. C. Schneirla*. San Francisco, CA: Freeman.
- Anastasi, A. (1958). Heredity, environment, and the question "how?" *Psychological Review*, **65**, 197-208.
- Arthur, W. B. (1993). Why do things become more complex. *Scientific American*, **268**, 144.
- Baltes, P. B. (1987). Theoretical propositions of life-span developmental psychology: On the dynamics between growth and decline. *Developmental Psychology*, **23**, 611-626.
- Barber, B. (1961). Resistance by scientists to scientific discovery. *Science*, **134**, 596-602.
- Barnes, B., Bloor, D., & Henry, J. (1996). *Scientific knowledge: A sociological analysis*. Chicago, IL: University of Chicago Press.
- Benno, R. H. (1990). Development of the nervous system: Genetics, epigenetics, and phylogenetics. In M. E. Hahn, J. K. Hewitt, N. D. Henderson, & R. H. Benno (Eds.) *Developmental behavior genetics: Neural, biometrical, and evolutionary approaches* (pp. 113-143). New York: Oxford University Press.
- Boker, S. M. (2001). Differential structural equation modeling of intraindividual variability. In L. M. Collins & A. G. Sayer (Eds.). *New methods for the analysis of change* (pp.5-27). Washington, DC: APA Press.
- Bonner, J. T. (1988). *The evolution of complexity: By natural selection*. Princeton, NJ: Princeton University Press.

- Boorstein, D. J. (1998). *The seekers*. New York: Vintage.
- Bouchard, T. J. (2004). Genetic influence on human behavior. *Current Directions in Psychological Science*, **13**, 148-151.
- Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Cambridge, MA: Harvard University Press.
- Brücke, E. (1861). *Die Elementarorganismen. Sitzungsberichte der Academie der Wissenschaften*, **44**, 381-406.
- Buss, D.M. (1999). *Evolutionary psychology: The new science of the mind*. Boston: Allyn and Bacon.
- Byrne, D. (1998). *Complexity theory and the social sciences: An introduction*. London, UK: Routledge.
- Cairns, R. B., Elder, G. H., & Costello, E. J. (Eds.). (1996) *Developmental science*. New York: Cambridge University Press.
- Cairns, R. B., Elder, G. H., & Costello, E. J. (1996). *Developmental Science*. New York: Cambridge University Press.
- Campbell, D. T. (1990). Levels of organization, downward causation, and the selection-theory approach to evolutionary epistemology. In G. Greenberg & E. Tobach (Eds.), *Theories of the evolution of knowing* (pp. 1-17). Hillsdale, NJ: Erlbaum.
- Chaisson, E. J. (2001). *Cosmic evolution: The rise of complexity in nature*. Cambridge, MA: Harvard University Press.
- Damon, W., & Lerner, R.M. (2001). *Theoretical models of human development*. New York: John Wiley & Sons.
- Deacon, T. W. (1990). Rethinking mammalian Brain Evolution. *American Zoologist*, **30**, 229-705.
- Dewey, J. (1886). The reflex arc concept in psychology. *Psychological Review*, **3**, 357-370.
- Dickens, W. T., & Cohen, J. L. (2004). Instinct and choice: A framework for analysis. In C. G. Coll, E. L. Bearer, & R. M. Lerner (Eds.) *Nature and nurture: The complex interplay of genetic and environmental influences on human behavior and development* (pp. 145-170). Mahwah, NJ: Erlbaum.
- Feibleman, J. K. (1954). Theory of integrative levels. *British Journal for the Philosophy of Science*, **5**, 59-66.
- Fitzgerald, L. A. (2002). Chaos: The lens that transcends. *Journal of Organizational Change Management*, **15**, 339-358.
- Ford, D. H., & Lerner, R. M. (1992). *Developmental systems theory: An integrative approach*. Newbury Park, CA: Sage Publications.
- Gold, I., & Stoljar, D. (1999). A neuron doctrine in the philosophy of neuroscience. *Behavioral and Brain Sciences*, **22**, 509-569.
- Goldstein, J. (1999). Emergence as a construct: History and issues. *Emergence*, **1**, 49 - 72.
- Goodwin, B. (1994). *How the leopard changed its spots: The evolution of complexity*. New York: Scribner's.
- Gottlieb, G. (1992). *Individual development and evolution: The genesis of novel behavior*. New York: Oxford University Press.
- Gottlieb, G. (1997). *Synthesizing nature-nurture: Prenatal roots of instinctive behavior*. Mahwah, NJ: Erlbaum.
- Gottlieb, G. (2001). A developmental psychobiological systems view: Early formulation and current status. In S. Oyama, P. E. Griffiths & R. D. Gray (Eds.). *Cycles of contingency: Developmental systems and evolution* (pp. 41-54). Cambridge, MA: MIT Press.
