Human activity is both organized and variable, dynamically changing in principled ways. Children and adults are flexible and inventive in their action and thought, adapting old ideas to new situations and inventing concepts, formulating plans, and constructing hypotheses while participating in a wide variety of cultural practices. Few developmentalists today would disagree, as, for half a century, psychologists have been accumulating a wealth of evidence on the constructive, self-regulating, and culturally contextualized nature of human psychological processes. If psychological function—the way people act—is constructive, dynamic, and culturally embedded, then psychological structure—the organization or pattern of activities—is equally so. Yet remarkably, the most widely used conceptions of psychological structure and its development do not reflect this dynamic, constructive, and contextualized picture of psychological processes. The opposite is true: The major models of development describe psychological structure in static, formal terms. Concepts like universal stages, innate linguistic modules, and innate cognitive competencies portray psychological...
organization as fixed and unchanging, insulated from variation in context and feedback from activity.

The hallmark of the dynamic nature of human behavior is its pervasive variability: People act differently in different situations, with different people, in different emotional states. Faced with the large and growing corpus of research evidence for variability in activity and development, researchers guided by static models have been continually surprised to find that children’s performance is nowhere near as stable as the static conceptions predict. A child who can solve an arithmetic problem (or a social problem) one day or in one situation frequently cannot solve the same problem the next day or in a different but apparently similar situation. Different children of precisely the same age often cannot perform the same cognitive tasks—sometimes in relation to cultural contexts or family environment, sometimes for reasons that are harder to explain. Even from moment to moment, a person performs a task differently as she or he adapts to variations in the situation, social context, or emotions of self and others. Indeed, when the data of cognitive developmental research is taken as a whole, variability in the level of psychological performance is the norm, not the exception.

The task of developmental science is to detect and describe patterns in this variability and to propose models to account for data patterns that reflect both stability and variability. We show how the concepts and methods of dynamic structural analysis provide a framework and tools for analyzing this variability and detecting the order in it—key findings such as the emergence of qualitatively new cognitive abilities or the transitions from one behavior to another.

In our view, performances vary so greatly because psychological structure is not static but naturally produces variability in activity and development arising from people’s constructive self-organization of their own psychological structures in relation to situations, other people, meaning systems, and their own bodies. Far from being a problem, patterns of developmental variability are the key to understanding the organization of these dynamic systems and the constructive processes by which human agents create new interrelations and thus new structures. The complexity of these systems is not something to be controlled for but to be described and understood. The patterns of variability that arise from the particular ways in which cognitive systems are organized are the key to understanding that organization and thus to understanding psychological structure. Tools from dynamic systems analysis provide ways of embracing the variability to find the order in it.

With this chapter, we present a framework for conceptualizing psychological structure in dynamic systems constructed by human agents. We show how this model describes and explains patterns of developmental variability in terms of the structures human beings build. The chapter begins with an introductory overview of dynamic structuralism as a general approach to development, elaborating a theoretical model of psychological structure as the dynamic organization of self-constructed, socially embedded skills and activities (actions and thoughts). We contrast this position with traditional static views of psychological structure, which dominate scientific dialogue in what amounts to a modern synthesis of traditionally opposed viewpoints of nativism and empiricism. These static views derive from reductionist scientific theory inherited from the Cartesian tradition in philosophy, which leads to systematic misunderstanding of the nature of psychological structure and blatant failures to explain the extent of developmental variability.

The dynamic framework and research tools specifically crafted for analyzing development and learning provide a research methodology for the study of psychological structures including both their variability and the order in the variation. These concepts and tools apply to both long-term development and short-term microdevelopmental variations in the building of dynamic structures, providing powerful methods for testing dynamic hypotheses about variation, change, and stability. Broad in scope and applicability, the dynamic structural model and methodology elucidate relations between cognitive, social, emotional, and neurological development—which all work together in the activities of human beings in all their rich complexity.

