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Coping with complexity: Developmental systems and multilevel analyses in developmental psychopathology

PETER J. MARSHALL
Temple University

Abstract

Developmental psychopathology is not characterized by adherence to one specific theory but instead serves as an organizational framework in which research is driven by a number of key assumptions. In the developmental psychopathology approach, two primary assumptions emphasize the importance of systems thinking and the utility of multilevel analyses. As will be illustrated here, these emphases are inextricably linked: a systems approach necessitates a multilevel approach, such that a level of organization must bring coherence to a level of mechanisms. Given this assumption, coming to an integrative understanding of the relation between levels is of central importance. One broad framework for this endeavor is relational developmental systems, which has been proposed by certain theorists as a new paradigm for developmental science. The implications of embracing this framework include the potential to connect developmental psychopathology with other approaches that emphasize systems thinking and that take an integrative perspective on the problem of levels of analysis.

Among the foundational emphases of developmental psychopathology are the necessity of a systems approach and the value of explanations that bridge multiple levels of analysis (Cicchetti, 2010; Sroufe & Rutter, 1984). Both of these emphases have played a significant role in the success of the developmental psychopathology approach by framing the understanding of adaptation and maladaptation across the life span. Accordingly, most contemporary developmental psychopathologists would view themselves as subscribers to some form of systems approach (e.g., as espoused by Cicchetti & Toth, 1997; Sameroff, 2000), and the encouragement and use of multilevel analyses remains a key theme (Burnette & Cicchetti, 2012; Cicchetti, 2008, 2011; Cicchetti & Curtis, 2007). It may therefore be objected that in undertaking a discussion of these familiar constructs I am preaching to the converted. However, my suggestion is that the 25th anniversary of the first volume of *Development and Psychopathology* presents an opportunity not only to reiterate the theoretical importance of systems thinking and multilevel analyses but also to consider the changing background for these emphases as we look ahead to the next 25 years.

The initial focus of this article concerns the influence of embryology and developmental biology on the systems approach in developmental science more generally and on developmental psychopathology more specifically. Although much of the original impetus for systems thinking came from classic work in embryology, recent advances in developmental and evolutionary biology have further underscored the necessity of a systems approach. These advances are illustrating the vast complexity involved in the construction of a phenotype, and they are putting a great deal of pressure on traditional approaches to conceptualizing the interplay of biology and environment in understanding developmental processes. With its status as an inherently integrative discipline, developmental psychopathology promises to be an important testing ground for these issues as we head into the next decades of the discipline.

One key premise of the current paper is that a systems approach and the need for multiple levels of analysis go hand in hand. This premise is based on the assumption that a systems approach requires the consideration of two types of explanations that can be seen as occupying different levels of analysis: a level of organization (i.e., a systems level) that serves to bring intelligibility to a different level of mechanisms. This key tenet is manifested in the central principle of organicism, which stipulates that mechanisms (i.e., the parts of a system) can only make sense in the context of a holistic systems level that, in turn, cannot be reduced to its parts (Pepper, 1942; von Bertalanffy, 1968).

Given the necessity of multiple levels of analysis, conceptualizing the relations between these levels becomes of

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Address correspondence and reprint requests to: Peter J. Marshall, Department of Psychology, Temple University, 1701 North 13th Street, Philadelphia, PA 19122; E-mail: peter.marshall@temple.edu.

utmost importance. Overton (2006, 2010) has written extensively on the contrast between a Cartesian worldview that imposes a "split," or separation between levels, and a relational worldview that emphasizes their interdependence. A worldview constitutes a broad metatheoretical framework "that both describes and prescribes what is meaningful and meaningless, acceptable and unacceptable, central and peripheral, as theory . . . and method . . . in a scientific discipline" (Overton, 2007, p. 154). As described by Overton (2013), the split and relational worldviews give rise to different "midrange metatheories," which in turn provide meaning contexts for more specific theoretical constructs. One such midrange metatheory that arises from the relational worldview is that of relational developmental systems, which Lerner and Overton have suggested provides a paradigm for the future of developmental science (Lerner, 2006; Lerner & Overton, 2008; Overton, 2006, 2010, 2013). As such, the relational developmental systems approach recognizes the dynamic complexity of developmental processes and exposes the inadequacy of split approaches, which emphasize simple interaction and the elevation of one level of analysis over another.

One goal of the current article is to explore the potential role for the relational developmental systems approach in maintaining the vitality of the study of adaptation and maladaptation in human development. To begin this exploration, I will first step back and briefly trace biological influences on systems thinking in developmental psychopathology. This tracing then leads to a discussion of the concept of the developmental system, its deep connections with developmental and evolutionary biology, and its place in the broader relational paradigm as formulated by Overton and Lerner (2012). This relational aspect is then more fully elaborated through an exploration of multiple levels of analysis.

Systems Approaches in Developmental Psychopathology: Biological Influences

As documented by Cicchetti (1990, 2010), the systems emphasis in developmental psychopathology has its origins in principles derived from the embryological studies of Kuo (1939), Spemann (1938), Waddington (1957), and Weiss (1939), among others. Key emphases from the classic work in embryology include the hierarchical nature of development, principles through which more complex forms arise from simpler ones, and the importance of context in early development. In turn, one even earlier influence was that of von Baer (1828/1956), who used his own findings concerning embryological development to formulate general principles of developmental change, particularly the concept of development as a continuing process of differentiation and integration.

One reason for the foundational quality of the classic work in 20th century embryology was that it was characterized by an organicist perspective that emphasized the emergent properties of higher level systems. Organicism is closely connected to the notions that parts of a system can only be understood through their relation to the whole system and that the behavior of a system cannot be predicted from, or reduced to, the simple aggregation of its parts (Pepper, 1942). Among other biological influences, the organicist perspective had received particular support from the embryological work of Spemann (1938), whose seminal findings with Mangold had highlighted the importance of plasticity, constraints, and context in early development (Mangold & Spemann, 1924, 2001).

Within developmental psychology, the influence of the organicist perspective in embryology was manifested in various ways (Cairns & Cairns, 2006; Sameroff, 1983). For instance, the orthogenetic principle of Werner (1948) and Piaget's (1977) concept of equilibration were partly formulated with reference to evidence about the generation of novelty from the study of embryological development. More recently, Gottlieb (1992, 1998, 2007) drew on research in embryology (including his own) in delineating the theory of probabilistic epigenesis, which stands as an example of a biologically inspired systems approach that has also been specifically applied to the area of developmental psychopathology (Gottlieb & Willoughby, 2006). Probabilistic epigenesis is fundamentally an organicist, holist theory that emphasizes the interconnected nature of the parts of the developmental system. From this perspective, conceptualizing these connections goes beyond simple notions of interaction to a more dynamic set of reciprocal, bidirectional, coacting, interpenetrating processes (Overton, 2013).

Related to its influence on developmental psychopathology, Gottlieb's seminal work played a formative role for a particular systems approach that is rooted in biology and that has been labeled *developmental systems theory* (DST). Here I wish to explore the contention that a broader extension of this approach, that of *relational* DST, can provide a potentially fruitful organizing framework for developmental science (Overton & Lerner, 2012). As a product of the relational worldview, this framework has at its core the related concepts of the developmental system and multiple levels of analysis (Overton, 2013). In this sense there is a distinct alignment between relational developmental systems and core tenets of the developmental psychopathology approach. However, noting this basic alignment is not enough for us to realize the transformative implications of the relational approach for developmental psychopathology. In order for that to take place, we also need to appreciate how the broader relational approach informs more specific, lower level theoretical approaches and how such approaches can inform empirical work in developmental psychopathology. As an initial step in this direction, we can now turn to the biologically inspired approach of DST as one such approach, and we can then consider how its extension through a broader relational aspect can expand the purview of this approach to the study of human adaptation and maladaptation across the life span.

DST

In the early 1990s, the term *DST* was introduced in two separate contexts and disciplines: by the developmental psychol-

ogists Ford and Lerner (1992) and then by two philosophers of biology, Griffiths and Gray (1994). Both sets of authors drew on the work of Gottlieb and other theorists (e.g., Lehrman, 1970; Oyama, 1985) who emphasized the importance of a systems perspective in the study of developmental processes. For current purposes, I will overlook differences between specific approaches (see Keller, 2005) and will simply introduce the core tenets of DST as a biologically oriented theory.

For proponents of DST, the *explanandum* (what is to be explained) is how the individual organism becomes constructed, and the *explanans* (the explanation) is the entire developmental system itself, which includes all biological and environmental resources available to the organism. This emphasis relates to the parity thesis of DST, which does not allow any one aspect of the developmental system to take an elevated causal role (Griffiths & Knight, 1998). From this perspective, parts of the developmental system derive their meaning from the context of the entire system, and the elevation of one developmental resource over another makes little sense (for a discussion, see Shea, 2011). This thesis gives rise to a fundamental tenet of DST, which is a strong objection to explanations of development that privilege the role of genes (see e.g., Ford & Lerner, 1992; Griffiths & Gray, 1994; Keller, 2010, 2011; Lerner, 2006; Lickliter & Honeycutt, 2003; Oyama, Griffiths, & Gray, 2001; Robert, 2004). Although DST theorists would acknowledge that the presence of genetic material is a necessary condition for cellular function, they emphasize that genes are not unmoved movers in that they only become causally relevant through their involvement in the entire developmental system.

