Review

Why Psychology is not a Biological Science: Gilbert Gottlieb and Probabilistic Epigenesis

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While Gottlieb recognized the significance of biological factors for behavioral development, the system of psychology he developed did not cast the discipline as a purely biological science. Rather, genes, brains, hormones were understood by him as participating, rather than causal factors in behavioral origins. He worked from two basic principles that he said he became aware of in graduate school: the importance of prenatal development and the bidirectional nature of structure-function relations. Development was, for him, epigenetic, although it was probabilistic and not predetermined. He was, therefore, against biological determinism and strict genetic reductionism. Behavioral origins have an experiential basis, although he understood much of that experience to be non-obvious and arduous to discern.

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In his recent book exploring the reasons why the mind brain problem will never be solved, Uttal (2006) described psychology as a biological science: "Psychology...can be completely explained in the language and data of neurophysiology – in principle if not in fact" (p. 155). The most mainstream of psychology journals, *The American Psychologist*, often includes articles which promote the biological nature of behavior. For example, "...schizophrenia is a kind of brain disease that should be approached as a problem in neuroscience. There are no viable alternatives" (Heinrichs, 1993). Even one of the editors of a major behaviorist journal, the *Journal of the Experimental Analysis of Behavior* has argued that psychology is a biological science – "Behavior is a biological property of organisms—what else could it be" (Maar, 2006)? And, of course, the general public is led to believe this as well:

> 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).

Part of the reasons for this were 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

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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).

Having just completed two major research efforts, the Decade of the Brain and the Human Genome Project , one goal of which was to elucidate the neural and genetic underpinnings of behavior, it may be understandable why biology, why brains and genes, is 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. Gilbert Gottlieb, who we honor in this special issue of this journal, understood the relationship of biology and psychology in just this way.

The Decade of the Brain and the Human Genome Project purported to put to rest the search for the origins of behavior. The former endeavor sought to place the entire burden of behavior on the brain, the latter on the human genome. To be sure, these two efforts yielded much significant and important information about the brain and the genome, but their impact on our understanding of neural and genetic influences on behavior were minimal (Lewontin, 2000; Strohman, 1997). While 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).

Additionally, both projects failed to "take development seriously" (Robert, 2004). Gottlieb was part of a group of 20th century psychologists who understood the proper role of biological processes in behavioral origins and development (Helson, 1964; Kantor, 1959; Kuo, 1967; Schneirla, 1949). While 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 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 impact significantly on behavior.

Despite the successes of the Decade of the Brain we are really no closer to understanding the relationship of the brain to behavior as we were in 1965 when Bullock could say that, "The gulf between our present level of physiological understanding and the explanation of behavior as we see it in higher forms is wider than the gulf between atomic physics and astronomy and is indeed the widest gap between disciplines in science" (1965/1970, p. 451). It is even the simplest of brains which still defy even the most basic understanding (Laurent, 2006). My point about this is summed up nicely by Bennett and Hacker (2003):

> Such assertions as these – namely, that human beings are machines, or that the behaviour of a human being is no more than the behaviour of their nerve cells, or that decisions are taken in and (apparently) by the brain – are not science but metaphysics (p. 356)....

Could neuroscience explain why birthdays are celebrated, why Tosca is worth going to, and why a husband might think it appropriate to get tickets to the opera for his wife's birthday treat? (p. 364)

And with respect to the Human Genome Project:

> 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? (Oyama, Griffiths & Gray, 2001, p. 1)

This point, of course, reflects the influence of the Central Dogma of Molecular Biology, first proposed by Crick in 1958, which amounts to "a nonstop defense of genetic determinism, pure and simple" (Strohman, 1997). The dogma asserts that information in the gene flows only in one direction – from the gene to the proteins. Gottlieb was among the few psychologists to criticize the Central Dogma: "...the genome is not encapsulated and is in fact a part of the organism's general developmental-physiological adaptation to environmental stress and signals" (2001, p. 47).

Despite the successes of the Human Genome Project, Anastasi's 1958 assessment is still valid:

> 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?" (P. 197).

