

CHAPTER 18

An Interdisciplinary Biopsychosocial Perspective on Psychological Development

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The biopsychosocial approach was proposed initially as an alternative to the biomedical approach for the investigation of the origin of abnormal psychological functioning (cf. Engel, 1977). The biomedical approach concentrated on specifically biological sources, such as abnormal genes, injury (particularly brain damage associated with premature birth, perinatal complications, postnatal accidents, or abuse), or exposure to pathogens in order to predict differences in functioning. The biopsychosocial approach added social and societal factors to the biological account. The social factors included not only the influences of parental care, peers, and adult models, but also psychological factors such as personal experiences, memories, and the interrelations among the psychological functions of language, cognition, and emotion. Societal factors included socioeconomic status, the media, formal schooling, and cultural traditions, pressures, and expectations. The biopsychosocial approach proposed that all of these factors should be considered when predicting individual differences in the well-being and psychological functioning of the individual (Borrell-Carrió, Suchman, & Epstein, 2004; Engel, 1977, 1980). Both approaches had the “medical” focus of identifying predictors of subsequent “abnormal” functioning for the purpose of rehabilitation and/or prevention.

Subsequently, the biopsychosocial approach was co-opted as the conceptual frame for all developmental research because it appeared to be a solution to the nature–nurture dilemma. That is, in this approach, both nature and nurture

were contributors to development as a result of some pattern of interaction among these factors. Within the biopsychosocial approach, biological, social/psychological, and societal factors could be examined separately (and then combined) to predict individual differences in psychological functioning. We argue that neither the biomedical nor the biopsychosocial approach is particularly developmental. Both focus on predicting functional differences among individuals at a certain period of their development (most often adulthood, although preschool, early school, and teen periods also have received considerable investigation). Seldom are the processes of development traced from a presumed origin toward the manifestation of the particular trait or function of interest. Thus, what appears to be a developmental study does not reveal the influences that directly affect the creation of similarities and differences in the *developmental trajectories* that yield species-typical, group-typical (e.g., culture), or individually unique traits.

Since both approaches attempt to predict particular types of psychological functioning from a specific set of earlier conditions or characteristics (a “development to” approach; Michel & Tyler, 2007b), they miss understanding *how* both “normal” and “abnormal” functioning develops. Moreover, although the biopsychosocial approach promotes a multidisciplinary perspective in research, it fails to provide an interdisciplinary account of human development because the contributions from each discipline often are treated as static predictors, which can interact as somewhat independent factors. It is presumed that the relative contribution of each factor in predicting the outcome describes the magnitude of its role in the development of the trait. However, this multidisciplinary approach misses the interdisciplinary account of how the development of any trait or function occurs under the influence of multiple dynamically changing, interrelated, and mutually influencing factors. These nonlinear coactions are not captured by techniques for measuring statistical, or additive, interactions. In contrast, the “development from” approach (Michel & Tyler, 2007b) treats factors affecting the development and expression of a trait as coactive factors that mutually influence one another during the development of the trait. We propose that an interdisciplinary biopsychosocial framework, which incorporates the “development from” approach, can provide a better account of infant development and its consequences. Therefore, this chapter is a call for the future construction of an expanded biopsychosocial approach that is both developmental and interdisciplinary, and yet continuous with the research reported within this handbook.

Before characterizing this new interdisciplinary biopsychosocial framework, we must describe the differences between a development to and a development from approach to the investigation of developmental phenomena. Then, we identify the strengths and weaknesses of the biomedical approach and compare those with the strengths and weaknesses of the conventional biopsychosocial approach. Finally, we introduce the new interdisciplinary biopsychosocial

approach and describe how it builds on the strengths of the other two approaches but corrects their weaknesses and encourages changes in the constructs that are used to characterize psychological development and the procedures used to investigate it.

Development “To” versus Development “From”

From the development to perspective, human (actually, all animals, but we focus on human) behavioral traits are the consequence of some biologically determined propensities (e.g., natural selection of genes that control the development of neuroanatomical mechanisms) interacting with socially and culturally constructed environmental events (e.g., working mothers, literacy, geographic separation of extended families, enculturation). This focuses developmental investigation on seeking the earliest manifestations of the trait and any disrupting factors during development. Such “disruptive factors” are used as explanations for how “abnormal” traits develop. When “biologically determined propensities” are unknown or very complex, biological “markers” of the propensity are sought (e.g., salivary, urine, or blood biochemistry, single-nucleotide polymorphisms, peculiarities of electroencephalogram [EEG]). In the development to approach, experience is unlikely to play a constructive role in the development of any trait; rather, the final product is often presumed to be preset as “encoded,” as a “neural module,” or as a “prewired program” (Bateson & Mamelí, 2007). Experience during development plays either a permissive role (permitting normal development) or a disruptive role (interfering with normal development). Knowing the genetically controlled propensities for particular traits would mean that the experiences of an individual might be controlled to prevent expression or permit expression of those traits relevant to a culturally preferred development.

