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ARTICLES

The Failure of Biogenetic Analysis in Psychology: Why Psychology is Not a Biological Science

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Many define psychology as a biological science and emphasize brains and genes as major determinants of behavior. Instead, it is argued here that psychology is a unique biopsychosocial science able to stand on its own. Biogenetic processes are indeed relevant but are simply participating, not causal, factors in behavioral origins. Long neglected by biologists and social scientists, the importance of developmental processes is emphasized. The author takes issue with behavior geneticists and argues that development is bidirectional—internal and environmental phenomena influence behavior—probabilistically. The author favors a relatively new model with roots in ideas from contemporary physics: emergence and self-organization—"relational developmental systems."

"It is always best to start at the beginning" said Glinda the *Wizard of Oz's* Good Witch. Advice sometimes comes from strange sources. I begin this article, then, with a definition of *psychology* as the biopsychosocial science of behavior. Doing so summarizes the essence of my contribution to this special issue of *Research in Human Development.*Although I will use this article as one more critique of behavior genetics, and therefore as a further attempt to "explode the gene myth" (e.g., Hubbard & Wald, 1993), I have criticized elsewhere the full extent of the

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biogenetic approach to psychology (Greenberg, 2007; Greenberg & Lambdin, 2007; Greenberg & Partridge, 2010). It is safe to say that most scientists, including most psychologists, believe psychology to be a biological science and that,as one prominent behaviorist put it, "Psychology . . . can be completely explained in the language and data of neurophysiology—in principle if not in fact" (Uttal, 2005, p. 155). Of course, the general public is led to believe this view as well as this statement by a *New York Times* columnist makes clear:

> In the 1950s, the common view was that humans begin as nearly blank slates and that behavior is learned through stimulus and response. Over the ages, thinkers have argued that humans are divided between passion and reason, or between the angelic and the demonic. But now the prevailing view is that brain patterns were established during the millenniums when humans were hunters and gatherers, and we live with the consequences. Now, it is generally believed, our behavior is powerfully influenced by genes and hormones. Our temperaments are shaped by whether we happened to be born with the right mix of chemicals. (Brooks, 2006, p. 14)

I was schooled in traditions that understood psychology differently—not as a biological science, but as a science that stands on its own, a unique psychological science, a natural science, consistent and compatible with the principles of other natural sciences. This perspective is nowhere made so clear as in a recent article by Overton and Müller (in press). This idea is, of course, not new being the position as well, of J. R. Kantor (1959), of B. F. Skinner (1953), and of T. C. Schneirla (Aronson, Tobach, Rosenblat, & Lehrman, 1972). I later became associated with Gottlieb's (2004) probabilistic epigenesis, Lerner's (1989, 1998) developmental contextualism, and Overton's (2010) relational, developmental systems view. From the perspective of these approaches to psychology, behavior is seen to be not a biological property of organisms, but a biopsychosocial property. Of course, we are biological organisms before we become psychosocial creatures; biology, however, is simply another participatingfactor in behavioral origins, not the causative factor.

The tendency to see wholes as the mere sums of their parts, that is, reductionism, still holds sway in many quarters of science. Today psychology and behavior are seen by many to be reducible to biogenetic substances—to brains and genes specifically. It is an unfortunate development that 21st-century psychology finds itself still hampered by reductionistic and counterfactual biological thinking: Of course, much of this reductionism is driven more by ideology than by pure science, as reflected in Lewontin's (1991) criticism of this controversy, which he titled *Biology as Ideology*. Part of the reasons for this biogenic focus was summed up by the executive director for Science of the American Psychological Association: "[Today's] newest age of reductionism is being fueled by the federal funding agencies, the Congress, and by the general public. Everyone seems to think that focusing on ever finer grains of sand will hasten cures for the worst of human afflictions and produce enormous leaps forward in our understanding of the human condition" (Breckler, 2006, p. 23).