Gottlieb, of course, spent his career fruitfully addressing the "How" question. 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 as Gottlieb (2004) and others (e.g., Lickliter & Honeycutt, 2003) have pointed out. 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 consistently and reliably demonstrated empirically in data from a large number 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).

"The problem has never been insufficient data, but rather insufficient understanding of that data, and specifically of the relationship between parts and whole in living systems" (Dorit, 2000). Gottlieb not only demonstrated his understanding of this relationship, he was among the leaders in promoting a developmental and a holistic approach to psychology. Not only did Gottlieb always take development seriously, he viewed differences in rates of development as a central mechanism underlying the diversity of behavioral outcomes across ontogeny. If a descriptor is needed for his brand of psychology, other than its being a natural science, the label is, "developmental science." An identifying feature of his approach to psychology is its emphasis on holism, the idea that while parts are important, it is the whole organism which behaves and that the organism's behavior takes place in a context, all features of which effect its behavior. From this perspective behavior is understood to be not a biological phenomenon, but, rather a set of psychological and developmental processes. It is important to point out that while his own research emphasized non-human animal behavior, Gottlieb's approach to psychology, and the principles he was able to discern from it, apply across the animal spectrum, to humans as well (Gottlieb & Lickliter, 2004).

Of course, it has been appreciated since the days of Dewey (1896) and the other Functionalists that it is the whole organism and not any one of its parts that is responsible for behavior. Indeed, current understanding allows us even to stretch Bentley's (1954) idea of the skin as philosophy's last line of defense and argue that it is the organism and its context that makes a behavioral event (Lerner, 1991). In this regard, it may be appropriate to regard the organism as a kind of chemical soup, a test tube in which important reactions are occurring. Gottlieb, for example, emphasized that gene expression is influenced by cellular, cytoplasmic factors. It is informative to examine his pictorial description of this complex interplay of factors (2003, p. 350) which makes clear the multilevel set of processes which underlie behavioral development.

Denying that psychology is not a biological science does not, of course, deny the importance of biology for psychology. Indeed, much of Gottleib's work was very much concerned with biological phenomena. He was a leader in the modern study of behavioral embryology (Gottlieb, 1973), having worked for a time with the great Chinese comparative psychologist, Z-Y. Kuo from whom he learned some important techniques. Gottlieb also engaged in a thorough study of pre- and postnatal sensory processes as they impacted on behavioral development (Gottlieb, 1971). He also saw the relevance of neuropsychology to behavioral development (Gottlieb, 2001b) reflecting his appreciation of the significance of a multiple level approach to the study of behavior (Aronson, 1984; Cacioppo, Bernston, Sheridan & McClintock, 2000; Schneirla, 1949/1972) in which processes below and above psychology have importance for the origins of behavior – hence the identification by some of psychology as a biopsychosocial science. Indeed, even physics becomes of interest in studying behaviors such as locomotion (Vogel, 1998).

Being a developmentalist, and given his appreciation of the role of epigenetic processes in behavioral development, Gottlieb was, of course, against the idea that behavior was in any way instinctive, i.e., programmed by the genes, a popular idea among ethologists and even psychologists at the time he began his career. Rather, Gottlieb believed that experiences formed the basis of all behaviors, though those experiences were often non obvious. "As for non obvious experiences, who could have dreamed that squirrel monkeys' innate fear of snakes derives from their earlier experience with live insects (Masataka, 1994)? Or that chicks perceiving meal worms as edible morsels is dependent on their having seen their toes move (Wallman, 1979)" (Gottlieb, 2001b, p. 2)? Of course, the search for these developmental precursors of behavior is arduous (Lerner, 2004). It is not always easy to find such experiences; that is what renders them non obvious. Kuo (1967), for example, examined 3000 (!) developing chicken eggs in examining the prenatal influences of the post hatching pecking behavior. Can what goes on in a developing egg be any more non obvious?

Probabilistic epigenesis

A recent popular science magazine stated that:

> Some scholars even contend that the genetic code predetermines intelligence and is the root cause of many social ills, including poverty, crime, and violence. "Gene as fate" has become conventional wisdom (Watters, 2006 p. 34).