A development from perspective focuses developmental research on how the transactions of the individual’s current phenotypic traits with the individual’s current social and physical environment at one phase during development results in the maintenance of those traits, their loss, or their transformation into different traits in the subsequent phase of development. This transaction continues through the lifespan. Modern molecular biology supports this development from perspective by confirming that gene expression is part of a complex system (network) of developmental causes that operate throughout the lifespan to produce phenotypic variability of traits. Information in the genome is intertwined with ecological influences from the environment in different ways and at different periods throughout the lifespan (cf. Gerhart & Kirschner, 1997; Gilbert, 2006; Kirschner & Gerhart, 2006; Raff, 1996; Schlichting & Pigliucci, 1998). Cells are chemical manufacturing plants controlled by an intricate and dynamic set of chemical messengers that travel within and between cells to turn “on” or “off” the expression of specific deoxyribonucleic acid (DNA) sequences and the

production and character of cellular structures and products. This layer of biochemical reactions that affect DNA expression is called the “epigenome.” The transduction of environmental stimuli into neurobiological processes permits “experience” of the individual’s social and physical environment to become a part of the epigenome, thus affecting DNA expression (Michel, 2010).

The epigenome plays a major role in heredity, as well as in development and health. These epigenomic processes begin before conception during the formation of germ cells (eggs and sperm) and continue throughout the lifespan. Moreover, whereas we inherit our DNA from our parents, we also inherit the environment—including diet (Drake & Walker, 2004; Mennella, Ziegler, Briefel, & Novak, 2006), specific social and physical experiences, and habitat (West, King, & Arberg, 1988). These inherited environments can alter epigenome activity throughout the lifespan. Such cross-generational communication can range from simply altering the environment for future generations to altering DNA expression through epigenetic inheritance to the setting of cultural goals and ideals. As Fleming and colleagues (2002) have demonstrated, there are multigenerational experiential effects. A mother rat’s caregiving affects how her pups, as adults, treat their own offspring. These “grandmother effects” force us to begin the investigation of developmental trajectories before the zygote and not assume that an individual’s development begins only at conception.

We propose that a development from approach is capable of accounting both for the expression of psychological patterns specific to the individual and the individual’s culture, as well as patterns common to humans, in general, without shifting explanatory constructs or frameworks from individual to society to culture. Thus, careful analyses of the mechanisms governing developmental trajectories have led to explanations of behavior that incorporate sociocultural and physiological information in a synthetic and nonhierarchical manner.

A Biomedical Perspective

Traditionally, the biomedical perspective reflected two misleading notions: (1) reductionism, or the notion that complex phenomena derive from a single primary principle; and (2) mind–body dualism, or the notion that mental phenomena are separable from the bodily phenomena (Engel, 1977). Reductionism requires that psychological functions are understood best by reducing them to the functioning of their neural components and these, in turn, would be best understood by reducing them to their gene-controlled biochemical signaling pathways. From a reductionist stance, the psychological functions (language, cognition, emotion, and social aptitude) of an individual are treated as consequences of neural circuits created by molecular genetic processes. Accordingly, genes are considered to provide coded information “blueprints” for all human phenotypes (including psychological functions) and the phenotypic development

of the individual is a maturational process during which psychological functions unfold or emerge over age according to genetically controlled processes of neural “wiring.” The environment (especially in the form of exposure to pathogens, brain damage, and physical abuse) can disrupt this maturational process but ordinarily is benignly permissive for development. Nevertheless, in cases of abnormal development, certain environmental interventions might help to prevent or rehabilitate abnormal functioning.

The weakness of this reductionist perspective has been revealed many times but perhaps Roger Sperry (1965, 1980), Nobel Laureate in developmental neurobiology, captured it best:

The molecules of the brain cell [are] obliged to submit to a course of activity in time and space that is largely determined by the overall dynamic and spatial properties of the whole [neural] cell [which does] not have very much to say about when they are going to fire their messages or in what time pattern they will fire them. The flow and timing of [neural activity is] governed largely by properties of the whole cerebral circuit, within which the given cells and fibers are incorporated, and also by the relationship of this circuit system to other circuit systems. Further, the general circuit properties of the whole brain may undergo radical and widespread changes [as a result of] a shifting pattern of central excitation [opening or priming] one group of circuit pathways [having special properties while] closing, repressing, or inhibiting other circuit potentialities. Of course, all of the simpler molecular, cellular, and physiological forces remain present and continue to operate, but these lower level forces and properties have been superseded by those of higher levels of organization. However, proper function in the uppermost levels always depends on normal operation at subsidiary levels. (1965, p. 79)

Although there has been an expansion of neuroscience and molecular biological research in the intervening 50 years, Sperry’s characterization of the complexity of causality involved at each of the different levels of organization in the actions of the nervous system from cells to circuits is still appropriate (Michel, 2014; Rose & Rose, 2012).

