The Role of Developmental Psychobiology in the Unification of Psychology

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Abstract:

The interdisciplinary nature of Developmental Psychobiology (DPB) means that it already unifies many perspectives in psychology. DPB explanations of the development of both individual differences and species-typical behaviors include information from cells, tissue, organ systems, family, societal groups, and sociocultural customs to explain the development of both "normal" and "abnormal" behavioral traits. DPB also contextualizes understanding of the developmental processes governing the manifestation of a behavioral trait with understanding of the adaptive functions and phylogenetic history of that trait. Thus, DPB links clinical, cognitive, social, and developmental psychology with physiology, molecular biology, evolution, ecology, and developmental biology to create explanations that are relevant for education, public health, and medicine.

Keywords: developmental trajectories | interdisciplinary | multilevel explanations | theory of psychology | unifying psychology | history

Article:

Only a shared history seems to hold together the various "perspectives" of modern psychology. Unlike the claim in some textbooks, psychology is more complex than the study of the "mind," human behavior, or the mind in society. However, I do believe that Developmental Psychobiology (DPB) can provide unification of some perspectives in psychology. For what follows, I will draw upon the conceptual framework of DPB presented in a book (Michel & Moore, 1995) designed to define the interdisciplinary character of DPB and provide examples of studies that reveal influences on behavioral development that had been missed by more conventional approaches.

The DPB framework has had a profound impact on our understanding of a wide range of psychological issues including behavior genetics, parental care, communication, social and emotional development, learning and memory, plasticity in neural functioning, the relation of development to evolution, perceptual development, prenatal development, sensorimotor development, and “normal” and “abnormal” development (Blumberg, 2004,2009, 2005; D. S. Moore, 2002). Evidence supporting this claim is available in several recent handbooks (Blass, 2001; Blumberg, Freeman, & Robinson, 2010; Hood, Halpern, Greenberg, & Lerner, 2010). In addition, an international society (International Society for Developmental Psychobiology) with annual conventions publishes a journal (*Developmental Psychobiology*) detailing relevant work in the field. Why, then, has DPB received so little attention in the wider field of psychology? Perhaps, as many students and professionals have complained, they cannot determine how to design and conduct research using a DPB framework. Often such concerns derive from seeing figures like that for Gottlieb’s “developmental manifold” (see Figure 1), in which everything appears to affect everything. If development involves multicomponent, multilevel, bidirectional mechanisms, how is it possible to identify what is causal? How can everything be studied at once, and must an investigator become expert in all those disciplines? This essay describes a conceptual framework of DPB that I hope facilitates the acquisition of expertise and guides the designing and conducting research.

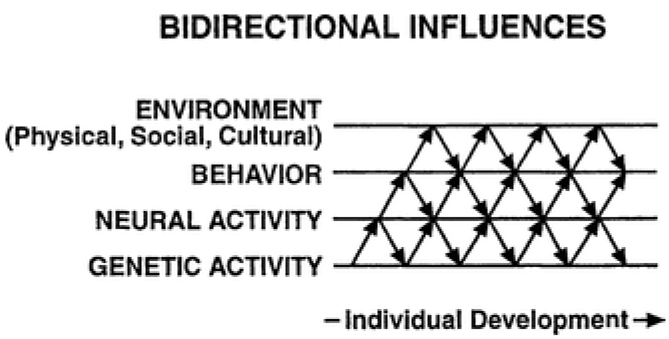

Figure 1. *Gottlieb’s model of the developmental manifold: Completely bidirectional influences operate across four levels of analysis (genetic activity, neural activity, behavior, and environment—its physical, social, cultural aspects). Reprinted with permission from Gottlieb, 2002.*

What Is DPB?

DPB is intrinsically an interdisciplinary science. It integrates three approaches to the investigation of behavior: developmental, environmental (both social and physical), and physiological (from cellular components to organ systems and their interactions). DPB can serve as a core component of any holistic approach to psychological phenomena that seek to integrate knowledge from the molecular to the societal or cultural levels of investigation. Researchers in our field have successfully produced explanations that combine information from such biological subdisciplines as molecular genetics, neurophysiology, endocrinology, immunology, ecology and evo-devo, and from such psychological subdisciplines as cognitive, social, and clinical, as well as from aspects of medicine, education, sociology, and public health. DPB explanations are not reductive, but synthetic accounts requiring the use of dynamical systems' theory constructs.