In denying a privileged developmental role for genes, DST is diametrically opposed to any suggestion that DNA contains the information needed to construct an organism. The notion of a "genetic blueprint" has been the focus of intense criticism from a variety of developmental systems theorists (Ho, 2010; Jablonka & Lamb, 2005; Lerner, 2006). This criticism has arisen through recent developments in biology that have challenged traditional notions of genetics (Charney, 2012) and evolution (Ho, 2010; Jablonka & Lamb, 2005). These developments have included advances in epigenetics (Meaney, 2010) and the way in which the genome is conceptualized (Keller, 2011) as well as the converging appreciation that what is inherited by an individual organism is not only a complement of genes but also the biological and environmental scaffolding of the developmental system (Griffiths & Gray, 1994; Ho, 2010; Jablonka & Lamb, 2005). Although a full discussion of these issues cannot be entered into here, they hold a great deal of importance for developmental science (Overton, 2013).

Today the gene-centric notion that the genome contains a blueprint for development, which ensures a direct relation between genotype and phenotype, is antithetical to most developmental scientists. However, it may still have some implicit appeal to those who are seeking ways to manage the complexity of development. To understand why, consider the suggestion of 17th century preformationists, aided by van Leeuwenhoek's advances in microscopy, that fully formed miniature adults could be glimpsed within sperm or eggs. As ridiculous as it seems today, this suggestion makes sense when placed in its historical perspective. At the time, the alternative to preformationism was a form of vitalism in which mysterious, unknowable forces direct the appearance of form in the initially formless material of the egg (Gilbert & Sarkar, 2000). Gould (1977) suggested that, when seen in this way, preformationism can be understood as an attempt to cope with the daunting complexity of embryological development. Its allure was that vital forces did not need to be invoked to explain the biological world: if development was mainly a process of getting bigger, it could be more readily placed within the mechanistic worldview of Newtonian science. However, the glimpses of the preformationists turned out to be misplaced, and explicit mentions of preformationism are now mainly confined to introductory lecture courses as an illustration of a failed and naïve attempt to understand human development. However, echoing back more than 300 years, proponents of DST argue that the preformation–vitalism debate remains relevant to contemporary developmental science. In short, they see the mission of DST as countering preformationism in its modern guise of genetic determinism with DST as a nonvitalistic, scientific, epigenetic organicism (Godfrey-Smith, 2000; Robert, 2004).

The rejection of preformationism or a simplistic genetic determinism may seem trivial to those who already endorse a developmental psychopathology approach. More broadly, it could be argued that the genetic blueprint metaphor represents a straw argument that is not the purview of contemporary developmental science. Perhaps we could take a less deterministic perspective on genes, denying them a fully explanatory or causal role and relaxing the literal blueprint metaphor to a kind of looser plan. In this arrangement, we could still see genetic information as specifying a latent, but potentially modifiable, representation of a trait and allowing other influences to play potentially important roles in determining the phenotypic expression of that trait. However, part of the challenge presented by DST is that even this looser conceptualization is seen as problematic: it is here that the stronger claims of DST take the approach into what may be less comfortable territory for many (Stotz, 2008). At the heart of DST is the view that the developmental system as a whole cannot be partitioned or split apart without a fundamental loss of intelligibility (Overton, 2007). Through its rejection of any such developmental dichotomy, DST stands in opposition to the notion that developmental outcomes are some combination of genetic and environmental influences (Oyama et al., 2001).

The oppositional stance of DST originally arose in part as a response to attempts by behavior geneticists to separate genetic and environmental influences into additive components (for a discussion, see Partridge, 2011). Although such attempts continue to be under distinct pressure from findings in developmental and evolutionary biology, Charney (2012) recently argued that they have not been replaced by an adequate paradigm that accounts for the immense complexity

of how a phenotype is constructed. In response, Lerner and Overton (2012) suggest that the paradigm of relational developmental systems that combines DST with a broader relational worldview can provide such a framework. To support this contention, one can turn to a vast amount of work in developmental biology that has begun to unravel the complexities of developmental processes at the level of gene expression and regulation. Although the accommodation of these complexities is not possible from the Cartesian perspective of traditional behavior genetics, DST was itself founded on the acknowledgement and understanding of these complexities (Keller, 2010).

Lessons from developmental biology

A primary source of support for DST comes from ongoing work in developmental biology describing how spatial and temporal patterns of gene expression and regulation in the developing embryo relate to the development of bodily form (Gilbert, 2010). Although early work in this area suggested the existence of "master control genes" that direct the formation of certain morphological features (Gehring, 1998), it has become clear that such genes operate in a highly context-dependent fashion (Mikhailov, 2005). For instance, expression of the paired box gene 6 gene is essential for eye formation in species as diverse as fruit flies and humans, but only in the presence of other transcription factors that are also involved in pattern formation in the head region. In other parts of the body, expression of the same gene plays an important role in very different functions (e.g., the differentiation of the pancreas).

One key lesson from this work (much of which has been done in model organisms such as drosophila) is that there are no genes that specifically or solely determine major characteristics of bodily form, such as segments, eyes, or wings. The same could be said for all bodily structures, including the mammalian brain (Stiles, 2008). Similar principles also extend to the development of more abstract bodily characteristics, such as symmetry or polarity (e.g., of hands, limbs, or eyes), which are not predetermined, but instead arise through the organized activity of the system (Minelli, 2009). There are genes *involved in* the development of all these structures and characteristics, and changes to these genes, in specific temporal and spatial contexts, can impede or divert the typical course of development. However, morphology clearly arises not through a specific genetic plan but through the reciprocal coaction of component parts of the wider developmental system.

Another lesson from developmental biology is that genes are not simply switched on and off in a maturational or predetermined fashion, but rather gene expression and regulation operate in the context of a wider and highly intricate developmental system. In support of the original organicist work in embryology, the picture that has emerged from developmental biology is that construction of the organism proceeds through dynamic cellular and molecular coactions involving genes, but not directed by them (Gottlieb, 2007). Thus, what becomes crucial are the laws governing these coactions rather than the programmed expression of genes. Developmental biologists have begun to uncover the principles that govern embryological growth at a cellular and molecular level, including fate maps, induction, morphogenetic gradients, redundancy, pleiotropy, positive and negative feedback, and nonlinearity (Gilbert, 2010; Rudel & Sommer, 2003; Wolpert, 1994).

The above themes suggest how the organicist framework in embryology, which provided part of the foundation for the developmental psychopathology approach, has been further strengthened by more recent findings in developmental biology. It is worth noting that lessons for developmental psychopathology from contemporary developmental biology extend much further than this brief treatment allows (Cicchetti & Cannon, 1999; Cicchetti & Curtis, 2006). For instance, other connections have been made through the emergent subfield of evolutionary developmental biology, or what is commonly known as "evo-devo" (Hall, 1992). Through the consideration of evolutionary influences on life history development (Gilbert, 2001), aspects of evo-devo have served as the inspiration for recent work on *phenotypic plasticity* in relation to environmental circumstances and the consequences of this plasticity for adaptation and maladaptation across the life span (Ellis & Bjorklund, 2012). However, it could be argued that much of the field of evo-devo has neglected the lessons from DST concerning the extended nature of the developmental system and the implications of this extension for evolutionary theory (Robert, Hall, & Olson, 2001).

Another theme shared with developmental biology comes from the notion that the process by which a pattern is constructed cannot be deduced from the final pattern itself, but only from a serious consideration of development. This connects to the raison d'être of developmental psychopathology: that a disorder can only be meaningfully viewed through the lens of development (Cicchetti, 2010). This issue may be more familiar as the concept of *equifinality*, the observation that the same pattern can arise through different mechanisms, with only the study of development being able to shed light on what these mechanisms might be. What is particularly fascinating is how far this core developmental principle extends, from the development of the patterns of butterfly wings (Brunetti et al., 2001) to the development of psychopathology (Cicchetti & Rogosch, 1996).

Complexity in developmental systems: Finding a way forward

The findings gleaned from developmental biology (as modern day embryology) have provided important insights into development as an epigenetic process that proceeds through dynamic and reciprocal coactions among coding and noncoding DNA, transcription and translation factors, the cytoplasm, and the intra- and intercellular environments more generally. From this perspective, the function of a gene depends heavily

on contextual factors, including its temporal and spatial coactions with other genes and gene products. Along these lines, there have been important changes in the definitions of what constitutes a gene and the genome as well as a reframing of the role of environmental influences on gene expression (Greenberg & Partridge, 2010; Jablonka & Lamb, 2005; Jablonka & Raz, 2009; Keller, 2011). These developments are very much in line with the core tenets of DST, which places the construct of the gene within the wider developmental system. These complexities are being increasingly recognized in terms of their implications both for developmental science more generally and developmental psychopathology more specifically (Grigorenko & Cicchetti, 2012; Rutter, 2012).

A related lesson can be seen in the realm of developmental disorders, where the appeal of a biologically oriented DST approach has been bolstered by the growing consensus that the original promise of the revolution in molecular psychiatric genetics has not been realized (Charney, 2012). For example, the hunt to isolate straightforward genetic effects in disorders such as autism and schizophrenia has been severely hampered by factors such as genetic heterogeneity, pleiotropic effects, de novo mutations, and polygenic inheritance (Wahlsten, 2012). This is not to imply that genetics is uninvolved in such disorders or that novel methodological combinations of genetic and neuroimaging methods cannot shed light on the development of psychiatric disorder (Addington & Rapoport, 2012). It is rather that the sheer complexity involved in the construction of a phenotype requires the adoption of revised sets of assumptions and principles that would essentially constitute a paradigm shift away from traditional approaches (Charney, 2012).