- Gottlieb, G. (2004). Normally occurring environmental and behavioral influences on gene activity: From central dogma to probabilistic epigenesis. In C. G. Coll, E. L. Bearer, & R. M. Lerner (Eds.). *Nature and nurture: The complex interplay of ge-*

- netic and environmental influences on human behavior and development* (pp. 85-106). Mahwah, NJ: Erlbaum.
- Gould, S. J. (1988). On replacing the idea of progress with an operational notion of directionality. In M. H. Nitecki (Ed.), *Evolutionary progress* (pp. 319-338). Chicago, IL: University of Chicago Press.
- Gould, S. J. (1997). Darwinian fundamentalism. *New York Review of Books*, **44**, 34-37.
- Greenberg, G. (1983). Psychology without the brain. *The Psychological Record*, **33**, 49-58.
- Greenberg, G. (1995). Anagenetic theory in comparative psychology. *International Journal of Comparative Psychology*, **8**, 31-41.
- Greenberg, G., Partridge, T., Weiss, E., & Haraway, M. M. (1998). Integrative levels, the brain, and the emergence of complex behavior. *Review of General Psychology*, **3**, 168-187.
- Greenberg, G., Partridge, T., Weiss, E., & Pisula, W. (2004). Comparative psychology, a new perspective for the 21st Century: Up the spiral staircase. *Developmental Psychobiology*, **44**, 1-15.
- Hebb, D. O. (1953). Heredity and environment in mammalian behavior. *British Journal of Animal Behaviour*, **1**, 43-47.
- Heinrichs, R. W. (1993). Schizophrenia and the brain: Conditions for a neuropsychology of madness. *American Psychologist*, **48**, 221-233.
- Hirsch, J. (2004). Uniqueness, diversity, similarity, repeatability, and heritability. In C. G. Coll, E. L. Bearer, & R. M. Lerner (Eds.) *Nature and nurture: The complex interplay of genetic and environmental influences on human behavior and development* (pp. 127-143). Mahwah, NJ: Erlbaum.
- Honeycutt, H. (2006). Studying evolution in action: Foundations for a transgenerational comparative psychology. *International Journal of Comparative Psychology*, **19**, 170-184.
- Hubbard, R. & Wald, E. (1999). *Exploding the gene myth: How genetic information is produced and manipulated by scientists, physicians, employers, insurance companies, educators, and law enforcers*. Boston, MA: Beacon Press.
- Kantor, J. R. (1924). *Principles of psychology. Vol. 1*. Bloomington, IN: Principia Press.
- Kantor, J. R. (1926). *Principles of psychology. Vol. 2*. Bloomington, IN: Principia Press.
- Kantor, J. R. (1947). *Problems of physiological psychology*. Chicago, IL: Principia Press.
- Kantor, J. R. (1959). *Interbehavioral psychology*. Bloomington, IN: Principia Press.
- Kaplan, G. & Rogers, L. J. (2003). *Gene worship: Moving beyond the nature/nurture debate over genes, brain, and gender*. New York: Other Press.
- Kauffman, S. A. (1993). *The origins of order: Self-organization and selection in evolution*. New York: Oxford University Press.
- Kauffman, S. A. (1995). *At home in the universe: The search for the laws of self-organization and complexity*. New York: Oxford University Press.
- Kauffman, S. (2000). *Investigations*. Oxford, UK: Oxford University Press.
- Koopmans, M. (2001). From double bind to n-bind toward a new theory of schizophrenia and family interaction. *Nonlinear Dynamics, Psychology, and Life Sciences*, **5**, 289-323.
- Kuo, Z. Y. (1967). *The dynamics of behavior development*. New York: Random House.
- Lerner, R. M. (1984). *On the nature of human plasticity*. Cambridge, UK: Cambridge University Press.
- Lerner, R. M. (1998). Developmental contextualism. In G. Greenberg & M. M. Haraway (Eds.), *Comparative psychology: A handbook* (pp. 88-97). New York: Garland.
- Lerner, R. M. (2004). Genes and the promotion of positive human development: Hereditarian versus developmental systems perspectives. In C. G. Coll, E. L. Bearer, & R. M. Lerner (Eds.) *Nature and nurture: The complex interplay of genetic and en-*

- vironmental influences on human behavior and development* (pp. 1-33). Mahwah, NJ: Erlbaum.
- Lerner, R. M. & Busch-Rossnagel, N. A. (Eds.; 1981). *Individuals as producers of their development: A life-span perspective*. New York: Academic Press.
- Lewin, R. (1980). Is your brain really necessary? *Science*, **210**, 1232.
- Lewin, R. (1992). *Complexity: Life at the edge of chaos*. New York: Macmillan.