**DYNAMIC STRUCTURALISM**

One reason psychological structure has so often been treated as static is that theorists have confounded structure with form. *Structure* refers to the system of relations (Piaget, 1970) by which complex entities such as biological organisms and psychological activities are organized. There are systematic relations, for instance, between the nervous system and the cardiovascular system such that each supports and responds to the other. The relations between these systems are in a constant balance or equi-
librium, which can only be maintained by constant activity on the part of each subsystem. Thus, systems of relations—structures—are necessarily dynamic.

**Form is an abstraction from structure**—a fixed pattern that can be detected in a dynamic structure. An orange has cellular and tissue-level structure, which lead to its cohesion in a spherical shape. The structure of the orange is dynamic, emerging developmentally, maintaining a dynamic equilibrium for a time, and then decaying. The concept of sphere, on the other hand, is an abstract form that we apply to describe one characteristic of the dynamic structure: the shape it produces. Beyond the orange, the concept of sphere is an ideal form that applies across myriad realities. The fact that this formal concept is unchanging across many situations is what makes it useful in describing similarities in many different objects such as balls, plums, or planets.

A structure/form problem arises when an abstraction used to describe reality is confounded with the reality described. People commonly expect patterns of phenomena in the world to conform to their underlying abstractions, instead of determining which patterns fit an actual object or experience. In personality and social relations, people commonly expect others to fit the stereotype of, for example, a shy, introverted person or a mother (Greenwald et al., 2002). Similarly, in science, researchers who focus on the sphere form may be surprised that baseballs, basketballs, and soccer balls are so different from one another, and researchers who focus on innate knowledge may be surprised to find that a 3-year-old really does not understand the numbers 1, 2, and 3 even though an infant can distinguish arrays of 1, 2, and 3 dots (Spelke, in press). For the sphere, the logical fallacy is obvious: The spherical shape is an abstraction of a common pattern across different objects, not an independently existing form that somehow dictates what the objects should be like. The same fallacy applies to the stereotypes and the nativist explanation of number.

This form fallacy has frequently led to perplexity among scientists and educators who expect patterns of thought and action to conform to an independently existing form such as stage, cognitive competence, or core knowledge. Scholars have been puzzled when a child reaches a certain stage or competence for one task or situation and he or she does not evidence the same ability in other tasks or situations, as if an underlying abstract logic could determine an individual’s performance in the real world (Piaget, 1985). The attempt to preserve formal conceptions of structure in the face of ever-growing evidence of variability in cognitive performance has led developmental theorists into pointless arguments over, for example, which of many varying performances represent an individual’s “real” logical ability, or at what age children “really” acquire a concept like object permanence. We demonstrate later how the confounding of form with structure has led to an explanatory crisis in developmental science with ever more tortured attempts to explain the pervasive evidence of variability in static conceptions of structure as form. (We also see hopeful signs that the field is shifting to deal more centrally with the dynamics of variation.)

Dynamic structuralism offers an alternative to static conceptions of structure, starting with the recognition of the complexity inherent in human psychological development and the central role of the person in constructing dynamic systems of action and thought. Instead of trying to eliminate or get beyond the complexity of relations among systems, dynamic structuralism uses the tools of contemporary developmental science to analyze patterns in the complexity—how the constructive activity of human agents leads to new relations among systems of action and thought. The analysis of the dynamic structures of human behavior provides a way of simplifying without discarding complexity, identifying the essential relations among systems, and explaining activities and developmental pathways in terms of those essential system relations. Dynamic structuralism thus differs from the classic structuralism of Piaget (1983), Chomsky (1995), and others, which isolates structure from the variability of mental dynamics, treats it as static, and attempts to explain development in terms of the static forms.