As Sperry (1980) noted, psychological functioning is dependent on the proper functioning of the biochemistry of neural cells; however, this dependency is not an example of reductionism. Experiential input from social and physical conditions can engender the development of neural systems that can support new psychological functions. In that way, psychological functioning (engagement with the social and physical world of the individual) can constrain neural functioning. Of course, psychological functioning cannot force neural systems to engender phenomena that the system cannot engender. In that way neural functioning constrains psychological functioning. However, there is much more plasticity in development than is usually considered.

Psychological functioning integrates and incorporates influences from the biomechanics of the skeletal–muscular system (e.g., height, weight), the

endocrine system (e.g., secretion of protein and steroid hormones), the immune system (e.g., cytokine secretions), and the digestive system (e.g., gut bacteria, digestive system secretions), as well as the nervous system. Moreover, these different systems are mutually coactive. Disruption of the functioning of these components may affect development because, as Kennedy (1992) proposed, psychological functioning (particularly behavior) is the physiology of the whole individual. And this physiology, in turn, is reflective of, and constrained by, the social and physical milieu of that individual. That milieu will be different for each individual. Hence, psychological functioning will be individually different and that difference will permeate every level of organization and functioning of the individual. In turn, that individual's functioning can affect his or her social and physical milieu. Psychological functioning is a collaborative coaction among multiple components and such coaction reduces the number of options possible within each component according to the particular pattern of coaction operative at any period during development.

The valuable aspect of the biomedical perspective is that it recognized the important role of physiology in psychological functions. What it missed was that physiological systems are intimately and collaboratively coactive (Figure 18.1). The nervous system does not interact with the endocrine system—they coact as a neuroendocrine system. Indeed, the immune system coacts with both the nervous and endocrine systems. Also missing is the recognition of biomechanical influences on psychological phenomena (e.g., size, weight, muscle mass). As Figure 18.1 illustrates, when determining the consequences of stressful conditions on the individual's functioning, perceptual systems are involved as well as complex coactions of various neural systems (particularly those involved with symbolic and mnemonic functions) along with the endocrine and immune systems.

Measuring cortisol in blood or saliva does not reveal the way other endocrines and neurotransmitters modulate (enhance and/or decrease) the influence of cortisol on target tissues or the way those target tissues have to be prepared by previous physiological processes prompted by the individual's experience with a social and physical environment. Nor does it reveal that the environment has rhythms that affect the individual's physiological rhythms, the secretion of cortisol, and the sensitivity of target systems to cortisol. There is too much complexity that is hidden by the simple biological marker but which is relevant for understanding the development of the individual's psychological functioning. It is this complexity of causality that is missing from the biomedical perspective that is its greatest weakness. However, there is an approach (developmental psychobiology) that reveals that both of the commonalities of psychological functioning and traits that occur across individuals that reflect social/cultural influences and those that reflect species-typical characters are a consequence of the same causal processes operating during development that produce individual differences (Michel, 2007, 2013b, 2014; Michel & Moore, 1995; Michel & Tyler, 2007a).