DPB emerged in the 1960s from earlier work on behavioral development from comparative psychologists like T. C. Schneirla (1966) and his students and colleagues (e.g., D. S. Lehrman, 1965, 1970, and G. Gottlieb, 1970, 1971, 1976, 1991) and the conceptual notions of D. O. Hebb (1949) and F. A. Beach (1948). The International Society for Developmental Psychobiology was founded in 1967 and the journal *Developmental Psychobiology* began in 1968; both, in part, by researchers empirically examining Hebb's notions about the effects of early experience. "Psychobiology" meant psychological phenomena were the primary focus, not reducible to physiological processes, but considered an aspect of biological science. Thus, it would be just as foolish to try to reduce psychology to biology, as it would be to try to reduce ecology to biology. Of course, just as ecology and physiology can inform one another, so too, can physiology and social psychology inform one another. Hence, molecular biological information about psychological phenomena contributes toward a synthetic explanation because social or experiential factors also affect molecular biological processes. Consider how the discovery, by Meaney (2010) and colleagues, that individual variation in how rat "mothers" cared for their pups altered the expression of the pup's DNA for the production of protein receptors for the glucocorticoids secreted by the adrenal glands. This changed our understanding of the development of individual differences in the ability to cope with potentially "stressful" situations. The combined social and molecular knowledge not only improved our understanding of the development of temperament traits in rats but may illuminate the sources of vulnerability and resilience in humans developing in situations of poverty, war, and so forth.

"Developmental" as a descriptor placed time into the analysis of behavior, not as a causal agent, but rather, as a "ruler" by which the processes of development can be observed and measured (cf., Michel & Tyler, 2005; Wohlwill, 1970). Initially, research focused on the effects of early experience or early development in general; later, the research examined developmental causes throughout the life span (Michel & Moore, 1995). By integrating molecular genetic information with behavioral embryology, developmental physiology, ecology, and the evolutionary study of animal and human behavior, DPB links to comparative psychology, ethology, conventional physiological psychology, and the animal model research of medicine and pharmacology.

The inclusion of animal behavior research in DPB, not simply as models for humans, but as interesting objects of study themselves (Michel 2010b), reflected the influence of the synthesis of ethology and comparative psychology that occurred in the 1960s (Beer, 1973; Hinde, 1966; McGill, 1965; Tinbergen, 1963). Consequently, DPB studies behavioral development within the framework posed by Nobel laureate, Niko Tinbergen's (1963) program for the study of the biology of behavior. Tinbergen proposed that understanding the biology of behavior required answers to four independent questions, each of which was to receive equal attention in research. These questions are:

1. *What are the proximate causes of the manifestation of a particular behavior at a particular time?* These causes typically involve the interaction of factors operating within and outside of the boundary of the individual (i.e., both physiological processes and social and habitat conditions). Thus, from this perspective, studies that only examine the impact of physiological manipulations on the expression of behavior, without considering social and physical context, do not illuminate the causes of the behavior's expression.

2. *What functions does the behavior serve both in terms of survival of the individual (e.g., acquisition and ingestion of nutrients, avoidance of predation) and reproductive success (e.g., attracting mates, increasing survival of offspring)?* Note that survival can be increased or reduced without necessarily affecting reproductive success and conversely, increases or decreases of reproductive success can occur without affecting survival. Unlike sociobiology and evolutionary psychology, developmental psychobiologists propose that whether a behavioral pattern contributes to reproductive success requires either experimental manipulation or *comparative* analyses of behavior-habitat correlations (cf., Buller, 2005; Kitcher, 2007).

3. *What is the evolutionary lineage of the behavior (e.g., its similarities to and differences from related species, its homology and homoplasy to ancestral forms)?* Identification of behavioral homology (Michel, 2013) is relevant not only to establishing the phylogenetic relationships among species (including *Homo sapiens*), but also for identifying how variations in developmental processes provide the phenotypic variations on which evolutionary processes (natural selection, drift, etc.) operate.

4. *How has the behavior developed?* This involves specifying its trajectory beginning with the zygote and continuing through the manifestation of the behavior throughout the individual's life span.

All of these questions relate directly to understanding psychological phenomena (from perception, memory, thinking, and language to social relationships and cultural behavioral traditions, rituals, attitudes, and values). Moreover, their answers initially require accurate, systematic, and appropriate descriptions of the behavior of interest, preferably using more than one descriptive technique (Martin & Bateson, 1993). Once described, the behavior of interest may be subjected to research procedures designed specifically to address each of Tinbergen's four questions. Although separate and each requiring a particular investigative approach, the answers to each question become the context for understanding the answers to the others. Therefore, for example, developmental answers improve when contextualized by a better understanding of function and even more so by a better understanding of physiology and phylogeny. These four questions, with the addition of accurate descriptions of behavior, *could* serve as a unifying force for much of psychology.