As noted earlier, acknowledging the complexity of development has long been a key aspect of DST, and in this sense it potentially provides a signpost for progress in developmental science. Taking this further, Overton and Lerner (2012) have suggested that the requisite paradigm shift can be achieved through the combination of DST with a broader relational worldview that emphases "co-acting, co-developing processes functioning according to the reciprocal causality entailed by complex positive and negative feedback loops" (Overton & Lerner, 2012, p. 376). However, to better understand what this approach entails, we need to look closely at the question of multiple levels, since the core of the relational developmental systems approach concerns a particular way of conceptualizing different levels of analysis and the relations between these levels.

Multilevel Approaches: Framing Different Levels of Analysis

As noted, an emphasis on studying a given phenomenon at multiple levels of analysis is considered a central tenet of the developmental psychopathology approach (Cicchetti, 2008). Here I wish to take a closer look at questions about levels, beginning with a general perspective, before closing with a consideration of the place of neurobiological data in a levels-based framework (see also Marshall, 2009). I hope that it will become clear how questions about multiple levels of analysis are intertwined with questions about developmental systems. In short, a systems approach necessitates a level of organization that brings coherence to a level of mechanisms that would otherwise have no reference point. The premise here is that a relational approach that connects these levels through a developmental perspective provides a potentially powerful framework for systems approaches in developmental psychopathology.

Before continuing, some clarification is needed about what is meant by the term *levels of analysis*. A multilevel approach is sometimes assumed to be signified by the use of multiple methods of assessment, typically some combination of self-report, caregiver/teacher report, direct behavioral observations, and neurobiological (neuroimaging/psychophysiological/neurochemical), or genetic measures. However, the focus of the discussion here, although related to questions of multiple measures, provides a broader theoretical view. Specifically, this treatment of levels is more concerned with different levels of analysis in the sense of different kinds of explanation.

A typology of explanation

When the first issue of *Development and Psychopathology* was published in 1989, I was preparing to begin my undergraduate studies in natural sciences at the University of Cambridge. As my studies progressed I gravitated toward a specialization in zoology, and in doing so, I became more aware of the utility of asking different types of questions about a particular behavioral phenomenon. One specific typology distinguished between questions about the adaptive value or function of a behavior, how the behavior might have evolved, how it develops over the life span of the individual, and the immediate processes that determine its manifestation. This four-question framework remains an important organizing influence on the science of animal behavior (Dewsbury, 1999; Manning & Dawkins, 2012).

The four types of questions in zoology are often mentioned in the context of an article by the ethologist Niko Tinbergen (1963), but their broader origins can be traced back more than 2,300 years to when Aristotle proposed his coordinated set of four *aitia,* or what have become known as the "four causes": the efficient, material, formal, and final causes. Aristotle's formal cause is a pattern explanation of *the way something is*, how it is organized, in a different sense from the pure forms or essences of Plato. The formal explanation of an object is concerned with what it is to be that object, with the other three explanatory vehicles then being seen through this lens. Efficient causes refer to what factors produce the object, material causes refer to what substances the object is made of, and the final explanation is the purpose of the object, in the sense of what it is for.

Taken together, Aristotle proposed that addressing questions entailing all four interrelated *aitia* would provide a comprehensive framework for explaining a given phenomenon.

Although the four causes of Aristotle are seldom explicitly invoked by contemporary psychologists (see, however, Blachowicz, 2012; Witherington, 2011), their traces are clearly visible under the surface of current approaches to conceptualizing different levels of analysis (Overton, 1991). In contemporary usage, the efficient and material factors are generally understood as traditional explanatory causes, whereas formal and final factors are thought of as explanations entailing the pattern, form, or organization of the object of interest (Overton, 2010). Compared with efficient and material causes, formal and final pattern explanations are more abstract but no less essential. They are reasons or principles that provide intelligibility for the other types of explanation and, as such, are necessary complements to efficient and material causes. In particular, the central importance of the formal explanation comes from its provision of a structure or pattern through which the other kinds of explanation can be understood.

The efficient cause is perhaps the most intuitive of Aristotle's *aitia*, since it is closest to everyday notions of cause and effect. Efficient causes are potentially observable factors or forces that effect change, are distinct from the object being acted on, and have a causal action that precedes the effect or outcome. In developmental psychopathology, risk factors are paradigmatic examples of efficient causes. Material causes are also potentially observable factors, but they refer to the substance of which something is made. In contemporary formulations of levels of analysis, the material cause may correspond to the level of neurobiology or physiology, although as will be discussed, this mapping is not quite as straightforward as it might initially appear.

As Aristotle himself emphasized, questions about the four explanatory factors are inextricably wound together. As noted by Witherington (2011), the Aristotelian framework exemplifies a pluralist notion of cause, in which "no one perspective constitutes the gold standard of understanding: only when brought together as four unique vantage points . . . will the phenomenon be open to complete understanding" (p. 73). Key to this notion is that the formal and final explanations are brought into being through efficient and material causes, and in turn, the efficient and material causes are themselves shaped by the more abstract formal and final patterns. This point is particularly important for the current discussion and will be returned to. For now, suffice to say that the different kinds of explanatory factors are deeply interconnected, and serious conceptual problems are encountered if one chooses to neglect these relations.

Competence, procedures, and hardware

How can we apply Aristotle's four causes to look more closely at what we might mean by different levels of analysis in developmental science more broadly and developmental psychopathology more specifically? Here I wish to draw on the work of Overton (1991), who places the formal and final factors at a "competence" level of analysis, in contrast to a level of mechanisms or "procedures," which refers to efficient causes in the Aristotelian sense. The material cause is perhaps less prominent in Overton's framework but can be seen as a level of "hardware." This latter level will be returned to in a discussion of the role of neurobiological data in a levels-based framework.

In Overton's framework of levels, competence refers to top-down design features of the system being explained, or the principles that drive the activity of the system. As formal explanations, questions about competence are interwoven with questions about organization, function, and teleology. One fundamental assumption is that the pattern explanation of competence must be formulated at a level of analysis that serves to bring meaning to a different level of mechanisms (i.e., the procedural level). This realization allows arrival at a relational frame of scientific understanding in which both causal (in the sense of efficient cause) and pattern explanations are legitimized, and the dialectical relation between them is appreciated (Overton, 2006). This notion is at the heart of the relational developmental systems approach, which as such, provides a useful theoretical foundation upon which to carry out multilevel work.

At a surface level, the framework of competence, procedures, and hardware resembles other three-level frameworks, such as the intentional–design–physical levels of Dennett (1987) and the computational–algorithmic–implementational levels of Marr (1982). The latter framework has been highly influential in conceptualizing different levels of analysis across the broad field of cognitive science and has also influenced certain approaches to levels in developmental psychopathology (Ozonoff, Pennington, & Solomon, 2006). Because of their relevance in this respect, I will return to a discussion of Marr's levels. However, for present purposes what sets Overton's framework apart is the relational interdependence of the levels and the centrality of this interdependence for understanding development. These qualities stand in contrast to the relative independence of the levels in the theories of Dennett and Marr, who also said very little, if anything, about developmental considerations.

Understanding competence in developmental psychopathology

Conceptualizing the nature of competence is vitally important to the understanding of multilevel analyses; however, the abstract quality of this level can result in conceptual confusion, which can easily lead us down errant paths. As discussed in detail by Witherington (2011), one such path is to minimize or dismiss the importance of structural explanation, under the assumption that higher level forms have no causal powers, emerging as inert epiphenomena from lower level processes. A different but equally mistaken path is to reify formal and final causes such that they become entities that directly exert causal influence in the same way as efficient causes. Both of these conceptual confusions reflect a serious neglect of the contextualizing and constraining roles that formal and final causes play as explanatory factors (Witherington, 2011).

Even if we acknowledge the explanatory necessity of Aristotle's formal and final explanations, it still seems all too easy to give precedence to efficient causes. Wimsatt (2007) has written that "we tend to be suspicious when we are called on to explain phenomena by going up a level" and that the dominance of reductionist methodology "implies a kind of explanatory priority, that things not explicable at a given level are to be referred to the next lowest level" (p. 216). However, we cannot ignore the competence level in the hope that formal explanations will become unnecessary if enough mechanisms are piled up. Doing so would present a conundrum that stretches far back in the history of philosophical and scientific thought, which is that every efficient cause or mechanism could not be caused by another efficient cause or mechanism. It is clear that mechanisms at the procedural level must be organized in some way: in and of themselves, mechanisms provide data with no context. It is precisely this issue that necessitates a different level of analysis, that of the competence level, which as a formal explanation is the *system* of a systems approach.

How should we view the abstract level of competence in the context of developmental psychopathology? The term *competence* has been used in various ways within the discipline, and is perhaps most strongly associated with the research tradition of Garmezy and colleagues (e.g., Garmezy, Masten, & Tellegen, 1984). However, the use of this term in the current context of the competence–procedures framework is at a more general level in terms of the role of pattern explanations in the study of mental life. Framed in this way, the competence–procedures distinction can broadly inform the way we think about the fundamental notions of adaptation and maladaptation in the context of developmental psychopathology. One example of this framing comes from Overton and Horowitz (1991) in a contribution to an early volume on models and integrations in developmental psychopathology (Cicchetti & Toth, 1991). Their discussion specifically concerned the construct of internal working models in attachment theory, and it continues to serve as a cogent example of the conceptual confusions that can arise when the distinction between competence and procedures is misunderstood.