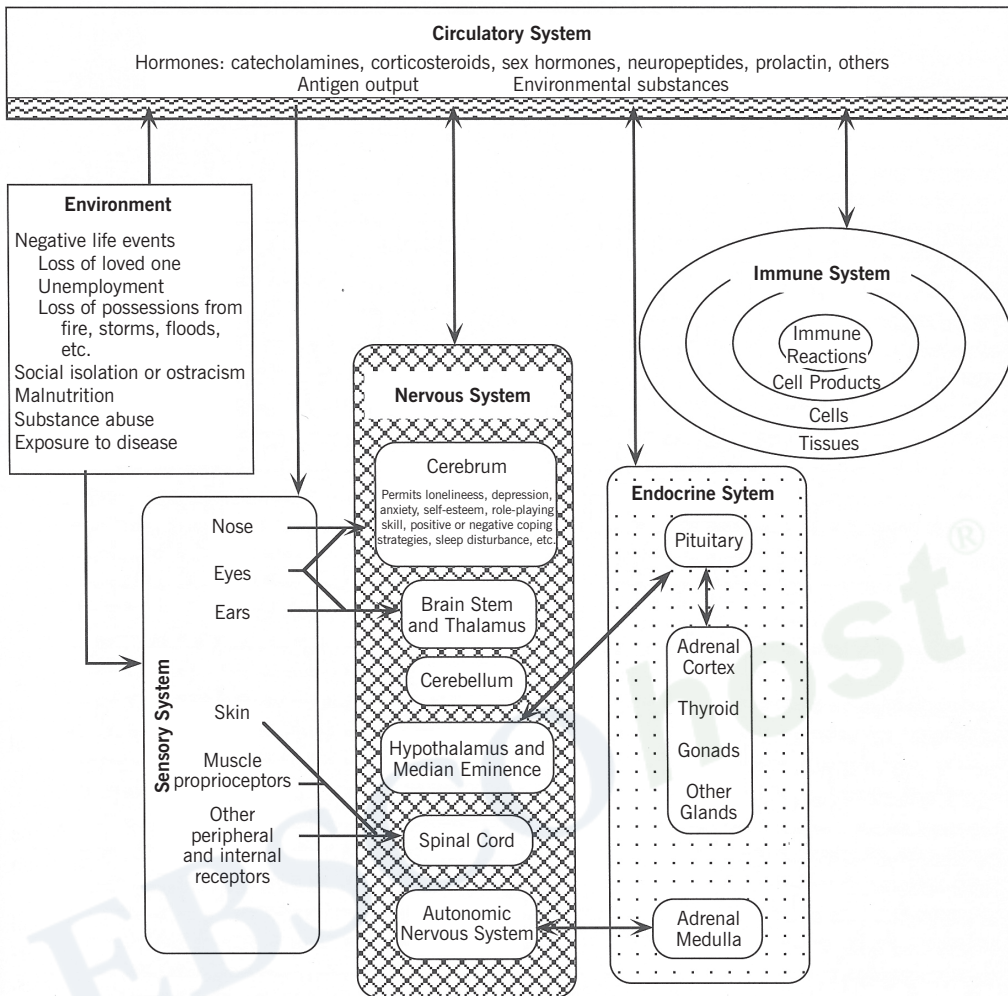


FIGURE 18.1. A schematic of the patterns of relations that exist among the physiological systems of the individual that are affected by stress-inducing situations. The schematic emphasizes the complexity of collaborative coaction among them. The circulatory system permits each system to influence and be influenced by the other systems. From Michel and Moore (1995). Reprinted with permission from MIT Press.

A Biopsychosocial Perspective

The biopsychosocial perspective correctly emphasized that understanding the phenomenon of psychological functioning must involve information acquired from the multiple levels of organization, that comprise the individual, combined with information from the context within which the individual operates. Studying a psychological function by focusing only on the systems of which the individual is composed will fail to capture the full causal network of that

function. Psychological functions and traits can be explained successfully only when knowledge of an individual's component systems (e.g., nervous system) is incorporated into knowledge of the systems of which the individual is a component (e.g., society; Bateson, 2005). For research purposes, psychological functions may be studied only on a psychological level, a neural level, or a molecular level, but the knowledge from each of these levels must relate to one another and to the knowledge about the individual's social and physical milieu (which are determined, in part, by the individual's culture and society).

The psychological functions and traits of the individual operate within a complex social and physical milieu of cultural and societal events and conditions (Bronfenbrenner & Morris, 1998). The biopsychosocial perspective captures those important influences, but fails to reveal how such influences come to affect the individual. Obviously, the infant's psychological functioning operates within, and is influenced by Bronfenbrenner's microsystem, but that microsystem is affected by the behavior, appearance, and biomechanics of the infant. Moreover, there is no theory as to how the microsystem is transduced into effective factors that can operate within the infant's physiological systems (see Michel, 2010, for one account). Nor is there any mechanism for how Bronfenbrenner's exosystem and macrosystem can affect each other or the microsystem. Without evidence for how transduction occurs across these different levels of influential factors, the study of development is left with simply identifying "markers" of social, cultural, and familial influences (e.g., socioeconomic status, racism, nationalism, religious sects, patterns of parental care) that may predict differences in the outcome of developmental trajectories. Again, this approach, like the biomedical approach, does not provide an account of the development that permits the use of the same causes for individual differences and social-cultural and species-typical commonalities of psychological functioning.

An Interdisciplinary Biopsychosocial Perspective

Both the biomedical and the biopsychosocial perspectives support multidisciplinary research, but in a very conventional manner. These multidisciplinary research designs incorporate different experts (e.g., from neuroscience, molecular genetics, psychology, education, sociology, and public health) to investigate a societally important psychological function (e.g., school failure). Unfortunately, this conventional approach is similar to the account of the blind men and an elephant. Without strong interdisciplinary expertise, even the best intentions of experts can result only in a hodgepodge account that provides little knowledge about the elephant.

In place of the conventional biopsychosocial perspective, we propose an interdisciplinary biopsychosocial framework that treats an infant's development as a continuous fusion of effects from the social and physical environment,

mediated by the sensory, motor, biomechanical properties, and physiognomy of the infant. The fusion of these effects across time governs the trajectory of prenatal and postnatal development. For analytic research purposes, investigators may examine separately biological, psychological, and social properties, and their effects on infant development. However, the eventual explanation of the development of any psychological function or trait must synthesize the knowledge derived from these different investigations into a coherent account of their collaborative coaction. Research must reveal how the transactions of the infant with his or her social and physical environment at each phase of development results in (1) the maintenance of psychological functions, (2) their loss, or (3) their transformation into different functions at subsequent phases (and so on through the lifespan). Adopting an interdisciplinary biopsychosocial perspective for investigating infant development will change conceptual frameworks, research procedures, and data analysis techniques because it requires extensive longitudinal research conducted by researchers with strong interdisciplinary expertise.