The Task of DPB

DPB tries to identify the causal mechanisms governing the *trajectory* of behavioral development rather than simply identifying factors that result in variation in the outcome of development. Our questions, such as why some individuals develop a complex trait whereas others do not, automatically incorporate both questions about what are the mechanisms that lead to the developmental expression of the trait and what are the mechanisms responsible for the individual differences in expression. Thus, developmental psychobiologists conceive of genes (their molecular activity), physiological processes (e.g., hormonal secretions, neurobiological activity), and environmental or experiential conditions and events as parameters in a developmental model of causal mechanisms. It is unsatisfactory to report that a gene, or a hormone, or a neural circuit, or a particular social condition (e.g., single parenting, SES), or environmental event (e.g., pollution, high altitude) is "responsible" for the development of a phenotypic trait or difference among individuals. Such a report is not the conclusion of a research project, it is barely the beginning.

The goal of DPB research is to determine *how* the gene, hormone, SES, or pollutants affect the developmental process leading to a particular behavioral characteristic. Once a presumed causal factor is specified in a developmental model, the model leads to questions of why that parameter had that particular effect. This leads to the search for those parameters that *facilitate* or *constrain* the manifestation of that particular effect. Thus, DPB researchers have discovered constraints on learning, on gene activity, on hormonal and neural influences, on neural plasticity, on social conditions, and so forth, precisely because the mechanisms that facilitate the development of any behavioral phenotype are investigated and the constraints are revealed.

DPB Definition of Development

DPB defines development as phase transitions in a dynamical "system" (the individual). The components of a dynamical system function interdependently with each other and at all levels of organization of the system (see Figure 1). Thus, the components are in a dynamic equilibrium, reflecting their influence on one another, and their relation to the milieu. The equilibrium is manifested by expression of system level traits (i.e., behavioral phenotypes) that permit it to operate within its environment. As the environment changes or the dynamics of the components alter, there can be shifts in the organization of the system. These shifts permit maintenance of the dynamic equilibrium both within the system itself and the relation of the system to its environment. The reorganization of the system results in the emergence of new behaviors that are relatively stable. Development, then, is a punctuated equilibrium in which periods of relative stability are interrupted by relatively quick shifts in organization (phase transitions). During phase transitions, we can expect greater variability in the individual's behavior as the system oscillates between the old and new organization. Variability is reduced when the state of equilibrium is reestablished (either when the system moves to a new organization, or when the system returns to the former organization). Phase shifts are marked by emergent behaviors that are new, coherent, and fit the environment. Descriptions of development, then, will point to sequentially organized behavioral transitions that generate our notions of stages and critically timed events.

As a consequence of this sequential process, earlier influences are different from subsequent influences because earlier influences affect the organizational basis upon which subsequent influences operate. For example, early exposure to a structured environment creates sensory experiences that are sufficient to establish “familiar” conditions against which “novel” conditions become apparent. The individual does not have to be taught, trained, or practiced to acquire the ability to discriminate familiar from nonfamiliar, nor does the individual need an inherent response tendency, innate program, or module. Although the properties of earlier organizations of the system typically are different from those emerging from a phase shift, some remain the same. Only systematic longitudinal description at frequent intervals can identify the trajectories of behavioral transitions. Unfortunately, this may make developmental psychobiological research appear more intimidating, but it is good science.

Because the “system” (the person in his or her environment) is in dynamic equilibrium, sometimes alterations in seemingly minor aspects of the milieu may produce a phase shift with strikingly different emergent abilities and a different trajectory. Other times, no phase shift may occur, even despite alteration in major aspects of the person’s environment, because the individual subsystems are in such a state of coherence with each other that they resist the environmental perturbation. Hence, “vulnerability” and “resiliency” fluctuate across development because the effects of the same perturbation can be small or large depending on the state of the individual when the perturbation occurs. In addition, the dynamical properties of the individual’s subsystems (neural, endocrine, and immune) can lead to “spontaneous” alterations that disrupt the coherence of the components resulting in phase shifts.

DPB research focuses on within-individual variability rather than between-individual variability and requires investigations to begin with knowledge of the participant’s initial abilities and states to identify how those starting abilities and states have consequences for subsequent phases of development (“development from,” in Michel & Tyler, 2007). This approach contrasts with conventional developmental studies that seek to identify traits in younger individuals that are characteristic of older (adult) individuals (“development to”). Development to studies force the researcher to focus on any similarities between early and later appearing characters which can result in a failure to identify what is different between them. In addition, nonintuitively obvious antecedents to the development of later characters can be missed (cf., Michel & Tyler, 2007).