This perspective was leant significant support by two major research efforts at the end of the 20th century: the Decade of the Brain (Tandon, 2000) and the Human Genome Project (2011). One important goal of these efforts was to elucidate the neural and genetic underpinnings of behavior. Thus, it may be understandable why biology, and more specifically why brains and genes, are seen to control behavior and why psychology is understood to be a biological science. Of course the biological foundations of behavior are indisputable; however, evolution, genetics, hormones, and neurophysiology are not, even together, the sole causative determinants of behavior. They are all necessary, although not sufficient, participating factors in the development of behavior.

The Decade of the Brain (Tandon, 2000) and the Human Genome Project (2011) purported to put to rest the search for the origins of behavior—to partition out the relative contributions to behavior of biology (nature) and environment (nurture), one assumption being that brains and genes are separable from and more important than environments and experiences. Although these two enormously expensive efforts yielded much significant and important information about the brain and the genome, their impact on our understanding of neural and genetic influences on behavior were minimal (Lewontin, 2000, 2011; Strohman, 1997). Although both efforts came down on the nature side of the nature/nurture equation,

> The Decade of the Brain has led to a realization that a comprehensive understanding of the brain cannot be achieved by a focus on neural mechanisms alone, and advances in molecular biology have made it clear that genetic expressions are not entirely encapsulated, that heritable does not mean predetermined. (Cacioppo, Bernston, Sheridan, & McClintock, 2000, p. 836)

In addition, both projects failed to "take development seriously" (Robert, 2004, p. xiii). Indeed, the idea of development has been sidestepped and neglected by biologists and psychologists. There was, however, a small group of 20th-century psychologists who understood the proper role of developmental biological phenomena in behavioral origins and development (Gottlieb, 1992; Kantor, 1959; Kuo, 1967; Schneirla, 1957). Although there are important differences in the systems outlined by these important contributors to modern psychology, there are as well crucial shared ideas, including the significance of a multilevel approach, the importance of history and development, and the contextual nature of behavior. Gottlieb, being the most contemporary member of this group, had the advantage of being able to apply our more recent understanding of ideas in biology and the other sciences that we now know significantly affect behavior. Gottlieb stressed that development was bidirectional; internal cellular and external contextual factors all influence the development of behavior (as well as structures). These influences are notcausal, but, rather, probabilistic.

Surprisingly, the perennial question of which contributes more to behavior, biology (nature), or experience (nurture) is not dead, a point made abundantly clear in Lewontin's (2011) recent review of Keller's 2010 book, *The Mirage of a Space Between Nature and Nurture*. It is worth quoting Lewontin:

> [We are in] an era when biological—and specifically, genetic—causation is taken as the preferred explanation for all human physical differences. Although the early and mid-twentieth century was a period of immense popularity for genetic explanations of class and race differences in mental ability and temperament, especially among social scientists, such theories have now virtually disappeared from public view, largely as a result of a considerable effort of biologists to explain the errors of those claims. The genes for IQ have never been found . . . . "DNA" has replaced "IQ" as the abbreviation of social import.(p. 26)

I don't usually find fault with Lewontin on such issues. He is, after all, one of the world's leading geneticists and has been consistently critical of biological determinism. But, though he went on to emphasize that genes are no longer seen to play the sole major role in biological disorders (diseases), I take issue with his assessment regarding the historical passing of ideas about genes and psychological characteristics. Diehard reductionists still exist, and they continue to try to find ways to split nature and nurture. Lerner (2004) agreed, pointing out that many behavioral scientists, psychologists especially, continue to believe that behavior genetics provides evidence for the inheritance of behaviors such as intelligence, parenting, morality, and even television viewing!

Research in molecular biology, in genetics, is neither easy nor inexpensive. It is, of course, necessary. Lerner (2004), for example, cautioned 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. (p. 20)

Such arduous relational, developmental systems research in the last few decades has revealed much about the nature and functioning of genes (Hood, Halpern, Greenberg, & Lerner, 2010). This research has caused us to dispense with a number of ideas we once accepted as gospel. These ideas include the notion that single genes affect single traits: eye color, for example. Although some single gene/single traits are claimed to exist, this idea has been disputed and dismissed in literature now more than 80 years old (e.g., Jennings, 1924). In addition, the common mode is for genes to act in concert with others,that is, most characteristics are polygenetic. Genes exist in a cell that has many components, all of which function in a manner akin to chemicals in a test tube. Everything in the test tube affects everything else in that test tube; so too, everything in the cell affects genes.