Left unspecified in the conventional biopsychosocial (and the biomedical) account are the developmental processes that tie the predictors (or markers) to the manifestation of psychological functions or traits. Construction of path models with measures of societal and biological factors as mediating or moderating contributors to the predictive correlation between earlier and later developing psychological functions is not an account of how the later function developed from the earlier function. Detailed trajectory descriptions and analyses are needed to identify how different sorts of interventions, occurring at different points in development, can shift the trajectory to a societally more appropriate path (Figure 18.2). Of course, modeling complex processes can be a daunting challenge when only parts of the model can be feasibly tested empirically with any one investigation. Therefore, the new interdisciplinary biopsychosocial perspective for understanding developmental phenomena requires long-term systematic and programmatic research projects, not conventional hypothesis-testing studies (Kagan, 2013).

Implications for Research Procedures

Infancy (roughly the first 18 postnatal months) represents the continuation and the consequences of prenatal developmental processes. Since birth involves the expansion of the individual's physical and social milieu, it also contributes to the formation of developmental processes essential for setting the trajectories of further development that likely affect the psychological functioning of adults. Of course, infancy can be a focus of research that has little relevance to developmental issues and questions. Because infants are especially vulnerable to many potential dangers to their survival, infants may manifest specific ontogenetic

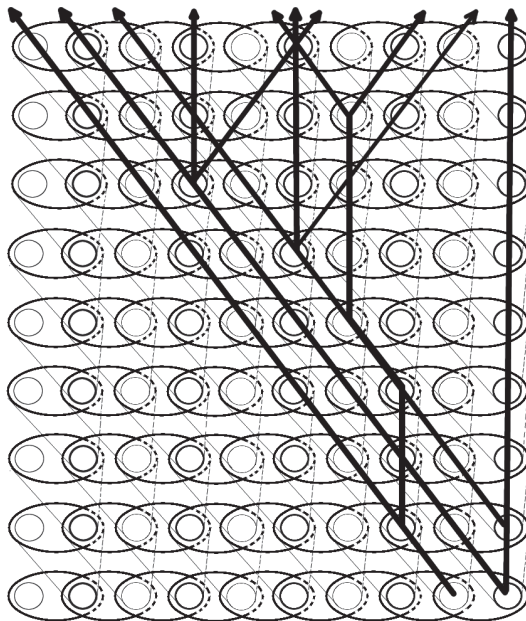


FIGURE 18.2. Development is a continuous transformation throughout the lifespan. At the lowest level of this figure, coaction of different genomes (dark and light smaller circles) with their environments (larger ellipses) results in the manifestation of certain phenotypes (second level). Trajectory analysis reveals the transitions during development, which affect phenotypic development. Such analyses identify when the coaction of individuals with their environments results in changes in trajectory, and this prompts investigation into the mechanisms for such change. Copyright 2014 by G. F. Michel. Reprinted with permission.

adaptations (Michel & Moore, 1995; Oppenheim, 1984) that relate to particular problems of infancy, but may not contribute to future developmental consequences other than to ensure that the infant has a future. For this chapter, we focus on infancy as a phase in development and do not address issues of ontogenetic adaptation (see Michel & Moore, 1995, about ontogenetic adaptations).

An interdisciplinary biopsychosocial approach begins with longitudinal designs that provide *detailed observations of a developmental phenomenon* in quasi-natural settings in order to identify developmental processes before undertaking further manipulative or comparative investigations (Kagan, 2013). Not only will this distinguish ontogenetic adaptations from development, but also investigation will not be biased by looking for the presence of adult functions in the infant (a problem of the “development to” approach; Michel & Tyler, 2007b). The psychological function of interest must be precisely defined so that potential differences in its character across development may be identified. Without precise descriptions, a function can appear not to develop because the description fails to detect changes in mechanisms or processes involved in the manifestation of the function. For example, the mechanisms underlying

performance in number comprehension tasks that rely on differential looking times for visually presented groupings of items in young infants may be quite different from the mechanisms involved in number symbol manipulation of preschool-age children. Failure to identify those mechanisms represents a failure to discover both how the infant's ability (sensitivity to looking at different groups of items) developed and how that ability is related to the child's ability.

Initial descriptive knowledge of infant development requires *longitudinal designs* in order to identify and characterize similarities and differences in the developmental patterns and pathways (trajectories) among individuals. However, in order to identify patterns of stability and change in development, these longitudinal designs must have a sufficient number of assessments to reveal the shape of the developmental trajectory. The frequency of data collection can influence the shape of the observed developmental trajectory and, as a result, change the description of the developmental pattern (e.g., Ferre, Babik, & Michel, 2010; Michel, Nelson, Babik, Campbell, & Marcinowski, 2013). Also, selecting the time period between descriptive assessments is critical to what may be discovered about the trajectory (Adolph & Robinson, 2008). For some psychological functions, weekly or daily assessments may provide a description of the function's development that reveals a different pattern in the trajectory from that which becomes apparent with monthly assessments (Michel et al., 2013). Unless the infant's development is being tracked into childhood, too few assessments during infancy leave the developmental trajectory underspecified for effective causal modeling.