Treating the individual as a system means that the physiological and the social become simply different perspectives of the system. The latter examines the relation of the individual with his or her environment and the former examines the coherence and integrity of the components within the individual. The DPB perspective leads to somewhat different questions about development including: (1) What developmental paths (trajectories) underlie the expression of both universal and individually different behavioral traits? (2) What factors facilitate and constrain the individual's progression along such paths? (3) What alterations of these factors produce new traits? (4) What alterations of these factors can reinstate a more typical outcome?

How Can Research Be Conducted Within a DPB Framework?

The research designs in DPB are the same as in any behavioral study, except that the research always requires an extensive description of the trait to be studied, some information about the trajectory of its development, and its distribution within the population. An example may help. Consider C. L. Moore's investigation of the development of sex differences in the reproductive behavior of rats (C. L. Moore, 1992, 1995, 2002, 2003, 2007). It was well known that genetic males secrete testosterone shortly after birth, which is important for development of male internal sex organs. In addition, early postnatal male castration results in adult males who do not exhibit male sex behavior, even when injected with testosterone. However, if neonatally castrated male pups (or even normal female pups) are injected with testosterone at birth, then they would become adults who, if given *second* injection of testosterone and placed with a receptive female, exhibit typical male sexual behavior. These results prompted the conventional interpretation that testosterone at birth organizes male-behavior neural circuits, which can be activated by testosterone in adults to produce the sex specific behavior. However, this is only a first step in determining the course of development in which social experiences, behavior, and physiological factors combine to produce the typical behavior. Careful research within a DPB perspective revealed a much richer story.

Moore began with a systematic description of how mother rats treat their male and female offspring. She found that *every* mother treats *each* male pup differently than *each*female pup. That treatment difference was elicited by testosterone's influence on the pup's preputial gland. The gland's secretions affect the odor of a male pup's urine that attracts the mother to lick the anal-genital region of her male pups more than that of her female pups. Removing the mother's ability to smell prevented her from treating her male and female pups differently. Male offspring of anosmic mothers failed to exhibit typical adult male sexual behavior, despite receiving the early "organizing" testosterone. More importantly, female pups who received extra anal-genital licking behaved like males as adults when given testosterone and a receptive female, despite not having been exposed to early testosterone. Moore went on to show how the maternal licking organized neural circuits in the spinal cord, brain stem, and hypothalamus. Moreover, males continue the increased licking of their anal-genital region after weaning, which facilitates the onset of their puberty.

Thus, early testosterone promotes sex differences in preputial gland secretions, which elicit sex differences in maternal care. The sexually differentiated adult behavior (essential for the rat's reproductive success) develops through a sequence of hormonally influenced social, self-generated, and self-stimulated experiences (Michel, 2007). These experiences shape the neural control of both behavior and hormonal secretions. DPB research fundamentally altered our understanding of how early testosterone affects the development of differences in sexual behavior in rats. Thus, DPB research does not require any unusual experimental designs; however, DPB research does focus on revealing the factors affecting the developmental trajectory of any behavioral trait.

What Is the Range of Expertise Required for DPB?

Developmental phenomena exist simultaneously at many levels of description (cells, tissue, organ systems, family, societal group, etc.) and downward as well as upward causation operates across these levels. It is not possible for a researcher to be expert at all levels; nevertheless, researchers should not be ignorant of any level of description. Expertise should be acquired not just for the level at which data are collected but also at one level "higher" and one level "lower." For example, investigations at the individual behavioral level require some expertise about social context and habitat and some expertise in relevant physiology (e.g., neural and hormonal functioning). Consider again, how Meaney and colleagues (Champagne, Francis, Mar, & Meaney, 2003; Zhang & Meaney, 2010) used data collected at one higher and one lower level of analysis to reveal how maternal care affects the development of a rat pup's temperament. The mother's pattern of maternal care is a consequence of how she was raised by her mother (up one level). The licking provided to the pup, activated neural systems that resulted in changes in the methylation of DNA in certain parts of the pup's brain (down one level) affecting the production of proteins sensitive to adrenal gland secretions (glucocorticoids). The production of these proteins in these areas of the brain is important for the regulation of the pup's reaction to potentially stressful situations (the pup's temperament).

Such DPB studies, using animal models, demonstrate how social or cultural factors can affect the cellular physiology underlying behavior. From a DPB perspective, it is not surprising that individual and cultural lifestyles (including social position in a group) affect human health and disease. DPB research provides information about how developmental mechanisms connect socioeconomic status, education, employment, and social capital to mental and physical health.