When Bowlby (1969) formulated the central tenets of attachment theory, he was strongly influenced by structural themes in psychoanalytic thought as well as by the constructivism of Piaget, both of which allow an important role for the formal level of explanation. However, one commonly cited supposition (e.g., Bretherton & Munholland, 1999; Main, 1991) is that in developing the key construct of internal working models, Bowlby was heavily influenced by particular work in the emerging field of cognitive science. More specifically, it has often been suggested that Bowlby forged his ideas about internal working models on the basis of Craik (1943), whose work was a precursor of an approach in cognitive science known as *mental models* (Johnson-Laird, 1983). In its original form, this approach was closely allied with emerging cognitivist perspectives that viewed the mind as a kind of computer, which is problematic since such a view precludes a real consideration of the formal level of competence (Overton, 2008) or meaning (Searle, 1980). If correct, this would consign internal working models to the level of procedural mechanisms, or simple mediators between input and output. This would then reduce attachment to basic social learning, which is inconsistent with much of Bowlby's original theorizing.

Overton and Horowitz (1991) suggested that these issues could be corrected by restoring Bowlby's original notion of internal working models as part of an overarching attachment system at the level of competence. Such a system provides the structure and context for attachment representations, which must be situated in the context of a meaning framework. From this perspective, attachment representations cannot simply be based on the actual behaviors of others but, instead, must reflect the expression of a deeper (theorized, abstract) competence system that we can call the attachment system. In this sense, internal working models mediate between the formal level of competence and the actual behavior of the person and not between direct input and output (Overton & Horowitz, 1991). This point has further implications for developmental psychopathology in terms of how we should view adaptation and maladaptation, a point to which I will return.

Although its applications are clearly much broader, the competence–procedures framework has its origins in the study of reasoning (Overton, 1991). In the realm of cognitive development, Ricco and Overton (2011) have pointed out the similarity between the competence–procedures distinction and dual systems approaches to the study of mental functioning, such as those of Stanovich (2009), Kahneman (2011), or Tversky and Kahneman (1974). There is a good deal of heterogeneity in how different theorists conceptualize dual systems (Frankish & Evans, 2009), but in general, the fundamental distinction is between an abstract, reflective, rule-based, propositional system for cognitive processing (that is closely related to the construct of competence) and a contextualized, associative system (that relates to the procedural level). One reason for raising this connection here is that breakdowns in the different systems would be manifested quite differently in terms of mental disorder (Stanovich, 2009), and thus, maintaining a distinction between these different levels may be fundamentally important for understanding psychopathology more broadly. For example, the potential utility of this distinction is illustrated by work that has examined the relation between reflective and associative processes in the development of addiction (Wiers, Ames, Hofmann, Krank, & Stacy, 2010).

Levels of analysis: Developmental considerations

Given the necessity of different levels of explanation, one key question is how we should conceptualize the relations between them. Following Overton and Dick (2007), the premise here is that considering the relations between the levels of competence and procedures automatically brings developmental considerations to the fore. The pattern explanation of competence can only be realized through the work of efficient causes or procedures. In turn, the procedural level of

mechanisms can only make sense in the context of the formal level of explanation. At the heart of the relational approach is the stipulation that the relations between these levels are reciprocal, coacting, or bidirectional. This approach then brings a series of essential developmental questions into focus. How can new structures arise that are qualitatively different from the sum of their parts? How can activity at one level of explanation produce change at another (qualitatively different) level? How can the product of "doing more of the same" not simply be "more of the same"? How can these questions be addressed without relying on some preexisting competence?

The relevance of these wider issues for developmental psychopathologists is that the problems we face in conceptualizing multilevel analyses are intricately tied up with the fundamental questions at the heart of developmental science more broadly. Although the magnitude of this issue may not inspire great confidence in a lasting solution, we do not have to arrive at a dead end in terms of understanding. As suggested earlier, the premise of particular developmental theorists (Greenberg & Partridge, 2010; Lerner & Overton, 2012) is that the solution lies in a paradigm that merges DST with a relational worldview. In this approach, the notion of a system provides a formal explanation, with the directional features of adaptation and self-organization constituting the final pattern explanation (Overton, 2010). By further focusing on the re-entrant quality of the connections between levels, relational DST has at its very foundation the concept of *development* writ large.

The key to understanding the transformative nature of a relational framework is that different epistemic levels of meaning and mechanism (i.e., competence and procedures) cannot be pitted against each other. This mistake is the domain of the sterile rationalism–empiricism debate, which neglects the coaction between levels that is a key to the relational approach. Recalling Aristotle, the level of formal competence could be considered to be what something *is,* in the abstract sense of a pattern explanation. If the level of procedures or mechanisms is seen as how the formal level is brought into being, and the formal level serves to organize the procedural level, we can start to see how the two levels of explanation are complementary. If we see this relation between competence and procedures as a dynamic tension in living systems, it can become the base of a truly developmental, constructivist perspective. Witherington (2011) operationalizes this tension as *circular causation,* which recognizes both the emergence of form through process and the constraining, "downward," influence of form on process. The potentially transformative power of this relational notion has been extensively discussed by Overton (2006, 2010) who has proposed that it can move us beyond the narrow confines of the nature–nurture debate and other fundamental dichotomies (e.g., brain vs. mind) that constrain the wider discipline of psychological science. As such, the relational developmental systems approach provides an alternative scientific paradigm to what Overton (2013) has termed the Cartesian–split–mechanistic worldview in which these dichotomies are accepted rather than precluded (see also Lerner, 2002).

Applying the relational framework

The paradigm of relational developmental systems could be considered a midrange metatheory that provides a set of core concepts for more specific theories and related empirical investigations (Overton, 2013). From the perspective of relational DST, living organisms are recognized as dynamic, adaptive, nonlinear, self-organizing, and self-regulating systems (Lerner, 2006; Lerner & Overton, 2008; Overton, 2006, 2010). From this vantage point, compatible theoretical approaches are those that eschew mechanistic, split, or reductionist approaches to human development and that acknowledge the complexity of the developmental system. With this in mind, questions can then be asked about more specific theoretical approaches and associated empirical methods that are particularly compatible with the relational worldview (Overton, 2013). Such questions bring the spotlight onto two approaches that will be briefly mentioned here: dynamic systems approaches and person-oriented approaches.

Dynamic systems approaches, with their focus on self-organization and emergence and the lack of privileging of any specific level of analysis, appear highly appropriate for understanding developmental processes from a relational perspective. These approaches are founded in dynamical systems theory, which has its origins in the study of chaos and complexity from a mathematical perspective and which provides a potentially powerful set of tools for carrying empirical work from a developmental systems perspective. Dynamic systems approaches are increasingly visible in developmental science (Hollenstein, 2011) and have also been discussed quite extensively in the domain of developmental psychopathology (Granic & Hollenstein, 2006; Granic & Patterson, 2006). Through an emphasis on nonlinearity, dynamic systems approaches are well suited to the study of developmental processes, and they are particularly compatible with relational metatheory through an acknowledgement of the dynamic coupling of the individual with its environment. Accounting for this coupling is inherent in the methodology of the state-space and phase-space models that have been the typical ways in which dynamic systems approaches have been applied within developmental science and developmental psychopathology (Partridge, 2011).

Van Geert (2012) argues that despite its intrinsic appeal, the dynamic systems approach has not yet been embraced within mainstream developmental science. If this is correct, it may be for several reasons, including its association with dense time series data, novel statistical methods, and the impression that to take a dynamic systems approach one must be aligned with specific, radical views. However, as also suggested by van Geert (2012), a dynamic systems approach does not commit its users to one particular theory of development. In this respect it is worth noting that, as Witherington (2007, 2011) points out, not all flavors of dynamic systems

are compatible with a relational framework. Some theorists (e.g., Spencer & Buss, 2011) would likely be happy to reject a relational framework of competence and procedures or any kind of related constructivist approach. A similar rejection is also apparent in the well-known dynamic systems work of Thelen and Smith (1994), which eschews the very idea of structure and argues that self-organization operating at a sensorimotor level is sufficient for developmental explanation. However, as Witherington (2011) argues, self-organization (as process) in itself cannot negate the explanatory, organizational, constraining role of a competence (or structural) level. In addition, the stipulations of a competence level push against the Gibsonian notion of preexisting environmental structure that is apparent in the dynamic systems approach of Thelen and Smith (1994). Instead, a relational approach is more aligned with Piagetian constructivism in that "meaning must be actively constructed and does not inhere in the world. . . . the world becomes meaningful . . . only in the context of an organism actively structuring it—assimilating it—and in turn actively accommodating to it" (Witherington & Margett, 2011, p. 287). This sentiment would be endorsed by those dynamic systems practitioners who see constructivism as being fundamentally consistent with dynamic approaches (van Geert, 2011), and as such, it would still seem appropriate as a guiding emphasis for the application of dynamic systems approaches to developmental psychopathology (Granic & Hollenstein, 2006).