Age (time) may be used as part of the description of development, however, not as a part of any explanation of development (Michel & Tyler, 2005; Tyler, 2006). Development is a process. Time (age) is an intrinsic aspect of the description of that process for any ability, trait, or character. Time (age) cannot explain how any ability, trait, or character (1) may remain stable across age in the face of environmental fluctuation, (2) may be enhanced or diminished across age, or (3) may change fundamentally across age. All of these aspects of the developmental process require identification of the necessary and sufficient conditions responsible for their occurrence. Removing age as an explanation of development fundamentally alters the construct of the critical period such that it prompts the investigation of those factors that initiate and end the period, and this permits discovery of factors that are nonintuitively related to the development of a trait that may, nonetheless, alter the trajectory at other points in development.

With the description of trajectories, the investigator can begin to seek *which factors are responsible for stability* and *which factors are responsible for the change in a trajectory* at particular phases of development. Indeed, some factors might facilitate development at certain phases, but hinder it at others. Again, investigations of the factors promoting change and maintaining stability require examination of the ways that the component systems of the individual relate to the individual's social and physical context. Development is a historical and

serially ordered process. Past events and functioning affect current functioning, that, in turn, affects future functioning, and so on. Development is a pattern of morphological and physiological phenotypes, which is both individually specific and characterized by species typicality (cf. Gilbert & Epel, 2009; Michel & Tyler, 2007a, for details about how species typicality may be achieved). Consequently, developmental research should reveal the factors creating and governing the serial order of the trajectories and the processes that produce both change and stability of that order over time and across individuals (Michel & Moore, 1995). The conceptual changes required by the interdisciplinary biopsychosocial perspective affect the description of development and the concepts of environment, experience, learning, critical periods, and human nature (among others).

Learning, Experience, and Environment

Too often, these three concepts are used interchangeably. Although learning is an aspect of experience and experience involves environmental influences, these three concepts represent important differences in how they operate during development (see Michel, 2010). *Learning* involves increasing or decreasing the frequency with which specific behaviors will occur or how specific behaviors are associated either with specific stimuli or with the consequences of other behaviors. In all cases of learning, there must be a nascent system upon which learning can lead to further development. Left unknown is how this initial nascent system develops. Although processes of conditioning, practice, training, observation, and imitation can be aspects of experience and contribute to the development of specific psychological functions, they cannot account for the development of the nascent systems upon which these processes depend. The use (via learning processes) of these nascent systems often improves their efficiency or the competence with which they operate, extends or restricts their range of use, converts a vaguely specified system into one that is more precise or detailed, or alters the stimuli that can activate the system. Thus, learning can expand the relation of a psychological function to new stimuli and other functions, and it can facilitate the manifestation and/or maintenance of the function once developed. However, other factors must operate for the developmental construction of a psychological function. Here we are in agreement with critiques of the learning theory approach to all psychological development (e.g., Buller, 2005).

In contrast to learning, *experience* represents the manner by which certain environmental factors influence the developmental construction of functions (e.g., induction; Gottlieb, 1992). Experience operates only through the transduction of environmental influences into physiological processes that, in turn, may affect the developmental organization and operations of the nervous system and other physiological systems. Transduction requires specific sensory

mechanisms that permit certain physical forces (e.g., chemical, mechanical, electromagnetic) to be converted into physiological processes that affect neural transmission. Experiential influences require that the sensory systems respond to physical forces and affect neural activity. Thus, experience is an embodied character of the individual.

During infancy, the sensory systems are developing from states of relative insensitivity to physical stimuli to states of increasing sophistication in the character of their sensitivity. However, even their activation during primitive states of sensitivity contributes both to their own developing sensitivity and to their influence on the nervous system. Because of changes in their developmental states, the capabilities of responding to physical forces and of affecting neural activity differ for different sensory transducers at various points during the individual's development. Moreover, the development of feedback mechanisms (in part provoked by sensory activity) to sensory systems contributes to the development of their sophistication in processing complex physical stimuli (involving temporal and spatial patterns). Thus, experiential influences can contribute to the development of the nascent systems upon which learning depends.

Failure to recognize what a sensory system can or cannot do at any point during development can lead to both over- and underestimation of the capabilities of the individual at that point. Different mechanisms may accomplish similar functions, but the mechanisms may differ strikingly in (1) the means by which they achieve the function; (2) the function's robustness in response to perturbation; and (3) the range of options available for producing variations of the function, some of which may result in shifts in the developmental trajectory. Auditory stimulation, extensive or insufficient contact, and light stimulation can affect the development of many of the infant's perceptual and other psychological functions (e.g., social relations), sometimes by affecting hormonal secretion as well as neural activity. Even the sensory feedback generated by the infant's own actions contributes to the development of sensorimotor programs and, perhaps, hemispheric specialization for information processing (Michel et al., 2013).

At each phase of development, the individual exhibits specific behavioral abilities in coaction with its social and physical environments that can "scaffold" the manifestation of the abilities. The behavior of the individual also provides specific kinds of stimulation that become, in turn, experiences that influence the individual's further development. These "circular relationships of self-stimulation" (Schneirla, 1957, p. 86) are an important source of psychological development. For analytic purposes, it may be important to consider the individual and his or her environment as separate; however, for the individual, there is no separation. Thus, stimulation from three sources (self-stimulation, self-generated stimulation, and externally generated stimulation) can provide embodied experiences that construct the nascent systems important for the

development of psychological functions. Although different, all three types of stimulation operate on the developing system in the same manner. That is, for stimuli to act as experiences in the individual's development, they must be embodied, or in other words, they must be transduced into cellular processes that can affect physiological functioning. Thus, as far as the individual's component systems are concerned, the source of the stimulation is irrelevant.