The Knowledge Generated by DPB

DPB research has traditionally focused on the development of species-typical phenotypes of a wide variety of mammals, birds, reptiles, fish, insects, mollusks, crustaceans, and so forth. Although generally regarded as innate or hard-wired behavioral characteristics, DPB investigations have revealed how such behaviors develop (Michel & Moore, 1995): how newly hatched chickens develop the ability to distinguish a flying hawk from a goose, differentiate grain from sand, and identify mealworms; how newly hatched gull chicks, ducklings, and quail develop the ability to identify their parent; how zebra finches develop songs and how that differs from song development in bullfinches and how both develop differently from that of cowbirds; how indigo buntings develop a celestial map for migratory navigation; how ring doves manage to reproduce more ring doves, and so forth. In each case, DPB research reveals exactly how the factors typically found in the species' environment interact with the individual's physiological processes to govern the development of these "instinctive" behaviors.

Developmental psychobiologists also examine the causal mechanisms governing individual differences (see Moore above). Meaney and colleagues (Champagne et al., 2003;Zhang & Meaney, 2010) have studied the development of individual differences in stress-reactivity of rats, describing causal mechanisms at levels-of-analysis ranging from social interaction to molecular signaling in neural cells in particular circuits of the nervous system. Investigation of these developmental processes in animals increases our understanding the origins of the individual differences in coping strategies in other species, including humans, which makes DPB research clinically translational and relevant to public health (cf., Hackman, Farah, & Meaney, 2010; Hofer, 2006; Moriceau & Sullivan, 2005).

DPB has discovered that several relatively ubiquitous social and environmental experiences contribute to both developmental stability and change throughout the individual's life span. These ubiquitous features affect motivation and emotional reactivity and include: gravity; diurnal, lunar, and seasonal variation; habitat (other animals, plants, and our own microbiome). Obviously, caregiver-young relations, peer group relations, and adult role models affect developmental trajectories. However, DPB research (Fleming et al., 2002) has also demonstrated multigenerational effects, as when a mother rat's influence on her pups affects how those pups, as adults, treat their own offspring. This cross generational "grandmother effect" forces us to begin the investigation of developmental trajectories before the zygote. Such cross-generational communication can range from simply altering the environment for future generations to altering gene expression through epigenetic inheritance to the setting of cultural goals and ideals.

A DPB Approach Can Help Connect Psychology With Biology

DPB is in a unique position to help psychologists understand development in ways quite different from the model proposed by behavior genetics (cf., Michel, 2007, 2010a). Because molecular genetics found no direct influence of genes on behavioral phenotypes, behavior-geneticists shifted to speaking about the "impact" of genes on key physiological factors ("the manifold dimensions of brain structure and functioning," Maheu & Macdonald, 2011, p. 20) that "tie" genes to psychological phenomena (e.g., personality traits, disorders, and diseases). These key physiological pathways, relating the genotype to behavioral phenotypes, are called endophenotypes (Gottesman & Gould, 2003). Because the characteristics of these endophenotypes are themselves affected by developmental factors, their investigation becomes part of the research program of DPB (Michel & Moore, 1995). Thus, DPB research is well positioned to provide insights into these extragenetic influences on behavioral development, because we have a long history of doing exactly that. Indeed, DPB found that "genes" are only one mechanism for carrying "information" from parental to offspring populations to produce the transgenerational concordance of phenotypes (Michel, 2010a; Michel & Moore, 1995). In addition, although genes may be involved differently at various points in any developmental trajectory for a psychological characteristic, they are neither governing nor primarily responsible for that trajectory.

How Can DPB Unify Psychology?

The entire field of DPB is devoted to crossing traditional boundaries within the discipline. Obviously, we study development, and bring together biological and psychological explanations. However, developmental psychobiologists also bridge several other divides: By adopting a dynamical systems theoretical approach, attending to Tinbergen's four questions, and accurately describing behavioral development, DPB has provided a unique insight into nearly all of the phenomena of human psychology (from perception, memory, and thinking to social relationships and cultural traditions and rituals). Careful analyses of the mechanisms governing developmental trajectories have led to explanations of behavior that incorporate sociocultural and physiological information in a synthetic and not reductive manner. Consequently, DPB provides insights into both "normal" and "abnormal" development. In addition, DPB links human behavioral development with natural history and our role in it. The latter contributes to our understanding of human psychology by revealing the similarities and differences in behavioral functioning among animals which, in turn, provides a more objective perspective from which we can evaluate human abilities (Michel, 2010b). Developmental psychobiologists will continue to create dynamic, multilevel explanatory models of behavior that place humans within the natural world and that will provide insights beyond those that can be accomplished by working within traditional domains of psychology and biology.

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