Genes are, in essence, catalysts. Genes influence other genes, turning some on and some off. In addition, the chemistry of the cell is very much influenced by external factors—an obvious example being a person's diet. Campbell (1990) referred to this influence as "downward causation" an idea that reflects the bidirectional nature of processes from gene and environmental levels (e.g., Gottlieb, 1998; Weiss, 1973). Much of these external factors are essentially random, so that the developmental process is not predetermined, but, rather, probabilistic. Put another way,

> Since it has become evident that genes interact with their environment at all levels, including the molecular, there is virtually no interesting aspect of development that is strictly "genetic," at least in the sense that it is exclusively a product of information contained within the genes. (Elman et al., 1996, p. 21)

Of course, our genes are now known to be turned on and off throughout our lives, as a result of our varied experiences.

These recent findings in molecular biology challenge the central dogma of molecular biology (Crick, 1970), that genetic information flows in one direction only—from inside to out, from the genotype to the phenotype. Much contemporary research has shown this view to be false, but it is still not widely known, most significantly among psychologists. Although few psychologists are familiar with these findings, it is significant that many biologists are also unaware of recent developments in molecular biology that render the standard programof genetics as an unfolding of a set genetic code, no longer valid: "While this fact is not well known in the social and behavioral sciences, it is surprising to find that it is also not widely appreciated in biology proper . . . [!]" (Gottlieb, 2001, p. 47). Gottlieb was not alone in this assessment, as even a molecular biologist has noted (Strohman, 1997).

That this intellectual lacuna is true today, in 2011, is somewhat startling when we realize that some scientists were discussing genetics in these terms very early in the 20th century. H. S. Jennings, one of the pioneers of genetics, made the following statements in his 1924 article:

> But no single thing that the organism does depends alone on heredity or alone on environment; always both have to be taken into account (p. 225).
>
> . . . it is not true that particular characteristics are in any sense represented or condensed or contained in particular unit genes. Neither eye color nor tallness nor feeble-mindedness, nor any other characteristic, is a unit character in any such sense.

> There is indeed no such thing as a "unit character," and it would be a step in advance if that expression should disappear. (228)

Surprisingly, that idea has not yet been vanquished.

> Open a book, read a newspaper, turn on the TV, read *Science* or *Nature* and you will find yourselfbombarded 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? (Oyama, Griffiths, & Gray, 2001, p. 1)

As Lewontin's review makes clear, the Human Genome Project taught us that genetics is far more complex thatthan we could have expected. Rather than furthering our understanding of the genetic basis of the biological and psychological characteristics of us, it has, as science often does, raised more questions than it answered. We have only recently learned that transcription of DNA to RNA protein producing factors is not one-to-one as we have long believed (Li et al., 2011). This finding, of course, deals another blow to traditional gene-centric thinking.

I have pointed out previously (Greenberg, 2005) that one of the more interesting things about behavior genetic analysis is the absence of any discussion as to how genetic influences might manifest themselves. No pathways are identified, though of course the pathway from genes to even structure is indirect and enormously complex. With respect to behavior, I have always found Skinner's (1966) views to reflect the true state of things: To the extent that we behave with structures we inherit, it may be possible to speak of the genetic or otherwise biological foundation of behavior. But although I have inherited two hands with a full complement of fingers I cannot play the piano. Slowly and gradually, out of a rich experience of the world, one builds a behavioral repertoire, including piano playing. As Moss (2003) pointed out, there is no explanation in attributing a trait, behavioral or structural, to genetics in light of what converging current research from several disciplines indicates.