Environmental influences on development (which must be distinguished from experiential influences because they operate without sensory transduction) can be divided into two (not mutually exclusive) types: (1) those environmental factors that are external to the organismic boundary (epidermis in humans) of the individual (e.g., foods, electromagnetic radiations, pollutants, pathogens), and (2) any factor in a cell (or that can enter cells) that is not DNA but can affect DNA activity (e.g., hormones, neurotransmitters, various proteins, certain parasites and viruses). These factors can influence development by directly or indirectly affecting cellular processes (as part of the epigenome). For example, prenatal and postnatal nutritional status can affect the development of the infant via its influence on cellular metabolism and its impact on the production of growth hormones. Moreover, the nutritional status during the development of the infant's grandparents can affect the infant's development in many ways. These cross-generation effects involve epigenetic processes whereby expression of the DNA in the grandparents' germ cells is altered by their nutritional status and passed on to their offspring, and so on.

In addition to environmental, experiential, and learning contributions to the development of the infant, researchers have to consider *self-organizational processes* in the development of the individual's anatomical/physiological systems. These self-organizational processes contribute to the organization of cell types and cellular relations essential for organ formation and many aspects of sense organs and neural development (cf. Hoffmann, 2012). In part, these contribute to the development of the nascent structures upon which systems involved in psychological functioning develop. Although disruptions of DNA functioning can alter the course of the developmental self-organization of these systems, they are not guided in their organization by DNA expression. Rather, the DNA is part of the necessary conditions within which their self-organization can emerge (Gilbert & Epel, 2009).

Too often, psychologists mistakenly believe that genes (DNA) contain information that specifies the predisposition for psychological traits ("the loaded gun") and the environment affects the extent of their manifestation ("pulling the trigger"). Hence, the developmental manifestation of a trait was considered a consequence of gene-environment interaction. This prompted studies designed to examine gene \times environment interactions. However, such studies do not reveal the influences that directly create the developmental trajectories that tie genetic and environmental markers to differences in the manifestation of psychological traits (Michel, 2010, 2014).

Critical Periods

The conventional concept “critical” or “sensitive period” assumes that normal development depends on certain experiences occurring during a particular time window. Abnormal development arises when these experiences do not occur during this time or when unusual experiences occur during this period. Moreover, the concept implies that rehabilitation of abnormal development is severely limited once the time has passed. Because the “description” and the “explanation” of development are different, the interdisciplinary biopsychosocial perspective requires more investigations into the “how” of development rather than further investigation of whether or not there are critical or sensitive periods in the development of sensory, motor, cognitive, or socioemotional traits and abilities. Only by focusing on the mechanisms of development can ways of “correcting” developmental trajectories, even during later phases, be identified (see Michel, 2012, for examples).

Human Nature

Infant research revealed many abilities that do not appear to be acquired through learning. The typical response to such observations is to consider the abilities to be the products of biological evolution (e.g., Bloom, 2013) and to label them as “human nature.” These abilities are sometimes described as innate or core abilities. However, the concept of innate has many different implications that need not relate to one another and can lead to conceptual confusion (Lehrman, 1970; Michel & Moore, 1995). The investigation of normally occurring stimuli and behaviors in a natural setting is important for revealing the developmental origins of species typicality. Thus, the development of a behavior pattern may appear “innate” and constant in all or nearly all individuals of a species (species-typical) because natural selection combined with the individual’s developmental processes to assure the compatibility of the interaction of the individual with the species-typical environment. Gottlieb (1992) and others (e.g., Lehrman, 1970; Michel & Moore, 1995; Schneirla, 1966) argued that only systematic developmental investigations can reveal the contributions of the species-typical environment to the manifestation of species-typical psychological functions.

Moreover, what is selected during evolution is not a specific state of the individual’s system, but rather mechanisms and processes that can produce a range of states in response to a range of conditions. The adaptability of the individual creates a range of alternative phenotypes (the norm of reaction; Schlichting & Pigliucci, 1998) on which selection can operate. The norm of reaction is a theoretical construct to prevent investigators from confusing some limited set of observed developmental functions with some intrinsic limit-setting conditions. The phenotypic norm of reaction for any individual genotype can be known only after it has developed in all combinations of conditions and durations of

exposure to each of those combinations of conditions. Thus, developmental processes harbor an unknown range of variability. Basing evolution on the variability in developmental trajectories (revealed by systematic investigation) eliminates the teleology inherent in the “development to” evolutionary explanations and permits random mutations to eventually help stabilize, but not solidify, the development of existing phenotypes.