**Variability in the Middle of Things: An Example of Representing Social Interactions**

Focusing on the pervasive variability of human activity, dynamic structuralism analyzes the patterns of stability and order in diverse patterns of activity in the variation (Bidell & Fischer, 1992; Fischer, Yan, & Stewart, 2003; Siegler, Chapter 11, this *Handbook*, Volume 2; Thelen & Smith, Chapter 6, this *Handbook*, this volume; van Geert, 1998). As in the study of ecology, the analysis begins in medias res, in the middle of things. Starting in the middle of things means that people’s activities are embodied, contextualized, and socially situated—understood in their ecology (Bronfenbrenner & Morris,
Chapter 14, this Handbook, this volume; Cairns, 1979; Gibson, 1979) as well as their structure. People act and understand through their bodies acting in the world, not through a disembodied mind or brain. The brain and nervous system always function through a person’s body and through specific contexts composed of particular people, objects, and events, which afford and support the actions. People act jointly with other people within culturally defined social situations, in which activities are given meaning through cultural frames for interpretation (Rogoff, 1990). Action in context is the center of who people are and how they develop (Lerner & Busch-Rossnagel, 1981; Brandstädter, Chapter 10, this Handbook, this volume).

Starting in the middle of things with embodied, contextualized, socially situated individual and joint activity requires two major steps: (1) to describe basic structures or organizations of activities in context and (2) to characterize how those structures vary as a function of changes in key dimensions of person, body, task, context, and culture. Whether the focus is on knowledge, action, emotion, social interaction, brain functioning, or some combination, the dynamic structural approach puts the person in the middle of things and frames the person’s activity in terms of multiple components working together. The maturity or complexity of people’s behavior varies widely and systematically from moment to moment and across contexts, states, and interpretations or meanings. Each individual shows such variations, in addition to the wide variations that occur across ages, cultures, and social groups.

Consider, for example, the wide variation documented for children’s stories or narratives about positive and negative social interactions (Fischer & Ayoub, 1994; Hencke, 1996; Rappolt-Schlichtman & Ayoub, in press; Raya, 1996). The developmental level, content, and emotional valence of a child’s stories vary dramatically as a function of priming and immediate social support, emotional state, and cultural experience. For example, the activities of 5-year-old Susan demonstrate some of the variations in both developmental complexity and emotional organization that have been documented in research. First, she watches her counselor act out a pretend story with dolls: A child doll named after Susan makes a drawing of her family and gives it to her father, who is playing with her. “Daddy, here’s a present for you. I love you.” Then the daddy doll hugs the girl doll and says, “I love you too, and thanks for the pretty picture.” He gives her a toy and says, “Here’s a present for you too, Susan.” When asked, the girl promptly acts out a similar story of positive social reciprocity, making Daddy be nice to Susan because she was nice to him.

Ten minutes later, the counselor asks the girl to show the best story she can about people being nice to each other, like the one she did before. Instead of producing the complex story she did earlier, she acts out a much simpler story, making the Daddy doll simply give lots of presents to the child doll, with no reciprocal interaction between them. There is no social reciprocity in the story but only a simple social category of nice action.

A few minutes after that, when the girl has spontaneously shifted to playing at fighting, the counselor shows her another nice story about father and child. This time, when the girl acts out her story, she switches the content from positive to negative with energetic aggression. The girl doll hits the Daddy doll, and then he yells at her, “Don’t you hit me,” slaps her in the face and pushes her across the room, showing the violence that often appears in the stories of maltreated children. The girl doll cries and says she is scared of being hit again. Note that, despite the shift to negative affect, Susan sustains a story involving social reciprocity: The Daddy doll hits the Susan doll because she had hit him, and she becomes afraid because he had hit her.

Then Susan becomes agitated; yelling, she runs around the room and throws toys. When the counselor asks her to do another story, she makes the dolls hit and push each other with no clear reciprocity and no explanation of what is happening. With her distress and disorganization, she no longer acts out a complex aggression story but is limited to stories of repeated hitting, even when she is asked to produce the best story she can. She uses a simple social category of mean action.