THE ONTOLOGICAL STRUCTURE OF PSYCHOLOGY

If behavior is not under the direct control of biogenetic phenomena, what then accounts for its development?I think it is fair to say that all of those scholars I mentioned above (e.g., Gottlieb,Kantor, Kuo, Lerner, Overton, Skinner, &Schneirla) have understood behavior to result—that is,to develop—because after all, psychology is a developmental science, a "life-span developmental science" (Greenberg, Partridge, Mosack, & Lambdin, 2006; Lerner, 2002, 2011; Overton, 2006, 2010) from the dynamic fusion of several sets of factors (Greenberg & Haraway, 2002; Seay & Gottfried, 1978), including the phylogenetic, ontogenetic, experiential, cultural, and individual.

Phylogenetic Set

The organism's evolutionary status, what it is as a species. This set is embodied in Kuo's (1967) "principle of behavioral potentials" that suggests that each species has the potential to behave in species-typical ways. Of course, there is no guarantee that those potentials will be actualized. Thus, as Montagu (1952/1962) pointed out, "The wonderful thing about a baby . . . is its promise" (p. 17)—we are born *Homo sapiens*, but we have to becomehuman beings.

Ontogenetic Set

The development of an organism, from its embryonic state to its state as an adult and its eventual death. Again, the probabilistic nature of this ontogeny is underscored. Nothing in development—embryological or behavioral—is guaranteed by genes; nothing is preformed or preordained (Gottlieb, 1992; Nieuwkoop, Johnen, & Albers, 1985). It should be noted here that the developmental stage of an organism profoundly affects its behavior and the way in which it reacts to stimuli. For example, a baby in its crawling period can only get under the sink, but when she begins to walk care must be taken to fasten the kitchen drawers.

Experiential Set

". . . [A]ll stimulative effects upon the organism through its life history" (Schenirla, 1957, p. 86). This concept refers as well to all actions initiated by the organism (Overton, 2006). Experience, then,is what happens to the organism and what it does. Kantor (1959) referred to this experiential history as the "reactional biography" (RB). The RB begins at conception and continues to be built up until the organism's death. Every stimulus and each act affects the organism and changes it, although some stimulation and some acts have much more profound and obvious effects than others. Learning, for example, is an important process in behavioral change, but it is nothing more than a special set of experiences.

Cultural Set

Organisms function in environments. The organism–environment relationforms a functional whole, and consequently environments are necessary features of the organism's biological and behavioral development. This relation is most obvious in humans, who have developed cultural systems (e.g., religion, dietary practices, social institutions) that affect behavioral development in multiple ways. But all living organisms, although perhaps at less complex levels, function within environments of their own making. Different species may inhabit different environments, eat different foods, and so on. This important point was stressed by the ethologist Jacob von Uexküll (1957) who termed the behavioral environment of an animal its *Umwelt*, its sensory-perceptual world (see Michel, 2010). Chimpanzees, for example, display different behavioral adaptations related to their unique environments (Matsuzawa, 1998). Individuals in two communities separated by only 10 km display markedly different behaviors. These differences include nest building, ant dipping, use of leaves for water drinking, food choices, and many others. These differences are less complex cultural traditions than are found in more complex species.

Individual Set

The uniqueness of each individual organismand how that uniqueness relates to its development. One animal may be more or less sensitive to sounds, or may have a developmental abnormality that limits its interactions with its world, or may be larger or smaller than its conspecifics, and so on. This set of factors recognizes the contribution of the individual's unique genotype and how the organism's biology, in dynamic interplay with contextual influences, may render it a different behaving creature than all others.

These five organizational sets provide the ontological structure of psychology. I am comforted by the use of a similar analysis by Overton (2006; Overton & Müller, in press) one of the world's leading developmental psychologists, who used different labels but is substantially in agreement that several sets of factors, at different levels of analysis and influence, play a dynamic role in human development. We are especially in agreement with respect to the significance of the physical ideas of "fluid dynamic holism and associated concepts such as *self-organization, system,* and the synthesis of wholes" (Overton, 2006, p. 19) as they apply to understanding development.