Another way in which a relational developmental systems approach can be applied is through person-oriented approaches that emphasize the study of intraindividual variation (Nesselroade & Molenaar, 2010; von Eye, Bergman, & Hseih, in press). Implications of the person-oriented approach for the study of developmental psychopathology have been outlined in various contributions to *Development and Psychopathology* (e.g., Bergman, von Eye, & Magnusson, 2006; Curran & Willoughby, 2003), including a keynote article (Sterba & Bauer, 2010) accompanied by commentaries (Ialongo, 2010; Molenaar, 2010; Mun, Bates, & Vaschillo, 2010; von Eye, 2010). There are a variety of specific statistical methods that could be seen as person-centered through an emphasis on the determinants of individual change over time. In outlining the diversity of these methods, Sterba and Bauer (2010) note that person-oriented methods are not isomorphic with theory, echoing the sentiment of van Geert (2012) that using dynamic systems methods does not necessarily mean a commitment to one specific theoretical approach.

An emphasis on intraindividual variation is consistent with the basic tenets of DST that, in its most fundamental form (e.g., as put forward by Ford & Lerner, 1992), is concerned with the construction and development of the individual organism over its life span (Pradeu, 2010). As with the concept of the developmental system, the individual in the person-centered approach is viewed as a complex dynamic system composed of a complex configuration of characteristics, some of which "are changing from moment to moment, day to day, week to week, whereas others are relatively stable" (Nesselroade & Ram, 2004, p. 10). Through the consideration of the individual as an integrated entity that constitutes an indivisible unit of analysis, person-oriented approaches are also consistent with the holistic or organicist foundation of DST (Molenaar, Huizenga, & Nesselroade, 2003).

Connected to the implications of the relational developmental systems approach for empirical work are broader questions of application, translation, and policy that are central to the developmental psychology approach. In this respect, Richard Lerner has written on how a focus on the relations between person and context "underscores the key implications of developmental systems models for research and application pertinent to promoting positive human development" (Lerner, Theokas, & Bobek, 2005, p. 36). As further framed by Lerner (2012), a relational approach can dissolve the split between applied and basic research, such that application and description or explanation are seen as equal partners in the enterprise of developmental science (see also Lerner & Overton, 2008).

Neuroscience and the question of different levels

Up to this point I have mainly discussed two different but fundamentally intertwined levels of analysis, specifically the levels of competence and procedures. However, any discussion of levels needs to address issues related to a third potential level, that of physiology or neuroscience. These issues essentially revolve around the explanatory status of Aristotle's material cause, or how we should approach the study of neurobiological substrates. How can we view this level and its relation to other levels of analysis? I have argued elsewhere that there is a good deal of potential for confusion in conceptualizing the relations between psychology and neuroscience more generally (Marshall, 2009). However, this question is of particular relevance for the study of psychopathology in light of the growing influence that developments in neuroscience have had on the study of mental disorders over the past decades (Kendler, 2012; Miller, 2010). As developmental psychopathologists, our challenge is to acknowledge the importance of neuroscience while coming to an integrative understanding of how it fits into our developmental models (Beauchaine, Neuhaus, Brenner, & Gatzke-Kopp, 2008; Cicchetti & Curtis, 2006; Cicchetti & Thomas, 2008).

In discussions of the concept of a physiological or neural level of analysis, one common starting point is the three-level framework of the vision scientist David Marr (1982). In brief, Marr proposed that the study of a particular task could be approached at three different levels: (a) a *computational* level, which refers to a functional analysis of the requirements of the task and the formulation of a general strategy to solve the problem at hand; (b) an *algorithmic* level, which describes a series of mechanical steps that would solve the problem that was outlined at the computational level; and (c) an *implementation* level, which refers to a description of the physical hardware needed to carry out the sequence of steps that was specified at the algorithmic level. Marr's levels have been used quite

commonly as a framework for exploring the relations between psychology and neuroscience, with this exploration extending to developmental psychopathology (Ozonoff et al., 2006).

In psychological science, part of the appeal of Marr's framework has been the suggestion that his three levels are levels of *realization*, such that the computational level is realized by the algorithmic level, which in turn is realized by the implementational level. From this viewpoint, levels of realization are just different ways of looking at the same thing, with no one level having particular explanatory priority (for a discussion, see Craver, 2007). However, despite its seeming attractiveness, framing Marr's levels of analysis in this way may misleadingly suggest that different levels of analysis can be considered in isolation. To avoid privileging the study of a particular level, one could state that questions about a phenomenon need to be addressed at multiple levels but then neglect any real consideration of the relations between levels. Such a splitting off would not be consistent with the relational perspective that has been the focus of the current article.

Despite this potential shortcoming, framing neuroscience as a level of implementation that realizes mental or behavioral phenomena of interest may also be attractive because it appears to avoid the appearance of reductionism (Marshall, 2009, in press). Miller (2010) has argued that such a relatively neutral approach is preferable to a causally reductionist one. These issues surrounding reductionism cannot be fully entered into here, although they are clearly relevant to the current discussion. Some may protest that, if we drill down, "it's all neuroscience," so why can reductionism not succeed? One answer to this should already be clear: The necessity of an organizational level of competence (i.e., the formal cause or a systems level) automatically precludes reduction from this level to a level of mechanisms because those mechanisms are meaningless in isolation. This is not to blindly dismiss the use of the term *neural mechanisms*, which has found a degree of utility in the field of cognitive neuroscience, but to emphasize that, in isolation, its explanatory power is necessarily limited. As Kosslyn and Koenig (1992) argued:

> The aim is not to replace a description of mental events by a description of brain activity. That would be like replacing a description of architecture with a description of building materials. Although the nature of the materials restricts the kinds of buildings that can be built, it does not characterize their function or design [i.e., system]. (p. 4)

Embodiment and neuroscience

Given the preceding discussion, how do we come to an integrative position that allows for a nonreductive but substantive contribution of a neurobiological level of analysis? To address this question, we should return our focus on the relational developmental systems approach that lies at the center of the arguments running through this paper. Recall that this approach is what Overton (in press) has termed a midrange metatheory that is the product of a relational worldview and the principles of DST. In turn, more specific theories and their associated empirical methods are nested under the metatheoretical umbrella of relational developmental systems. Coherence among these more specific theories and the midrange metatheory is established through the core concepts of *system*, *action*, and *embodiment* (Overton, in press). Although the system concept has been a key theme in the present article, these three concepts are all relevant to developmental psychopathology, and embodiment is particularly relevant for addressing the conundrums about neuroscience that were raised in the previous section.

The concept of embodiment can be understood in various ways (Kiverstein, 2012), and a full discussion of these intricacies would be out of place here. However, one of the most important general tenets of embodiment concerns the coupled nature of the brain–body–environment system. Acknowledging this coupling requires the understanding of the organism as an active agent that is tightly interconnected with its environment, such that the actions of the individual modify its relation to the environment, which in turn influences subsequent actions. At a fundamental level, this concept of the action feedback loop is the basis of a dynamic system in which boundaries between individual agent and environment cannot be definitively determined (Stewart, Gapenne, & Di Paolo, 2010). In turn, the concept of action feedback loops allows brain function to be framed as being less about traditional notions of cognition and more about the guidance and coordination of action (Clark, 1998, 2013).

Rather than seeing the brain as a disconnected, descriptive storage device, *embodiment* as a perspective places the brain as a prescriptive component of a wider system. In emphasizing the brain's active role in coordinating perception and action, embodiment also challenges folk notions of the brain as a container for thoughts and memories (Gottfried, Gelman, & Schultz, 1999; Marshall & Comalli, 2012). One helpful approach in this regard comes from Engel (2010), who places brain function in the context of the system that arises through the coupling of brain, body, and environment. From this perspective, patterns of neural activity are viewed as one (empirically accessible) aspect of this wider system that can only be meaningfully considered within the context of the state of the entire system.

As I have discussed elsewhere (Marshall, 2009, in press), the reframing of brain function through embodiment runs counter to cognitivist approaches to the study of mental life that emerged from the "cognitive revolution" of the 1960s and 1970s (see Miller, 2003). In framing cognition as a disembodied process occurring on an isolated computational device, cognitivism also precluded any real consideration of meaning (Bruner, 1990). Perhaps the most exciting aspect of the surge of interest in the emerging field of embodied cognition is the possibility of returning the study of meaning to the center of psychological science. As described by Overton (2008), this possibility arises because embodiment is fundamentally a relational perspective through the interplay of two standpoints: the biological standpoint of the form of the body and the "lived experience" of the body from a contextual social, cultural, and environmental standpoint. This interplay draws on the notion that the body is not merely an

object among other objects, but is instead the phenomenal body (Merleau-Ponty, 1962) or "the situation from which our world and experience flows" (Johnson, 2008, p. 164).

In terms of the broader implications of these views for developmental psychopathology, one particular view of embodiment, the enactive approach, allows us to effectively frame the biological nature of what could be called "sense making," such that the individual brings forth or enacts the world in which it exists and sustains its identity as a self-organizing system (Thompson, 2007). This relates closely to the notion of *autopoiesis* as put forward by Maturana and Varela (1980), who frame living systems as being self-organizing in a fundamentally different way from nonliving systems. From this *enactive* perspective, living systems do not rely on externally imposed influences to maintain their existence; instead they "construct themselves by generating the very boundary conditions necessary for the creation and maintenance of their self-organization" (Witherington, 2011, p. 79). This notion not only allows living systems to be studied from the empirical viewpoint of self-organization but also enables us to consider questions of individuality, identity, and meaning.

From the viewpoint of developmental psychopathology, these issues relate closely to the fundamental concepts of adaptation and maladaptation (Cicchetti & Roisman, 2011). As noted in the earlier discussion of internal working models in attachment theory, the level of procedures or action mechanisms mediates between the level of competence and behavior, not between an objective outside world and behavior. Any process of adaptation, therefore, needs to be seen in the light of competence. Adaptation is therefore not about aligning one's cognitions with the "real" (Overton & Horowitz, 1991) but is instead a process of sense making on the part of the individual organism in the world that it enacts. From this perspective, embodiment has particular implications for conceptualizing and treating psychopathology (Santostefano, 2010).