Since the individual is an organized system, delaying or accelerating the rate of development among different features or traits (heterochrony) can ramify to affect the development and expression of other features. Heterochrony across the development of traits is considered a fundamental source for the production of new patterns of organization upon which natural selection can operate (de Beer, 1930; Gould, 1977). Distinctly different individuals can emerge from alterations in the relative rate of development among specific features or traits. Indeed, maintaining or failing to maintain a trait beyond its typical developmental time frame can have ramifications on the development and functional organization of other traits because the individual is a coherent system. It is these developmental mechanisms that create the variability in development that marks the character of human nature and upon which natural selection operates (Michel, 2013a). However, since natural selection is differential reproductive success, only those traits that demonstrably affect reproduction and are reliably transmitted across generations can come under natural selection pressure, which will be delimited by the developmental options available (Gilbert & Epel, 2009).

Future Directions and Caveats

Investigation of infant development must begin with detailed descriptive data collected from direct observation of the infant’s behavior that identify behavior and experiences directly, and not via parental reports or standardized tests (Kagan, 2013). Perhaps the common neglect of detailed observational data (Kagan, 2013) derives in part from the conventional wisdom that only randomized experimental designs can capture causal links among variables. However, historical phenomena such as human development can derive causality from model construction and testing (much as it is done in modern cosmology and physics). Since infant development is a complex process with multiple influences and individual variations in trajectory, observational data must document the correlations among many variables. Fortunately, modern statistical programs permit translation of the correlations among many variables into a model that represents a causal hypothesis (Shipley, 2000). Building these models begins with correlations among observational data (typically represented by a “directed graph”; Pearl, 2000) in which variables are connected by lines (a path analysis). This graph models a causal hypothesis. Competing hypotheses can then be constructed and *new data must be collected* that will permit adjudication among these competing hypotheses using either standard methods of

statistical analysis, or more modern techniques that compare competing models using criteria derived from information or Bayesian theory.

Developmental research traditionally investigates relations between biological “markers” and psychological outcomes by connecting a modern neuroscience procedure (e.g., EEG, functional magnetic resonance imaging [fMRI], genomewide association studies [GWAS], magnetoencephalography [MEG], near-infrared spectroscopy [NIRS], salivary cortisol) with a modern procedure for assessing infant psychological functioning (e.g., attachment, behavioral inhibition, face recognition, phoneme discrimination, stranger anxiety). Adding a biological marker (e.g., salivary cortisol, EEG data) or a social marker (e.g., a measure of social class or of exposure to parental abuse) to a psychological study does not meet the requirements of an interdisciplinary investigation. Indeed, even knowledge of all research on the use of cortisol as a marker of adrenal functioning (or stress) is not equivalent to understanding how cortisol functions in concert with other hormones, other systems, circadian and other rhythmic cycles, immune function, and neural activity. That is the kind of *biological expertise* that is needed for comprehending how environmental conditions can become “stressors” for parents that, in turn, can produce differences in parental care that affect infant development.

Employing a measure of socioeconomic status or of exposure to certain forms of media is not the same as understanding how social status and institutions affect the organization of social relations, or how media is structured and disseminated among the populace. The latter is the kind of *social expertise* that needs to be combined with biological expertise for comprehending how these factors can become “stressors” for parents that, in turn, can produce differences in parental care that affect infant development. Also, it is important to determine how these macro-, exo-, and microsystems are transduced into factors that can affect the infant’s development. An interdisciplinary biopsychosocial perspective requires that researchers acquire expertise in two or three systems within which the individual functions. Only then will they effectively relate the causes operating within and across each system. In this way, several experts can combine their overlapping expertise so as to achieve the more synthetic integration proposed by Bateson (2005).

Conclusions

One prevailing message of this chapter is a plea to study *the processes of development*, rather than predictors and outcomes. Development is a complicated process, resulting from multiple levels of influences, including traditionally biological (e.g., cellular processes, systemic physiology), psychological (e.g., behavioral organization, problem solving, self-differentiation), and social (e.g., habitat, cultural traditions, familial dynamics) factors (a biopsychosocial perspective).

Instead of studying these levels in isolation or seeking simple “markers” for each level, infant behavior should be viewed as emerging from a history of *all* of these continuously changing influences throughout infancy. A simple predictor–outcome study, even with markers of social, biological, or psychological characteristics treated as potential mediating or moderating factors cannot capture the pattern in an infant’s developmental trajectory. For developmental theory, it is the specific character of these trajectories that signify later developmental consequences. Since each infant experiences a unique environment and age (time) cannot act upon the infant, grouping and comparing infants by age will not reveal the processes contributing to development.

Moreover, in contrast to a multidisciplinary approach, interdisciplinary knowledge facilitates comprehension of the ways that various levels fuse to shape the trajectory of the infant’s development. Working with this perspective places greater emphasis on the “development from” approach (Michel & Tyler, 2007b) that requires the investigator to focus on identifying how various factors affect earlier functions so that they give rise to later functions. Therefore, we propose that an interdisciplinary biopsychosocial framework can guide future developmental research toward a richer understanding of infant development.

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