The common theme that runs throughthese organizational sets is that temporal processes and relational constructs are the central conceptual features of each set. The challenge for the study of psychological development is to account for these dynamic relational processes that occur at multiple spatial and temporal streams, becoming manifest in the nexus of the individual organism. Although many scientists acknowledge the importance of multiple factors in behavior (although many still cling to the nature/nurture split) few recognize that these factors do not simply interact. Such a formulation would grant nature and nurture factors individual and independent significance in influencing behavior (Pronko, 1988). Rather, the dynamic interplay between these factors is a fusion (Tobach &

Greenberg, 1984)—one cannot therefore say how much is determined by phylogeny, how much by ontogeny, how much by nature, how much by nurture, in much the same way we cannot determine how much of the area of a rectangle is a function of its width or its height. There is much to agree with in Pronko's (1988) comment that "We must not neglect genetic and other biologic factors, but, instead of treating them as causal, we regard them as *aspects* of an integrated field event or events" (p. 78).

DEVELOPMENT IS PROBABILISTIC

The preceding critique of the biogenetic approach in psychology leads to a discussion of development, biological and psychological, not as something fixed or guaranteed, but as probabilistic. Nothing is guaranteed by the genes, something that contemporary molecular biology makes clear. That we have to fight to make this point universally accepted is remarkable given that it was understood by even the earliest pioneers of genetics. I again turn to H. S. Jennings (1924):

> The genes are simply chemicals that enter into a great number of complex reactions, the final upshot of which is to produce the completed body. The characters of the adult are no more present in the germ cells than is an automobile in the metallic ores out of which it is ultimately manufactured. [p. 230] . . . What any cell shall become depends in fact on the conditions surrounding it: on its relation to the other cells. *Development, it turns out, is a continual process of adjustment to environment.* (p. 231, emphasis added)

We now understand that what a gene does is very much influenced by which other genes are being turned on or off at any particular time during development. In other words, genes do their work along with other genes, rather than individually. Genes, then, are not encapsulated and isolated from the environment, they are, rather, an integral part of that environment.

THE ROLE OF DEVELOPMENT

Human development is complex, and our understanding of it invokes complex ideas, some of which come from the other sciences—biology of course, but also physics, especially complexity and dynamic systems theories (Partridge & Greenberg, 2010). Among the best discussions of development—its concepts, implications, and meanings—are those by Lerner (2002, 2011) and Overton (2006). I have in other places invoked the important idea of emergence (Greenberg, Partridge, & Ablah, 2006; Partridge & Greenberg, 2010), an idea from modern physics with parallels in Gestalt psychology (e.g., "The whole is different from the sum of the parts"). As Lerner (2004) points out, "The complexity of these [developmental] theories can be daunting [even] to scholars" (p. 1).

A common question todayin theoretical papers regarding development, whether implicitly or explicitly posed, asks what is the role of biology, of brains and genes, in shaping development. Such questions take the form of hypotheses regarding the relationship between a given allele and trajectories of behavioral outcomes. In these situations, there is an underlying assumption that development is subsidiary to biological factors. In other words, it is assumed that ontogeny is a function primarily of phylogeny and that behavioral development is shaped by the organism's biology. Thus, biology (genes, neural circuits, hormones), is understood to be the guiding force that drives individual differences in the development of behavior. This view is a persistent problem with the behavior genetic approach to behaviorit attempts to set values for the relative roles of the several sets of factors that influence behavior. This approach is, of course, interaction(e.g., Pronko, 1988), rather than fusion.

THE RELATIONAL, DEVELOPMENTAL SYSTEMS VIEW OF PSYCHOLOGY

However, a relational holistic position takes a dramatically different perspective on the relationship between biology and psychological development. From this perspective, development is an active system of processes superordinate to biology and evolution. Thus, it is not that genes and brains explain development, but that the developmental system explains the functioning of the gene, the brain, and even evolution at the level of individual ontogeny. The developmental system integrates biological functions into coordinated patterns which support behavior. It is, then, the process of development that shapes biological organization and provides a temporal context for biology-behavior-ecology interrelationships (Lerner & Bush-Rossnagel, 1981; Overton & Müller, in press).