- Lewontin, R. (1991). *Biology as ideology: The doctrine of DNA*. New York: Harper Collins.
- Lickliter, R. & Honeycutt, H. (2003). Developmental dynamics: Toward a biologically plausible evolutionary psychology. *Psychological Bulletin*, **129**, 819-835.
- Lissack, M. R. (1999). Complexity: The science, its vocabulary, and its relation to organizations. *Emergence*, **1**, 110-126.
- Magnusson, D. (1996). *The life-span development of individuals: Behavioral, neurobiological, and psychosocial perspectives. A synthesis*. Cambridge, UK: Cambridge University Press.
- Mahner, M. & Bunge, M. (1997). *Foundations of biophilosophy*. Berlin, Germany: Springer.
- Marks-Tarlow, T. (1999). The self as a dynamical system. *Nonlinear Dynamics, Psychology, and Life Sciences*, **3**, 311-345.
- McCrone, J. (2004). Exploding the 10 percent myth. *Science and Consciousness Review*, September, www.sci-con.org/2004/09/exploding-the-10-percent-myth.
- Michel, G. F., & Moore, C. L. (1995). *Developmental psychobiology: An interdisciplinary science*. Cambridge, MA: MIT Press.
- Moltz, H. (1965). Contemporary instinct theory and the fixed action pattern. *Psychological Review*, **72**, 27-47.
- Montagu, A. (1962). Our changing conception of human nature. In *The humanization of man* (pp. 15-34). New York: Grove Press. (Reprinted from *Impact [UNESCO]*, 1952, **3**, 219-232).
- Morgan, C. L. (1901). *Introduction to comparative psychology*. London, UK: Scott.
- Morgan, C. L. (1923). *Emergent evolution: the Gifford lectures*. London, UK: Williams and Norgate, 1923.
- Moss, L. (2003). *What genes can't do*. Cambridge, MA: MIT Press.
- Needham, J. (1929). *The sceptical biologist*. London, UK: Chatto.
- Nelkin, D. (1993). The grandiose claims of geneticists. *Chronicle of Higher Education*, *March 3*, B1-B2.
- Newell, K. M., & Molenaar, P.C.M. (1998). *Applications of nonlinear dynamics to developmental process modeling*. Mahwah, NJ: Erlbaum.
- Nicolis, G. (1989). Physics of far-from-equilibrium systems and self-organisation. In P. Davies (Ed.). *The new physics* (pp. 316-347). Cambridge, UK: Cambridge University Press. (Reprinted, 1994).
- Novikoff, A. (1945). The concept of integrative levels and biology. *Science*, **101**, 209-215.
- O'Conner, T. & Jacobs, J. D. (2003). *Philosophical Quarterly*, **53**, 540-555.
- Oyama, S., Griffiths, P. E., & Gray, R. D. (Eds.). (2001). *Cycles of contingency: Developmental systems & evolution*. Cambridge, MA: MIT Press.
- Panskepp, J. & Panskepp, J. B. (2000). The seven sins of evolutionary psychology. *Evolution and Cognition*, **6**, 108-131.
- Partridge, T. (2002). Biological and caregiver correlates of behavioral inhibition. *Infant and Child Development*, **12**, 71-87.
- Partridge, T. (2003). Temperament: Developmental and ecological dimensions. In J. R. Miller, R. M. Lerner, & L. B. Schiamberg (Eds.). *Human ecology: An encyclopedia of children, families, communities, and environments* (pp. 678-682). Santa Barbara, CA: ABC-Clío.

- Prigogine, I. & Stengers, I. (1984). *Order out of chaos: Man's new dialogue with nature*. New York: Bantam Books.
- Pinker, S. (2002). *The blank slate*. New York: Penguin.
- Pringle, J. W. S. (1951). On the parallel between learning and evolution. *Behaviour*, **3**, 174-215.
- Pronko, N. H. (1963). *A textbook of abnormal psychology*. Baltimore, MD: Williams Wilkins.
- Pronko, N. H. (1980). *Psychology from the standpoint of an interbehaviorist*. Belmont, CA: Wadsworth.
- Razran, G. (1971). *Mind in evolution*. New York: Houghton Mifflin.
- Robert, J. S. (2004). *Embryology, epigenesis, and evolution: Taking development seriously*. Cambridge, UK: Cambridge University Press.
- Robert, J. S., Hall, B. K. & Olson, W. M. (2001). Bridging the gap between developmental systems theory and evolutionary developmental biology. *BioEssays*, **23**, 954-962.
- Rutter, M. (2002). Nature, nurture, and development: From evangelism through science toward policy and practice. *Child Development*, **73**, 1-21.
- Rumbaugh, D. & Washburn, D. (2004). *Intelligence of apes and other rational beings*. New Haven, CT: Yale University Press.