Conclusion

Great strides have been made in developmental psychopathology over the last 25 years, with the developmental psychopathology approach being successfully applied to a broad array of domains and topics (Cicchetti & Cohen, 2006). As described here, two themes that have been important for this progress are an emphasis on a systems approach and the value of multilevel analyses. My contention has been that, as we enter the next 25 years of the discipline, these themes will become even more important in the light of the increasing body of knowledge concerning the complexities of development. In this respect, the paradigm of relational DST provides a potentially powerful umbrella under which to work. It is notable that this framework partly shares its inspiration with the biologically informed, organicist foundations of developmental psychopathology, and in this respect there is much that is already in common between these approaches. However, what this paradigm adds is a broader framework that allows developmental psychopathology to connect with more recent findings across biology and embodied cognitive science and to move toward a truly integrative perspective on systems and levels.

Despite my general optimism, what I am suggesting here does not lend itself to a particularly tidy conclusion. For instance, in the last section of this article I argued for widening the lens through which we view neuroscience data through the adoption of an embodied approach. However, this presents a challenge for the idea that such data represent a separate level of analysis, a level of implementation or a level at which cognitive processes are realized. Instead, embodiment places brain processes as one part of a wider system such that the different levels of analysis blur together. In turn, this brings with it a challenge to any tidy conceptualization of separate levels, and it means that considering the dynamic relations between levels becomes paramount to a point where conventional approaches to levels can run aground. Thus, the picture of multiple levels becomes anything but a tidy one, and for developmental psychopathologists it presents distinct challenges. To be somewhat provocative, our research programs and grant proposals need to be tidy and presentable, and we may feel a need to emphasize the importance of multilevel analyses, particularly the inclusion of a neurobiological, physiological, or genetic level of analysis. However, a tidy presentation is at odds with the actual, messy business of systems and levels. Our challenge for the next 25 years is not only to acknowledge this but also to actively cope with the complexities of developmental systems in a truly integrative fashion.

References

Addington, A. M., & Rapoport, J. L. (2012). Annual research review: Impact of advances in genetics in understanding developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *53*, 510–518.

Beauchaine, T. P., Neuhaus, E., Brenner, S. L., & Gatzke-Kopp, L. (2008). Ten good reasons to consider biological processes in prevention and intervention research. *Development and Psychopathology*, *20*, 745–774.

Bergman, L. R., von Eye, A., & Magnusson, D. (2006). Person-oriented research strategies in developmental psychopathology. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology: Vol. 1. Theory and method* (2nd ed., pp. 850–888). Hoboken, NJ: Wiley.

Blachowicz, J. (2012). *Essential difference: Toward a metaphysics of emergence*. Albany, NY: SUNY Press.

Bowlby, J. (1969). *Attachment and loss: Vol. 1. Attachment*. New York: Basic Books.

Bretherton, I., & Munholland, K. A. (1999). Internal working models in attachment relationships: A construct revisited. In J. Cassidy & P. R. Shaver (Eds.), *Handbook of attachment: Theory, research, and clinical applications* (pp. 89–111). New York: Guilford Press.

Bruner, J. (1990). *Acts of meaning*. Cambridge, MA: Harvard University Press.

Brunetti, C. R., Selegue, J. E., Monteiro, A., French, V., Brakefield, P. M., & Carroll, S. B. (2001). The generation and diversification of butterfly eyespot color patterns. *Current Biology*, *11*, 1578–1585.

Burnette, M. L., & Cicchetti, D. (2012). Multilevel approaches toward understanding antisocial behavior: Current research and future directions. *Development and Psychopathology*, *24*, 703–704.

Cairns, R. B., & Cairns, B. D. (2006). The making of developmental psychology. In R. M. Lerner & W. Damon (Eds.), *Handbook of child psychology:*

Vol 1. Theoretical models of human development (6th ed., pp. 89–165). Hoboken, NJ: Wiley.
Charney, E. (2012). Behavior genetics and postgenomics. *Behavioral and Brain Sciences*, *35*, 331–358.
Cicchetti, D. (1990). A historical perspective on the discipline of developmental psychopathology. In J. E. Rolf, A. S. Masten, D. Cicchetti, K. H. Nuechterlein, & S. Weintraub (Eds.), *Risk and protective factors in the development of psychopathology* (pp. 2–28). New York: Cambridge University Press.
Cicchetti, D. (2008). A multiple-levels-of-analysis perspective on research in development and psychopathology. In T. P. Beauchaine & S. P. Hinshaw (Eds.), *Child and adolescent psychopathology* (pp. 27–57). Hoboken, NJ: Wiley.
Cicchetti, D. (2010). Developmental psychopathology. In M. E. Lamb, A. M. Freund, & R. M. Lerner (Eds.), *The handbook of life-span development: Vol. 2. Social and emotional development* (pp. 511–589). Hoboken, NJ: Wiley.
Cicchetti, D. (2011). Pathways to resilient functioning in maltreated children: From single-level to multilevel investigations. In D. Cicchetti & G. I. Roisman (Eds.), *Minnesota symposia on child psychology: Vol. 36. The origins and organization of adaptation and maladaptation* (pp. 423–459). Hoboken, NJ: Wiley.
Cicchetti, D., & Cannon, T. D. (1999). Neurodevelopmental processes in the ontogenesis and epigenesis of psychopathology. *Development and Psychopathology*, *11*, 375–393.
Cicchetti, D., & Cohen, D. J. (2006). *Developmental psychopathology* (Vols. 1–3). Hoboken, NJ: Wiley.
Cicchetti, D., & Curtis, W. J. (2006). The developing brain and neural plasticity: Implications for normality, psychopathology, and resilience. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology: Vol. 2. Developmental neuroscience* (2nd ed., pp. 1–64). Hoboken, NJ: Wiley.
Cicchetti, D., & Curtis, W. J. (2007). Multilevel perspectives on pathways to resilient functioning. *Development and Psychopathology*, *19*, 627–629.
Cicchetti, D., & Rogosch, F. A. (1996). Equifinality and multifinality in developmental psychopathology. *Development and Psychopathology*, *8*, 597–600.
Cicchetti, D., & Roisman, G. I. (2011). *Minnesota Symposia on Child Psychology: Vol. 36. The origins and organization of adaptation and maladaptation*. Hoboken, NJ: Wiley.
Cicchetti, D., & Thomas, K. M. (2008). Editorial: Imaging brain systems in normality and psychopathology. *Development and Psychopathology*, *20*, 1023–1027.
Cicchetti, D., & Toth, S. L. (Eds.). (1991). *Rochester Symposium on Developmental Psychopathology: Vol. 3. Models and integrations*. Rochester, NY: University of Rochester Press.
Cicchetti, D., & Toth, S. L. (1997). Transactional ecological systems in developmental psychopathology. In S. S. Luthar, J. A. Burack, D. Cicchetti, & J. R. Weisz (Eds.), *Developmental psychopathology: Perspectives on adjustment, risk, and disorder* (pp. 317–349). New York: Cambridge University Press.
Clark, A. (1998). *Being there: Putting brain, body, and world together again*. Cambridge, MA: MIT Press.
Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *Behavioral and Brain Sciences*, *36*, 181–253.
Craik, K. J. W. (1943). *The nature of explanation*. Cambridge: Cambridge University Press.
Craver, C. F. (2007). *Explaining the brain*. New York: Oxford University Press.
Curran, P. J., & Willoughby, M. T. (2003). Implications of latent trajectory models for the study of developmental psychopathology. *Development and Psychopathology*, *15*, 581–612.
Dennett, D. C. (1987). *The intentional stance*. Cambridge, MA: MIT Press.
Dewsbury, D. A. (1999). The proximate and the ultimate: Past, present, and future. *Behavioural Processes*, *46*, 189–199.
Ellis, B. J., & Bjorklund, D. F. (2012). Beyond mental health: An evolutionary analysis of development under risky and supportive environmental conditions. *Developmental Psychology*, *48*, 591–597.
Engel, A. K. (2010). Directive minds: How dynamics shapes cognition. In J. Stewart, O. Gapenne, & E. A. D. Paolo (Eds.), *Enaction: Toward a new paradigm for cognitive science* (pp. 219–243). Cambridge, MA: MIT Press.
Ford, D. H., & Lerner, R. M. (1992). *Developmental systems theory: An integrative approach*. Thousand Oaks, CA: Sage.
Garmezy, N., Masten, A. S., & Tellegen, A. (1984). The study of stress and competence in children: A building block for developmental psychopathology. *Child Development*, *55*, 97–111.
Gehring, W. J. (1998). *Master control genes in development and evolution: The homeobox story*. New Haven, CT: Yale University Press.
Gilbert, S. F. (2001). Ecological developmental biology: Developmental biology meets the real world. *Developmental Biology*, *233*, 1–12.
Gilbert, S. F. (2010). *Developmental biology* (10th ed.). Sunderland, MA: Sinauer.
Gilbert, S. F., & Sarkar, S. (2000). Embracing complexity: Organicism for the 21st century. *Developmental Dynamics*, *219*, 1–9.
Godfrey-Smith, P. (2000). Explanatory symmetries, preformationism, and developmental systems theory. *Philosophy of Science*, *67*, S322–S331.
Gottfried, G. M., Gelman, S. A., & Schultz, J. (1999). Children's understanding of the brain: From early essentialism to biological theory. *Cognitive Development*, *14*, 147–174.
Gottlieb, G. (1992). *Individual development and evolution: The genesis of novel behavior*. New York: Oxford University Press.
Gottlieb, G. (1998). Normally occurring environmental and behavioral influences on gene activity: from central dogma to probabilistic epigenesis. *Psychological Review*, *105*, 792–802.
Gottlieb, G. (2007). Probabilistic epigenesis. *Developmental Science*, *10*, 1–11.
Gottlieb, G., & Willoughby, M. T. (2006). Probabilistic epigenesis of psychopathology. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology: Vol. 1. Theory and method* (2nd ed., pp. 673–700). Hoboken, NJ: Wiley.
Gould, S. J. (1977). *Ever since Darwin: Reflections on natural history*. New York: W. H. Norton.
Granic, I., & Hollenstein, T. (2006). A survey of dynamic systems methods for developmental psychopathology. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology: Vol. 1. Theory and method* (2nd ed., pp. 889–930). Hoboken, NJ: Wiley.
Granic, I., & Patterson, G. R. (2006). Toward a comprehensive model of antisocial development: A dynamic systems approach. *Psychological Review*, *113*, 101–131.
Greenberg, G., & Partridge, T. (2010). Biology, evolution, and psychological development. In W. F. Overton & R. M. Lerner (Eds.), *The handbook of life-span development: Vol. 1. Cognition, biology, and methods* (pp. 115–148). Hoboken, NJ: Wiley.
Griffiths, P., & Gray, R. (1994). Developmental systems and evolutionary explanation. *Journal of Philosophy*, *91*, 277–304.
Griffiths, P., & Knight, R. D. (1998). What is the developmentalist challenge? *Philosophy of Science*, *65*, 253–258.
Grigorenko, E. L., & Cicchetti, D. (2012). Genomic sciences for developmentalists: The current state of affairs. *Development and Psychopathology*, *24*, 1157–1164.
Hall, B. K. (1992). *Evolutionary developmental biology*. London: Chapman & Hall.
Ho, M. W. (2010). Development and evolution revisited. In K. Hood, C. T. Halpern, G. Greenberg, & R. M. Lerner (Eds.), *Handbook of developmental science, behavior, and genetics* (pp. 61–109). Hoboken, NJ: Wiley.
Hollenstein, T. (2011). Twenty years of dynamic systems approaches to development: Significant contributions, challenges, and future directions. *Child Development Perspectives*, *5*, 256–259.
Ialongo, N. (2010). Steps substantive researchers can take to build a scientifically strong case for the existence of trajectory groups. *Development and Psychopathology*, *22*, 273–275.
Jablonka, E., & Lamb, M. W. (2005). *Evolution in four dimensions: Genetic, epigenetic, behavioral, and symbolic variation in the history of life*. Cambridge, MA: MIT Press.
Jablonka, E., & Raz, G. (2009). Transgenerational epigenetic inheritance: Prevalence, mechanisms, and implications for the study of heredity and evolution. *The Quarterly Review of Biology*, *84*, 131–176.
Johnson, M. (2008). What makes a body? *Journal of Speculative Philosophy*, *22*, 159–169.
Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.
Kahneman, D. (2011). *Thinking, fast and slow*. New York: Farrar, Straus, and Giroux.
Keller, E. F. (2005). DDS: Dynamics of developmental systems. *Biology and Philosophy*, *20*, 409–416.
Keller, E. F. (2010). *The mirage of a space between nature and nurture*. Durham, NC: Duke University Press.