In endorsing this relational holistic position, I am proposing that the focus of study in developmental psychology should be on the pattern of interrelationships between biological structure, psychological states, and ecological contexts. A clear characterization of development is that organisms initially comprise relatively undifferentiated biological and behavioral features that over time become increasingly differentiated and reintegrated into a coherent biological and behavioral system (Overton, 2006, 2010). It is the probabilistic, epigenetic, and self-organizing principles of development (e.g., Gottlieb, 1992) within a dynamic ecological context that shape the processes of differentiation and integration that characterizes a given individual's genetic, neurological, and behavioral attributes, rather than the other way around.

Although many of these ideas have been discussed by earlier developmentalists, their treatment by Overton and Müller (in press) shows much more clearly the significance of how some of these concepts from physics bear directly on our contemporary understanding of psychological development. These concepts pertain to the ideas of system (that the parts of organisms function interdependently and that behavior is a process,and not a substance or thing,of the system), of hierarchy or directionality (as a fundamental principle of science that the universe exists in as a family of hierarchies in which natural phenomena exist in levels of increasing organization and complexity), of emergence and self organization(that a corollary of the Big Bangtheory is that given enough time hydrogen and helium become sentient beings), and of epigenesis(an holistic approach to understanding development, discussed in the next section). In Overton and Müller's language, developmental psychology as currently envisioned is in a post positivist era.

THE ROLE OF EPIGENESIS IN DEVELOPMENT

At least since the broad acceptance of the modern synthesis in biology the gene construct has served as the central biological organizing feature assumed to guide biological and behavioral development. However, the very notion of just what a gene is has changedsince the end of the 20thcentury. It is no longer sufficient to speak of "the" gene; the term has come to mean different things to different people. The term *gene* is now understood to be shorthand for several different kinds of units. It may be that *gene* is not so much an identifiable thing as it a processinvolved in binding DNA to other factors which act together in polypeptide production. At its inception, and indeed, until only very recently, the gene, seemingly so concrete and definitive a structure, was nothing more than a hypothetical construct in a statistical equation (Burian, 1985, Keller, 2002). Behavior geneticists are, however, undaunted by this history of facts. They have continued to work under the false assumption that once the human genome was sequenced behavioral science would be able to incorporate genetic profiles into a general linear model calculus and be able to predict with a reasonable amount of statistical precision the general trajectory of behavioral development, especially those which had been demonstrated to be highly heritable and thus largely under genetic control.

However, it is now indisputable that"high heritability does not mean developmental fixity" (Lerner, 2002, p. 254) and that it does not equate to "largely under genetic control." These facts were recognized very early by Jennings (1924) and were emphasized by many contributors to Harris's(1957) important book, *The Concept of Development*. For example, in that volume, Schneirla (1957) pointed out that, "in experiments with the fruit fly . . . the same gene may influence the development of different wing size and structure according to what temperature prevails during the development of the phenotype" (p. 85). The assumption that genes control development was based on the premise that genes contained developmental information guiding biological development. Behavioral geneticists could then argue for genotypic control of the behavioral phenotype via the neurological endophenotype. However, as I have discussed above, the sequencing of the human genome (Venter, Adams, Myers, Li, Mural et al., 2001), has not yielded the scientific fruit for behavioral science that many leading behavioral geneticists envisioned. As a result there has been a growth of interest in epigenesis as a developmental process and of epigenetics as a mechanism through which genes and contexts transact through development.