- Sameroff, A. (1975). Transactional models in early social relations. *Human Development*, **18**, 65-79.
- Saunders, P. T. & Ho, M. W. (1976). On the increase in complexity in evolution. *Journal of Theoretical Biology*, **63**, 375-384.
- Saunders, P. T. & Ho, M. W. (1981). On the increase in complexity in evolution. II. The relativity of complexity and the principle of minimum increase. *Journal of Theoretical Biology*, **90**, 515-530.
- Saunders, P. T. & Ho, M. W. (1984). The complexity of organisms. In J. W. Pollard (Ed.) *Evolutionary theory: Paths into the future* (pp. 121-139). New York: Wiley.
- Savage-Rumbaugh, E. S. & Sevcik, R. A. (1984). Levels of communicative competency in the chimpanzee: Pre-representational and representational. In G. Greenberg & E. Tobach (Eds.), *Behavioral evolution and integrative levels* (pp. 197-219). Hillsdale, NJ: Erlbaum.
- Savage-Rumbaugh, E. S., Murphy, J., Sevcik, R. A., Brakke, K. E., Williams, S. L., & Rumbaugh, D. M. (1993). Language comprehension in ape and child. *Monographs of the Society for Research in Child Development*, **58**, (Whole Nos. 3-4).
- Schneirla, T. C. (1949). Levels in the psychological capacities of animals. In R. W. Sellars, V. J. McGill & M. Farber (Eds.). *Philosophy for the future* (pp. 243-286). New York: Macmillan.
- Simon, H.A. (1999). Can there be a science of complex systems? In Y. Bar-Yam (Ed.), *Unifying themes in complex systems: Proceedings from the International Conference on Complex Systems 1997* (pp. 4-14). Cambridge, MA: Perseus Press.
- Skinner, B. F. (1966). The phylogeny and ontogeny of behavior. *Science*, **153**, 1205-1213.
- Skinner, B. F. (1974) *About behaviorism*. New York: Knopf.
- Skinner, B. F. (1988). Genes and behavior. In G. Greenberg & E. Tobach, (Eds.). *Evolution of social behavior and integrative levels* (pp. 77-83). Hillsdale, NJ: Erlbaum.
- Smith, J. M. & Szathmáry, E. (1995). *The major transitions in evolution*. Oxford, England. W. H. Freeman.
- Smith, L. B., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Science*, **7**, 343-348.
- Spencer, J. P., Smith, L. B., & Thelen, E. (2001). Tests of a dynamic systems account of the A-not-B error: The influence of prior experience on spatial memory abilities of two-year-olds. *Child development*, **72**, 1327-1346.

- Stebbins, G. L. (1969). *The basis of progressive evolution*. Chapel Hill, NC: University of North Carolina Press.
- Sulis, W. & Trofimova, I. (Eds.). (2000). *Nonlinear dynamics in life and social sciences*. Amsterdam, The Netherlands: IOS Press.
- Teresi, D. (2002). *Lost discoveries: The ancient roots of modern science – from the Babylonians to the Maya*. New York: Simon and Schuster.
- Thelen, E. (1989). Self-organization in developmental processes: Can systems approaches work? In M.R. Gunnar & E. Thelen (Eds.). *Systems and development: The Minnesota symposium in child psychology*, **22**, 77-117.
- Thelen, E. (2004). Motor development as a foundation and future of developmental psychology. In W.W. Hartup & R.K. Silbereisen (Eds.). *Growing points in developmental science* (pp. 1-23). New York: Psychology Press.
- Tobach, E. & Schneirla, T. C. (1968). The biopsychology of social behavior of animals. In R. E. Cook S. Levin (Eds.), *The Biological basis of pediatric practice*. New York: McGraw-Hill.
- Torrey, E. F. (1983). *Surviving schizophrenia: A family manual*. New York: Harper & Row.
- University of Sheffield, Sheffield, UK, Department of Philosophy. (2007). *Innateness and the structure of the mind*. Retrieved December 6, 2006, from the University of Sheffield, Department of Philosophy. Web site: <http://www.philosophy.dept.shef.ac.uk/AHRB-Project/people/>
- Uttal, W. R. (2001). *The new phrenology: The limits of localizing cognitive processes in the brain*. Cambridge, MA: MIT Press.
- Uttal, W. (2005). *Neural theories of mind: Why the mind-brain problem may never be solved*. Mahwah, NJ: Erlbaum.
- Valenstein, E. (1973). *Brain control*. New York: Wiley
- Valenstein, E. (1998). *Blaming the brain*. New York: The Free Press
- Wahlsten, D. (2003). Airbrushing heritability. *Genes, Brain, and Behavior*, **2**, 327-329.
- Woodger, J. H. (1929). *Biological principles: A critical study*. London, UK: Routledge and Kegan Paul.

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