That article is about epigenetics, which is identified as a new science, although of course Gottlieb had been discussing the role of epigenetics in development in his first papers (e.g., 1970). Indeed, epigenetic processes have been known since the time of Aristotle (Van Speybroeck, de Waele, & Van de Vijver, 2002). Even some contemporary researchers see their findings of epigenetic effects as new. For example, in a study of transgenerational effects of smoking and diet, Pembrey, et al (2006) stated, "Our findings add a *new* multigenerational dimension to the interplay between inheritance and environment in health and development; they provide proof of principle that sex-specific, male-line transgenerational effects exist in humans" (p. 165, emphasis added). What may be new about their findings is their existence in humans; Gottlieb had earlier reported on epigenetic transgenerational transmission (Gottlieb, 1992; Johnston & Gottlieb, 1990). Epigenesis has been described in a variety of ways, but none so 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 epigeneticist's view, the environment is not benignly supportive, but actively implicated in determining the very structure and organization of each response system (p. 44).

In one of his earliest theoretical papers (actually written in 1965, although not published until later), Gottlieb distinguished between predetermined and probabilistic epigenesis, the former firmly on the unbending nature side of the nature-nurture issue. Thus, according to predetermined epigenesis "sensory stimulation does not influence or determine the course of behavioral development in any significant way" (Gottlieb, 1970, p. 112). This approach to behavior understands it to be the outcome of biology (or nature), with very little influence at all of experience (or nurture) (Gottlieb, 2001a). Gottlieb's own work (1973), as well as that of others (e.g., Kuo, 1967; Smotherman & Robinson, 1988) has shown that to be simply wrong.

The alternative position explicated by and favored by Gottlieb, is that of probabilistic epigenesis in which "behavioral development of individuals within a given species does not follow an invariant or inevitable course, and, more specifically, that the sequence and outcome of individual behavioral development is probable...rather than certain" (2001a, p. 43). Indeed, this is seen now to hold not just for behavior, but "is recognized in many quarters as a defining feature of development" (Gottlieb, 2003, p. 341).

Two lessons that remained with Gottlieb from his graduate education were the importance of prenatal development and the bidirectional nature of structure-function relations (2001a). He never denied that genetics played a role in structural and functional development, just that other factors were involved as well ["...genes are part of the developmental system..." (2003, p. 345)], and that structure function relations were bidirectional. He was, in fact, among the first to demonstrate that sensory stimulation enhanced gene expression in the duck embryo. Indeed, at the time of that research, "...there was only one other study in the literature implicating exteroceptive influences on genetic activity..." (Gottlieb, 2001a, p, 46).

Gottlieb has suggested that few psychologists, and in fact many biologists, are simply unaware of recent developments in molecular biology that render the standard program of genetics as an unfolding of a set genetic code as 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...[!]" (Gottlileb, 2001a, p. 47). He was not alone in this assessment as even a molecular biologist has noted (Strohman, 1997).

I prefer to understand this failure to recognize these facts as reflecting part of the sociology of science in which new ideas are seen as threatening (Barber, 1961; Barnes, Bllor & Herny, 1996) and thus ignored, or, perhaps, awaiting a new paradigm that can accommodate them (Strohman, 1997). Indeed, the bidirectional nature of gene action was acknowledged by Hull as early as 1972 who also noted it to be ignored by his contemporaries, "...we have, until now, all but ignored the effect of the environment on genetic reactions. The same molecular structures behave differently under different circumstances" (p. 498). This, of course, is a key message in virtually all of Gottlieb's later writings.