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

> 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 epigeneticists' view, the environment is not benignly supportive, but actively implicated in determining the very structure and organization of each response system. (p. 44)

While the concept of epigenesis originated in biology, the usefulness of *probabilistic* epigenesiswas recognized and promoted throughout the 20th century by psychologists such as Zing-Yang Kuo (1967), Gilbert Gottlieb (1992), and T. C. Schneirla (1957), although Schneirla never specifically employed the term *epigenesis* in his writing (Aronson et al., 1972). Probabilistic epigenesis has gained support from an exciting set of developments in contemporary science subsumed under the rubric of "dynamic systems theory and relational developmental systems theory," in which complex developmental processes are understood as composed of interrelations among many active system components of the whole developmental system, which I have discussed above. The implication of this position is that in a dynamic and changing environment, rather than genes specifying a particular developmental outcome, be it structural or behavioral,every outcome is an emergent result of the transaction between genes and their cellular, organismic, ecological, and temporal contexts. This view of epigenesis is epitomized by discoveries in biology that even identical genomes in extremely similar environments do not always follow the same developmental pathways. Ko and colleagues (Ko, Yomo, & Urabe, 1994), studying enzyme activity in bacteria, found that despite identical genomes and extremely uniform culture conditions, individual cells developed different levels of enzyme activity and grew into colonies of different size. Ko's studies showed that cell state in bacteria is determined not only by genotype and environment. Rather, "Changes of state can occur spontaneously, without any defined internal or external cause. By definition, these changes are epigenetic phenomena: dynamic processes that arise from the complex interplay of all the factors involved in cellular activities, including the genes" (Solé &Goodwin, 2000, p. 63).

METHODOLOGICAL ISSUES

As a result of the convergence of the ideas I discussed in this article, developmental psychologists now have at their disposal a conceptual architecture and an emerging methodology that is commensurate with their core theoretical principles (e.g., Molenaar, 2010). We find now that not only do empirical data (largely from experimental embryology and comparative psychology) indirectly support inferences about the role of integrated biopsychosocial systems in shaping phenotypic outcomes, but theoretical physicists and mathematicians have demonstrated that these same principles hold widely. Thus, there is now a set of methodological tools using systems methods that have the capability of testing many of the developmental systems postulates directly (Urban, Osgood, & Mabry, 2011). What is perhaps not especially surprising, unfortunately, is that though methodologies are routinely used in other systems disciplines (e.g., engineering, physics, biology, ecology) they "have been slower to diffuse in behavioral and social science" (Urban et al., 2011, p. 9).

The concepts of hierarchy, integrative levels and systems, self-organization, and emergence have been rather fully developed over the last quarter century and are being employed with considerable alacrity by scientists in many disciplines. The larger point here is that through experimental studies of developing organisms, it has become clear that the conceptualization of the gene as held by the central dogma was untenable; it would not explain empirical findings. Many sciences have a long history of physics envy, and as such a number of experimental disciplines drew from new ideas in physics emerging at the turn of the 20th century for an explanatory heuristic that was more consistent with the findings within their respective fields. Independently, but concurrently, theoretical physicists (e.g., Layzer, 1974, 2000) were continuing to develop a mathematical formalism with which to test hypotheses regarding the dynamics of hierarchically nested systems, complex systems with no centralized controls, and so on and also concluded that all systems, be they computational (i.e., bits of information), physical, biological, or social, displayed exactly the properties suggested by early theorists in both of these fieldsboth sets of disciplines. Working from different approaches—one primarily inductive, the other primarily deductive—these respective sets of scholars found a convergent set of shared ideas which have profoundly greater explanatory capability and parsimony than those central to genocentric orientations like behavioral genetics and evolutionary psychology. The newly formed ideas are capable of empirical verification and are consistent with concepts from other sciences and may provide a more parsimonious model for lifespan development.

As I have discussed in another context (Partridge & Greenberg, 2010), one of the more important outcomes of this convergence is that we can now specify hypotheses directly corresponding to the key principles of this relational, developmental systems perspective (Overton & Müller, in press) and test them using appropriate methodological tools. As molecular biologists are beginning to recognize "Key notions such as emergence, nonlinearity, and self-organization already offer conceptual tools that can contribute to transform and improve science" (Mazzocchi, 2008, p. 13).