What is the “real” story for the child? Does she represent relationships between fathers and daughters as positive or negative? Is she capable of representing reciprocity, or is she not? These are the kinds of questions that are often asked in child development, but these questions assume an opposition that makes no sense. Susan plainly shows four different “competences”—positive reciprocity, positive social category (without reciprocity), negative reciprocity, and negative social category. Depending on the immediate situation, her emotional state, and the social support from her counselor, she demonstrates each of these four different “abilities.” Her four skills vary strongly in both emotional valence and developmental level (complexity) with the different skills linked to the social context, her emotional state, and her relationship with her father and her counselor.
Different contexts for assessment routinely produce substantial variations, although most developmental theories and methods do not deal with this variability. Children (and adults) show distinct levels of competence under different conditions, even for a single domain such as stories about nice and mean social interactions between peers (A. Brown & Reeve, 1987; Fischer, Bullock, Rotenberg, & Raya, 1993). Figure 7.1 shows the best (most complex) performances of eight 7-year-old children who were acting in (a) several contexts in which an interviewer provided high social support for complex stories, such as prompting the gist of the plot, and (b) several contexts providing no such support. As the context shifted, the children’s competence for representing mean, nice, or nice-and-mean social interactions shifted dramatically and systematically. Every individual child showed a similar pattern of shifting across conditions—competence at step 6 or 7 for high-support conditions, and competence at step 2, 3, or 4 for low-support conditions. This variation is an example of developmental range, the spread between competence with high support and competence with little support. With both positive and negative stories, Susan demonstrated a developmental range varying from interactions with social reciprocity to interactions based on a single, non-reciprocal category. For example, she showed a higher competence of social reciprocity when the interviewer first demonstrated a story of nice reciprocity for her and a lower competence of nonreciprocal social interaction when she later made up a story without the interviewer’s demonstration. Labeling her as having or understanding social reciprocity misrepresents the range of her competence, as does labeling her as having only a nonreciprocal social category.

Depending on their emotional state, children also show different emotional valences in their representations, just as Susan did in her shift to negative stories. Maltreated children often shift the content of stories from positive to negative, and, when they become agitated, the sophistication of their negative stories deteriorates and remains low until they become calmer (Ayoub & Fischer, in press; Buchsbaum, Toth, Clyman, Cicchetti, & Emde, 1992). These kinds of variations need to be center stage and the focus of developmental analysis. Only by including these variations as a function of context, culture, state, and other key contributors to behavior can scholars build an effective framework for explaining the many shapes of human development. Dynamic structuralism provides concepts and tools for founding developmental explanation and description of these variations, and it encourages the building of theory and method that capture the rich complexity that is the legacy of the human species.

**Dynamic Nature of Psychological Structure**

What is psychological structure? Why is it important in explanations of development? The answers depend on assumptions about the nature of the mind and its relation to other biological, psychological, and social phenomena. Psychological structure is the organizational property of dynamic systems of activity, and analysis of dynamic structure starts with assumptions that are fundamentally different from the traditional view of...
structure as static form. The concept of structure in stage theory and related viewpoints equates form with structure and thus founders on the “discovery” of variability in development (as do most other traditional psychological concepts). The continued dominance of the structure-as-form paradigm has prevented an adequate resolution of the crisis of variability in developmental theory.

To build successful models of dynamic psychological structure, it is essential to understand how dynamic structure differs from static form. An essential first step is to focus simultaneously on variability and stability. Indeed, the neglect of variability helps ensure that models remain static, missing the sources of order in the variation and treating structures as static forms. Any adequate account of psychological structure must explain not only the stability that allows systems to function and maintain themselves over time and space but also the wide variability that arises from the dynamics of self-organizing systems. Models of psychological structure must specify mechanisms by which activities are organized dynamically in relation to multiple influences that are biological, psychological, and social.

In this section, we illustrate how a dynamic structural framework deals with variability and stability simultaneously and thus introduces powerful explanations of development, including cognition, social interaction, emotions, and even brain development.

**Dynamic Structure in Living Systems**

All living systems—whether biological, psychological, or social—must be organized to function. A living organism that becomes sufficiently disorganized dies. A disorganized society collapses. A disorganized mind leaves a person helpless in the face of everyday problems. This organizational aspect of living systems is what we call structure, a dynamic patterning and relating of components that sustain the organized activities that define life and living things.

To say that a system is structured or organized implies that specific relations exist among its parts, subsystems, or processes. In the human body, for example, the respiratory, circulatory, digestive, metabolic, and nervous systems must all function in very specific relations to maintain the overall functioning and health of the organism. Similarly in a complex society, the economic system, judiciary, political/electoral system, and government must maintain specific relationships to sustain the society. In this way, dynamic structure exists only where relationship exists, and relations among the parts of a system provide its specific organization.