Keller, E. F. (2011). Genes, genomes, and genomics. *Biological Theory*, *6*, 132–140.

Kendler, K. S. (2012). The dappled nature of causes of psychiatric illness: Replacing the organic–functional/hardware–software dichotomy with empirically based pluralism. *Molecular Psychiatry*, *17*, 377–388.

Kiverstein, J. (2012). The meaning of embodiment. *Topics in Cognitive Science*, *4*, 740–758.

Kosslyn, S. M., & Koenig, O. (1992). *Wet mind: The new cognitive neuroscience*. New York: Free Press.

Kuo, Z. Y. (1939). Studies in the physiology of the embryonic nervous system: IV. Development of acetylcholine in the chick embryo. *Journal of Neurophysiology*, *2*, 488–493.

Lehrman, D. S. (1970). Semantic and conceptual issues in the nature–nurture problem. In L. R. Aronson, E. Tobach, D. S. Lehrman, & J. S. Rosenblatt (Eds.), *Development and evolution of behavior: Essays in memory of T. C. Schneirla* (pp. 17–52). San Francisco, CA: Freeman.

Lerner, R. M. (2002). *Concepts and theories of human development*. Mahwah, NJ: Erlbaum.

Lerner, R. M. (2006). Developmental science, developmental systems, and contemporary theories of human development. In R. M. Lerner & W. Damon (Eds.), *Handbook of child psychology* (Vol. 1, pp. 1–17). Hoboken, NJ: Wiley.

Lerner, R. M. (2012). Developmental science: Past, present, and future. *International Journal of Developmental Science*, *6*, 29–36.

Lerner, R. M., & Overton, W. F. (2008). Exemplifying the integrations of the relational developmental system: Synthesizing theory, research, and application to promote positive development and social justice. *Journal of Adolescent Research*, *23*, 245–255.

Lerner, R. M., & Overton, W. F. (2012). Relational developmental systems: A paradigm for developmental science in the postgenomic era. *Behavioral and Brain Sciences*, *35*, 375–376.

Lerner, R. M., Theokas, C., & Bobek, D. L. (2005). Concepts and theories of human development: Historical and contemporary dimensions. In M. H. Bornstein & M. E. Lamb (Eds.), *Developmental science: An advanced textbook* (5th ed., pp. 3–43). Mahwah, NJ: Erlbaum.

Lickliter, R., & Honeycutt, H. (2003). Developmental dynamics: Toward a biologically plausible evolutionary psychology. *Psychological Bulletin*, *129*, 819–835.

Main, M. (1991). Metacognitive knowledge, metacognitive monitoring, and singular (coherent) vs. multiple (incoherent) model of attachment: Findings and directions for future research. In C. M. Parkes, J. Stevenson-Hinde, & P. Marris (Eds.), *Attachment across the life cycle* (pp. 127–159). New York: Tavistock/Routledge.

Mangold, H., & Spemann, H. (1924). Über induktion von embryonalanlagen durch implantation artfremder organisatoren [Induction of embryonic primordia by implantation of organizers from a different species]. *Roux's Archiv für Entwicklungsmechanik*, *100*, 599–638.

Mangold, H., & Spemann, H. (2001). Induction of embryonic primordia by implantation of organizers from a different species. *International Journal of Developmental Biology*, *45*, 13–38.

Manning, A., & Dawkins, M. S. (2012). *An introduction to animal behavior* (6th ed.). New York: Cambridge University Press.

Marr, D. (1982). *Vision*. San Francisco, CA: W. H. Freeman.

Marshall, P. J. (2009). Relating psychology and neuroscience: Taking up the challenges. *Perspectives on Psychological Science*, *4*, 113–125.

Marshall, P. J. (in press). Embodiment, development, and neuroscience. In W. F. Overton & P. C. Molenaar (Eds.) & R. M. Lerner (Series Ed.), *Handbook of child psychology and developmental science* (7th ed., Vol. 1). Hoboken, NJ: Wiley.

Marshall, P. J., & Comalli, C. E. (2012). Young children's changing conceptualizations of brain function: Implications for teaching neuroscience in early elementary settings. *Early Education and Development*, *23*, 4–23.

Maturana, H. R., & Varela, F. J. (1980). *Autopoiesis and cognition: The realization of the living* (Vol. 42). Dordrecht: D. Reidel.

Meaney, M. J. (2010). Epigenetics and the biological definition of gene × environment interactions. *Child Development*, *81*, 41–79.

Merleau-Ponty, M. (1962). *Phenomenology of perception*. London: Routledge.

Mikhailov, A. T. (2005). Putting evo-devo into focus: An interview with Scott F. Gilbert. *International Journal of Developmental Biology*, *49*, 9–16.

Miller, G. A. (2003). The cognitive revolution: A historical perspective. *Trends in Cognitive Sciences*, *7*, 141–144.

Miller, G. A. (2010). Mistreating psychology in the decades of the brain. *Perspectives on Psychological Science*, *5*, 716–743.

Minelli, A. (2009). *Forms of becoming*. Princeton, NJ: Princeton University Press.

Molenaar, P. C. M. (2010). Testing all six person-oriented principles in dynamic factor analysis. *Development and Psychopathology*, *22*, 255–259.

Molenaar, P. C. M., Huizenga, H. M., & Nesselroade, J. R. (2003). The relationship between the structure of interindividual and intraindividual variability: A theoretical and empirical vindication of developmental systems theory. In U. M. Staudinger & U. Lindenberger (Eds.), *Understanding human development: Dialogues with life span psychology* (pp. 339–360). Dordrecht: Kluwer Academic.

Mun, E. Y., Bates, M. E., & Vaschillo, E. (2010). Closing the gap between person-oriented theory and methods. *Development and Psychopathology*, *22*, 261–271.