Because "a major objective of developmental research is to study processes of change" (Nesselroade & Molenaar, 2010, p, 30), psychology as a developmental science requires more sophisticated methodologies to address its issues and ideas. Over the last decades important advances have been made in adapting state space and phase space portrait analyses to the level of data and measurement methodology common to psychology. Most psychophysiological data (e.g., electroencephalogram, or EEG) can be directly analyzed using such techniques. The developmentalist needs other techniques, some of which have been discussed in a recent special issue of this journal (Mabry & Urban, 2011). Other examples are those of Thelen and her colleagues (e.g., Thelen & Smith, 1998), who have used state and phase portrait analytic approaches to revolutionize the field of motor and perceptual development in infancy.

For the present, data at the behavioral level does not meet the requirements of these approaches directly. Yet important work adapting these analytic tools to be better suited to traditional psychological data has substantially bridged that gap (e.g., Granic & Hollenstein, 2003). For example, Lewis, Lamey, and Douglas (1999) characterized the developmental dynamics of two dimensions of early childhood socioemotional development: intensity of distress and attention to mother. Using a two-dimensional ordinal state space grid provided unparalleled insight into the dynamics of infant emotional development—insight that was not feasible with more traditional statistical analyses.

Sigmond Koch (1969) once asked whether a coherent science of psychology was even possible. Fortyyears later we know the answer to that question to be *yes*. I have maintained that psychology is, in fact, a natural science. Accordingly, the methods used, and in this context, especially by developmentalists, have become increasingly rigorous. Psychology is, of course, the science of individual behavior, and thoughwe have a long history of statistical methods analyzing groups, it is now clear that as a developmental science our focus is on the individual. An interesting analogy is proposed by Nesselroade and Molenaar (2010), in which the individual is likened to the Brownian movement of a single particle. As we follow a person across his or her life span, the relational developmental system model I discussed here allows us to discern the emergence of behaviors using newly developed methodologies.

A full description of these methods is beyond the scope of this article. Rather the aim here is to provide a brief description of a few of the analytic methods developed to study the properties of nonlinear dynamic systems, how these methods have been incorporated into related disciplines, and, most importantly, that the phenomena for which these methods were designed are conceptually identical to many of the central concepts. I have discussed linking these core concepts with analytic and methodological tools such as the use of cellular automata, Bayesian network analyses, state and phase portraits, state space grids, and nonlinear dynamic systems approaches to longitudinal covariance modelsis where the future of developmental science lies.

CONCLUDING COMMENTS

I began this article as a polemic against behavior genetics, and one could say I wandered somewhat from my topic and presented a discussion of psychology as a developmental science. My title is meant to reflect the uniqueness of psychology as a science and not that biological factors do not have a role to play in behavioral ontogeny. Indeed, as Overton (2006) made clear biological principles, from evolution to ecology (i.e., context), are important participating factors in behavior ontogeny. From the perspective I am promoting here, behavior is a process—not a thing or substance, a point discussed by Overton (2006) and Overton and Müller (in press).

The implication of this is that,though brains and genes are important, behavior is a phenomenon that emerges as the organism develops. Although many of the scholars I have discussed above understood the role of development, many contemporary scientists, especially behavioral scientists, have ignored development. A small, but growing group of influential scientists is leading the charge to reverse this trend, among them Lerner (2002, 2011) and Overton (2006, 2010). They are among the growing group of behavioral scientists spelling out the concepts and principles of developmental science.

When I was a graduate student at the University of Wichita, my mentor at the time, N. H. Pronko (see Pronko, 1973, 1980) expressed optimism that the point of view I espouse in this article would succeed. Although the going has been difficult, this optimism still prevails among an increasing number of behavioral scientists. At the 2003 meeting of the Society for the Study of Human Development, following a presentation by the late Gilbert Gottlieb, a member of the audienceexpressed concern that this approach was not widespread. Lerner responded by noting the several hundred members of the audience—professors and students—who agreed with Gottlieb's views. Lerner offered his prediction that those numbers can only increase. From where I sit today, the future looks rosy.

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