To flourish, living systems must be more than just organized. They must be dynamic. Systems must constantly move and change if they are to carry out their functions and maintain their integrity and their interrelations with other functioning systems. A system that becomes static—unable to change and adapt to varying conditions—will quickly perish. Social, psychological, or biological systems must be able to stretch the limits of their current patterns of organization, and even to actively guide and reorganize the relations that constitute their structure. An organism or society that becomes inflexible and incapable of adaptive response to variations in its environment will die as surely as one that becomes disorganized. Thus, structure must be distinguished not only from disorganization but also from static form, which really is the antithesis of structure. Structure is fundamentally dynamic because it is a property of living, changing, adapting systems. Susan demonstrated this dynamic adaptation in her variable representations of social interactions with her father and counselor. Dynamic variation is a fundamental property of human action and thought.

The human mind is a specialized living system that participates in and with other bodily, environmental, and social systems. The specialized function of the human mind is to guide and interpret human activity in relation to the world of people and objects. The activity takes places *in medias res*, in the middle of things, not in the person alone or in the brain. The objects and people in the physical and social world of the actor are actually part of the activity.

Moreover, living systems are *agentive*—self-regulating and self-organizing, adapting and changing as a consequence of goal-oriented activity, as in Susan’s activities (Bullock, Grossberg, & Guenthner, 1993; G. Gottlieb, 2001; Kauffman, 1996). In seeking its goals, a living system is involved in multiple relations with other living and nonliving systems, and they are part of one another’s dynamics.

This agency and interaction lead naturally to variability in systems. If systems were static, they would be unchanging; but because they move and change, they give rise to patterns of variability. The more complex a system, the more relations are entailed by its structure and the greater the variability it is likely to display. Human beings show more variability in activity than lizards,
rats, or monkeys. This variability can easily elude overly simple theoretical models that ignore the dynamic complexity and interrelationships of living systems.

**Variation and Order in Development: The Constructive Web**

People unknowingly ground their concepts and activities in metaphoric frames that give meaning (Lakoff & Johnson, 1999). Concepts and theories in science derive from metaphoric frames in the same way as everyday concepts, except that research systematically tests their grounding in observation and action. Traditional static conceptions of development in psychological structure are closely related to the widespread cultural metaphor of a ladder. Development is conceived as a simple linear process of moving from one formal structure to the next, like climbing the fixed steps of a ladder. It matters little whether the steps of the ladder are conceived as cross-domain stages, levels of a domain-specific competence, or points on a psychometrically based scale. In each case, the beginning point, sequence of steps, and endpoint of the developmental process are all linear and relatively fixed, forming a single ladder. With such a deterministic, reductionist metaphor, it is difficult to represent the role of constructive activity or contextual support because there appears to be no choice of where to go from each step. The richness of children's development, including the variability in their skills across contexts, is simply lost with the ladder metaphor. Development means just moving to the next step—an overly simple theory that clearly does not capture the variability that Susan showed in her stories about nice and mean interactions.

A more dynamic metaphor for development, which includes variability as well as stability in development, is the constructive web (Bidell & Fischer, 1992; Fischer et al., 2003). The metaphor of a web is useful for dynamic models because it supports thinking about active skill construction in a variety of contexts and for diverse variations. Unlike the steps in a ladder, the strands in a web are not fixed in a determined order but are the *joint product* of the web builder's constructive activity and the supportive context in which it is built (like branches, leaves, or the corner of a wall, for a spider web). The activity of an agent in constructing a web is particularly clear. For example, a given strand may be tenuous at first, dependent on surrounding strands for external support, and like the spider, the person can reconstruct it until it becomes a stable part of the web. Also, unlike most spider webs, human developmental webs are constructed jointly by multiple agents, not by an individual alone, although most psychological research examines individuals isolated from their social networks. We show how people often join together to construct parts of their developmental webs.