Concluding remarks

Comparative psychology is concerned with the development and evolution of behavior. The discipline has received criticism, however, for a lack of guiding theory and for misunderstandings of evolutionary theory, and more important for the present discussion, for the failure to recognize the role played by biology in behavioral origins. Gilbert Gottlieb's work did much to further comparative psychology's aim and answer its critics. Gottlieb's thesis was that it is ontogenetic novelty that produces evolutionary change. This is in essence an ontological reversal of mainstream evolutionary thought. In developing his argument, Gottlieb provided a conceptual framework that is significant for comparative psychology, adds to the evolutionary dialogue, and damages behavioral explanations derived from an assumption of genetic determinism. The nexus of his work, empirical and theoretical, is an attempt to integrate empirical knowledge of contextual effects influencing morphological and behavioral development and modern evolutionary theory. Thus, the "nature-nurture controversy" is resolved by understanding that behavior is the result not of genes, or biology, nor of nurturance, but is, rather, the result of the complex and dynamic interplay of these factors. Psychological organisms are biosocial beings, and nature and nurture are fused in their influence on behavior. One often neglected and misunderstood implication of this fusion is the bidirectionality of epigenetic processes. Genes affect an organism's phenotype, but the organism's behavior (a phenotypic characteristic) is also now shown to impact the genotype itself.

Gottlieb emphasized several concepts in his writings, but two are especially worth emphasizing and were discussed in several of his works, most cogently in his 1992 book: those of behavioral neophenotypes and of reaction ranges. The former concept is borrowed from Kuo (1967) and refers to the drastic changes in behavioral development that can arise from significant alterations in the contextual conditions of usual organismic development. Gottlieb cited as an example Kuo's experiment in which the previously thought instinctive sexual behavior of male dogs was virtually reversed by controlling the experiential history of the animals. Essential to the creation of neophenotypes are the timing, duration, and quality of contextual alteration.

The second concept is that of the norm of reaction, which is contrasted with the concept of the reaction-range. Largely as the result of mainstream evolutionary thinking, which takes a neo-Haeckelian approach, it has been assumed that an organism's genotype sets narrow limits on the range of phenotypic expression. This line of thinking is referred to as the reaction-range concept. In contrast, the norm of reaction concept assumes that there are no presupposed limits on phenotypic expression. In this conception, genes are limited to a necessary role but of a more limited ontogenetic significance than they have typically been granted. Gould discussed this point in an article he titled "Hen's teeth and horses toes" (1983).

These two concepts provide propositions from which enormous intraspecies behavioral plasticity can be deduced. Further, these behavioral novelties, Gottlieb contends, can be, and are canalized to produce speciation. While Gottlieb was certainly not the first to recognize or discuss this (e.g., Plotkin, 1988), that his treatments have included evidence for this process should do much to assure its broad acceptance by biologists and psychologists alike.

Psychology amassed a great many facts in seemingly intractable debates between cognitive nativists and behaviorist environmentalists since the days of Wundt. It became quite clear in the latter half of the 20th century that these debates were intractable because, in part, these various schools of thought were examining their own small parts of the same integrated biopsychosocial system. The central task of scientific psychology in the 21st century should be to articulate a set of principles which can fruitfully organize the set of factors ranging from genetic, to neural, to intra-personal, to micro- and macro-ecological. Gottlieb's (2003) take on the evidence at hand is that development is that organizing principle, specifically the meta-theoretical perspective of developmental systems. In sharp contrast to our colleagues made weak by finding and fact, yet failing to yield and clinging to the search for an organizing "executive agent," be it the brain or the gene, the developmental systems perspective so forcefully promoted by Gottlieb builds on the empirical properties of dynamic complex adaptive systems (Ford & Lerner, 1992; Gottlieb, 1992, 2001a; Oyama, Griffiths & Gray, 2001a). 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 dynamical transactions of the genetic and epigenetic aspects of the biopsychosocial ecology in which behavior is embedded. Behavior can thus be understood to be an emergent property of the dynamic processes involved in development.

It is not uncommon in science to find little more than lip service granted to important concepts. In twelve years and six biennial T. C. Schneirla conferences organized around the concept of "integrative levels" we have found that while most scientists acknowledge the significance of this crucial organizing principle, reductionistic thinking still prevails in the behavioral and the biological sciences. With respect to the work discussed here, the same can be said of the concept of development and its significance for understanding evolution and evolutionary theory (on this point see too, Michel & Moore, 1995). Gottlieb's work is important for all evolutionary scientists, not least because, in his own words: "It is now acknowledged in many different quarters, both within and without the modern synthesis...., that the time has come to include the role of individual development in evolution and I cannot but hope that [my work] makes some contribution toward that aim" (1992, p. 194).

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