Nesselroade, J. R., & Molenaar, P. C. M. (2010). Emphasizing intraindividual variability in the study of development over the life span: Concepts and issues. In W. F. Overton & R. M. Lerner (Eds.), *The handbook of life-span development: Vol. 1. Cognition, biology, and methods* (pp. 30–54). Hoboken, NJ: Wiley.

Nesselroade, J. R., & Ram, N. (2004). Studying intraindividual variability: What we have learned that will help us understand lives in context. *Research in Human Development*, *1*, 9–29.

Overton, W. F. (1991). Competence, procedures, and hardware: Conceptual and empirical considerations. In M. Chandler & M. Chapman (Eds.), *Criteria for competence: Controversies in the conceptualization and assessment of children's abilities* (pp. 19–42). Hillsdale, NJ: Erlbaum.

Overton, W. F. (2006). Developmental Psychology: Philosophy, concepts, methodology. In R. M. Lerner & W. Damon (Eds.), *Theoretical models of human development* (6th ed., pp. 18–88). Hoboken, NJ: Wiley.

Overton, W. F. (2007). A coherent metatheory for dynamic systems: Relational organicism–contextualism. *Human Development*, *50*, 154–159.

Overton, W. F. (2008). Embodiment from a relational perspective. In W. F. Overton, U. Mueller, & J. L. Newman (Eds.), *Developmental perspectives on embodiment and consciousness* (pp. 1–18). New York: Erlbaum.

Overton, W. F. (2010). Life-span development: Concepts and issues. In W. F. Overton & R. M. Lerner (Eds.), *The handbook of life-span development: Vol. 1. Cognition, biology, and methods* (pp. 1–29). Hoboken, NJ: Wiley.

Overton, W. F. (2013). Relationism and relational-developmental-systems: A paradigm for developmental science in the post-Cartesian era. In J. Benson (Series Ed.) & R. M. Lerner (Vol. Ed.), *Advances in child development and behavior: Vol. 44. Embodiment and epigenesis: Theoretical and methodological issues in understanding the role of biology within the relational developmental system* (pp. 21–64). Amsterdam: Elsevier.

Overton, W. F., & Dick, A. S. (2007). A competence–procedural and developmental approach to logical reasoning. In M. J. Roberts (Ed.), *Integrating the mind: Domain general vs. domain specific processes in higher cognition* (pp. 233–256). New York: Psychology Press.

Overton, W. F., & Horowitz, H. A. (1991). Developmental psychopathology: Integrations and differentiations. In D. Cicchetti & S. L. Toth (Eds.), *Rochester symposia on developmental psychopathology: Vol. 3. Models and integrations* (pp. 1–42). Rochester, NY: University of Rochester Press.

Overton, W. F., & Lerner, R. M. (2012). Relational developmental systems: A paradigm for developmental science in the postgenomic era. *Behavioral and Brain Sciences*, *35*, 375–376.

Oyama, S. (1985). *The ontogeny of information: Developmental systems and evolution*. Cambridge. Cambridge University Press.

Oyama, S., Griffiths, P. E., & Gray, R. D. (2001). *Cycles of contingency: Developmental systems and evolution*. Cambridge, MA: MIT Press.

Ozonoff, S., Pennington, B. F., & Solomon, M. (2006). Neuropsychological perspectives on developmental psychopathology. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology: Vol. 2. Developmental neuroscience* (2nd ed., pp. 332–380). Hoboken, NJ: Wiley.

Partridge, T. (2011). Methodological advances toward a dynamic developmental behavioral genetics: Bridging the gap. *Research in Human Development*, *8*, 242–257.

Pepper, S. C. (1942). *World hypotheses*. Los Angeles: University of California Press.

Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures*. Oxford: Viking.

Pradeu, T. (2010). The organism in developmental systems theory. *Biological Theory*, *5*, 216–222.

Ricco, R. B., & Overton, W. F. (2011). Dual systems competence ←-→ procedural processing: A relational developmental systems approach to reasoning. *Developmental Review*, *31*, 119–150.

Robert, J. S. (2004). *Embryology, epigenesis, and evolution: Taking development seriously*. New York: Cambridge University Press.

Robert, J. S., Hall, B. K., & Olson, W. M. (2001). Bridging the gap between developmental systems theory and evolutionary developmental biology. *Bioessays*, *23*, 954–962.

Rudel, D., & Sommer, R. J. (2003). The evolution of developmental mechanisms. *Developmental Biology*, *264*, 15–37.

Rutter, M. (2012). Gene–environment interdependence. *European Journal of Developmental Psychology*, *9*, 391–412.

Sameroff, A. J. (1983). Developmental systems: Contexts and evolution. In W. Kessen (Ed.), *Handbook of child psychology* (1st ed., pp. 237–294). New York: Wiley.

Sameroff, A. J. (2000). Developmental systems and psychopathology. *Developmental and Psychopathology*, *12*, 297–312.

Santostefano, S. (2010). Developmental psychopathology—Self, embodiment, meaning: A holistic-systems perspective. In W. F. Overton & R. M. Lerner (Eds.), *The handbook of life-span development: Vol. 1. Cognition, biology, and methods* (pp. 792–836). Hoboken, NJ: Wiley.

Searle, J. R. (1980). Minds, brains, and programs. *Behavioral and Brain Sciences*, *3*, 417–457.

Shea, N. (2011). Developmental systems theory formulated as a claim about inherited representations. *Philosophy of Science*, *78*, 60–82.

Spemann, H. (1938). *Embryonic development and induction*. New Haven, CT: Yale University Press.

Spencer, J. P., & Buss, A. T. (2011). Finding a way out: Why developmental science does not need another "ism." *Child Development Perspectives*, *3*, 166–168.

Sroufe, L. A., & Rutter, M. (1984). The domain of developmental psychopathology. *Child Development*, *55*, 17–29.

Stanovich, K. E. (2009). Distinguishing the reflective, algorithmic, and autonomous minds: Is it time for a tri-process theory? In J. S. B. T. Evans & K. Frankish (Eds.), *In two minds: Dual processes and beyond* (pp. 55–88). New York: Oxford University Press.

Sterba, S. K., & Bauer, D. J. (2010). Matching method with theory in person-oriented developmental psychopathology research. *Development and Psychopathology*, *22*, 239–254.

Stewart, J., Gapenne, O., & Di Paolo, E. A. (Eds.). (2010). *Enaction: Toward a new paradigm for cognitive science*. Cambridge, MA: MIT Press.

Stiles, J. (2008). *The fundamentals of brain development: Integrating nature and nurture*. Cambridge, MA: Harvard University Press.

Stotz, K. (2008). The ingredients for a postgenomic synthesis of nature and nurture. *Philosophical Psychology*, *21*, 359–381.

Thelen, E., & Smith, L. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.

Thompson, E. (2007). *Mind in life: Biology, phenomenology, and the sciences of mind*. Cambridge, MA: Belknap Press/Harvard University Press.

Tinbergen, N. (1963). On aims and methods of ethology. *Zeitschrift fur Tierpsychologie*, *55*, 410–433.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*, 1124–1131.

van Geert, P. (2011). The contribution of complex dynamic systems to development. *Child Development Perspectives*, *5*, 273–278.

van Geert, P. (2012). Dynamic systems. In B. Laursen, T. D. Little, & N. A. Card (Eds.), *Handbook of developmental research methods* (pp. 725–741). New York: Guilford Press.

von Baer, K. E. (1956). Commentar zu der schrift: De ovi mammalium et hominis genesi. *Zeitschrift für Organische Physik, 2*. In A. W. Meyer (Trans.), *Human generation: Conclusions of Burdach, Döllinger and von Baer* (pp. 90–123). Stanford, CA: Stanford University Press. (Original work published 1828)

von Bertalanffy, L. (1968). *General system theory: Foundations, development, applications*. New York: George Braziller, Inc.

von Eye, A. (2010). Developing the person-oriented approach: Theory and methods of analysis. *Development and Psychopathology*, *22*, 277–285.

von Eye, A., Bergman, L. R., & Hseih, C.-A. (in press). Person-oriented approaches. In W. F. Overton & P. C. Molenaar (Eds.) & R. M. Lerner (Series Ed.), *Handbook of child psychology and developmental science: Theory and methods* (7th ed., Vol. 1). Hoboken, NJ: Wiley.

Waddington, C. W. (1957). *The strategy of the genes*. London: Allen & Unwin.

Wahlsten, D. (2012). The hunt for gene effects pertinent to behavioral traits and psychiatric disorders: From mouse to human. *Developmental Psychobiology*, *54*, 475–492.

Weiss, P. A. (1939). *Principles of development: A text in experimental embryology*. New York: Henry Holt.

Werner, H. (1948). *Comparative psychology of mental development*. New York: International University Press.

Wiers, R., Ames, S. L., Hofmann, W., Krank, M., & Stacy, A. (2010). Impulsivity, impulsive and reflective processes and the development of alcohol use and misuse in adolescents and young adults. *Frontiers in Psychology*, *1*, article 144. doi:10.3389/fpsyg.2010.00144

Wimsatt, W. C. (2007). *Reengineering philosophy for limited beings*. Cambridge, MA: Harvard University Press.

Witherington, D. C. (2011). Taking emergence seriously: The centrality of circular causality for dynamic systems approaches to development. *Human Development*, *54*, 66–92.

Witherington, D. C., & Margett, T. E. (2011). How conceptually unified is the dynamic systems approach to the study of psychological development? *Child Development Perspectives*, *5*, 286–290.

Wolpert, L. (1994). Do we understand development? *Science*, *266*, 571–572.