The separate strands in a web represent the various pathways along which a person develops. The strands in a web can start in a number of places, take a variety of directions, and come out at a range of endpoints, all determined by active construction in specific contexts. The several strands composing one line may be constructed in a different sequential order from the strands composing another line in a different section of the web. At the same time, there is order in the web, including similar orderings of spatial positions for some strands, separations and junctions of strands, and related starting and ending points for some strands. Using the constructive web as a metaphor for devising models of development facilitates the unpacking of variability relating to constructive activity and context, which are conflated in the image of a linear ladder of static structures.

Figure 7.2 depicts an idealized constructive web. The lines or strands represent potential skill domains. The connections between strands represent possible relations among skill domains, and the differing directions of the strands indicate possible variations in developmental pathways and outcomes as skills are constructed.
for participation in diverse contexts. Groupings of strands represent domains of skill, such as mother, father, and counselor, for each of the three clusters of strands. Within each strand, people's activities also vary, demonstrating a developmental range (like Susan's) varying between high competence with contextual support and lower competence without it (Fischer, et al., 1993; Fischer et al., 2003). In the discussion that follows, the web metaphor is articulated to facilitate analysis of variability in the development of dynamic skills.

**DYNAMIC STRUCTURE IN COGNITIVE AND EMOTIONAL DEVELOPMENT**

To explain both variability and stability in development and learning, an alternative framework is needed to replace the structure-as-form paradigm as a basis for research and interpretation. Static conceptions of psychological structure must be replaced with dynamic ones such as the constructive web. Reified notions of structures existing separately from human activity must give way to a new understanding of structure as the dynamic organization inherent in the activity itself. Such a framework is emerging in dynamic systems theory, which is influencing a variety of fields and a growing number of researchers. (This volume shows the extent of the growth of dynamic systems in human development, with a majority of chapters taking a dynamic systems perspective.)

Common in many dynamic systems models is a shift in the treatment of order and variation from being dichotomized to being intrinsically related (Hua & Smith, 2004; Kelso, 1995; Port & van Gelder, 1995; van Geert, 1998). Phenomena that were once viewed as random or chaotic are now seen as organized in complex ways that lead to specific patterns of variation. Descriptions and models of the activity and change start with analysis of relations between organization and variability in specific phenomena. For instance, the jagged patterns of seacoasts—seemingly erratic jumbles of random erosions—can be closely modeled with fractal geometry, revealing an intrinsic organization to a geologic process of erosion and sedimentation once thought of as disorderly. By recognizing that organization is related to variability, geologists and mathematicians have been able to create models of the dynamic organization of the erosion process that can predict and explain the variability observed in the changing coastline (Kruhl, Blenkinsop, & Kupkova, 2000). Similarly, biologists model the structures of evolution of living organisms (Kauffman, 1993) and the dynamics of brain functioning and development (e.g., Marcus, 2004; Polsky, Mel, & Schiller, 2004; Spruston & Kath, 2004).

Full realization of the potential of dynamic systems analysis requires not only connecting nonlinear dynamic concepts to psychological processes but also building explicit dynamic models of those processes. Global concepts can be powerful and useful, but ultimately they must be tested out as models with explicitly defined properties. Only with such models can researchers determine whether the processes they hypothesize in fact produce the dynamic patterns of development and variation that they expect (Fischer & Kennedy, 1997; Thelen & Smith, Chapter 6, this *Handbook*, this volume; van der Maas, 1995; van Geert, 1998; van Geert & van Dijk, 2002). Happily, computer-based tools including spreadsheets such as Excel can be readily used to build explicit dynamic models and test them against empirical data.

From a dynamic systems viewpoint, psychological structure is the actual organization of systems of activity. It is not a separately existing entity, such as a logical stage dictating behavior, or a preformed linguistic or cognitive capacity awaiting actualization, but instead is a property of human activity systems. Because real systems of activity are dynamic—constantly moving, adapting, and reorganizing—they must be dynamically structured. Variability is a natural consequence of system dynamics, and because systems are organized, the variability is not random but patterned, as evident in the variable stories that Susan told. Just as geologists have modeled the structures of coastal evolution and biologists have modeled the structures of evolution of living species, developmental scientists can build models of the dynamic structures of development and learning in human action and thought.

To move beyond a general call to dynamic structural analysis and model the dynamics of development successfully, scholars need specific psychological constructs that support analyzing structures behind variation for particular research problems. There is not one correct construct for a dynamic approach to psychological structure. A number of contemporary constructs are useful for this purpose because they have been developed specifically to facilitate analysis of variation and organization of activities in context. The concept of script, for example, focuses on the organization and variation in everyday activities for storytelling, narratives, goals, and recall for scripted activities in specific contexts (Fischer, Shaver, & Carnochan, 1990; Nelson,
Dynamic Structure in Cognitive and Emotional Development

The concept of strategy has a long history of illuminating variations in the organization of problem-solving activity (Bruner, Goodnow, & Austin, 1956; Siegler & Jenkins, 1989; Siegler, Chapter 11, this Handbook, Volume 2). Concepts such as apprenticeship (Rogoff, 1990), environmental niche (Gauvain, 1995), and setting (Whiting & Edwards, 1988) facilitate analysis of the dynamic social organization of activities across contexts.

A construct that we find especially useful for facilitating a dynamic approach to psychological structure is dynamic skill; it provides a useful way of integrating many of the necessary characteristics of dynamic psychological structure into a single, familiar idea (Fischer, 1980b; Fischer & Ayoub, 1994; Fischer, Bullock, et al., 1993). This construct is based on concepts that were central to the cognitive revolution of the late 1950s and 1960s (Bruner, 1973; Gardner, 1985), the ecological revolution of the 1960s and 1970s (Bronfenbrenner & Morris, Chapter 14, this Handbook, this volume; Gibson, 1979), and the emotive revolution of the 1980s and 1990s (Campos, Barrett, Lamb, Goldsmith, & Stenberg, 1983; Frijda, 1986; Lazarus, 1991). These revolutions have emphasized, for example, the importance of goals, self-regulation, organism-environment interaction, bias or constraint, and the social foundations of activity. Most importantly, Piaget (1970) and Vygotsky (1978) insisted on activity as the basis of cognitive structures, defined as systems of relations among activities.

In the following discussion, we explicate the construct of dynamic skill, using it to articulate essential characteristics of psychological structures. We show how the dynamic analysis of structure can both predict and explain specific patterns of developmental variability, focusing on three key types of variability frequently observed in developmental research: (1) sequence, (2) synchrony, and (3) range. In subsequent sections, we show how these dynamic characteristics differ from those in static views of structure, and we describe key methodology for studying the dynamics of change, microdevelopment in learning and problem solving, development of emotion, and the role of brain functioning in development of cognition and emotion.

Psychological Structure as Dynamic Skill

In ordinary English usage, the term skill both denotes and connotes essential characteristics of the dynamic organization of human activities (Bruner, 1973; Welford, 1968). Skill is the capacity to act in an organized way in a specific context. Skills are thus both action-based and context-specific. People do not have abstract, general skills, but they have skills for some specific context: a skill for playing basketball, another for telling a children’s story, or yet another for interpersonal negotiation. Skills do not spring up fully grown from preformed rules or logical structures. They are built up gradually through the practice of real activities in real contexts, and they are gradually extended to new contexts through this same constructive process (Fischer & Farrar, 1987; Fischer & Immordino-Yang, 2002; Granott, Fischer, & Parziale, 2002).

The concept of skill also helps to conceptualize the relations among various psychological, organismic, and sociocultural processes and to cut through artificial dichotomies between mind and action, memory and planning, or person and context. A skill—such as telling children stories about emotional interactions with other children—draws on and unites systems for emotion, memory, planning, communication, cultural scripts, speech, gesture, and so forth. Each of these systems must work in concert with the others for an individual to tell an organized story to specific children in a particular context, in a way that it will be understood and appreciated. The concept of dynamic skill facilitates the study of relations among collaborating systems and the patterns of variation they produce and inhibits treating psychological processes as isolated modules that obscure relations among cooperating systems. To see how, let’s consider some of the characteristics of skills.

Integration and Interparticipation

Skills are not composed atomistically but are necessarily integrated with other skills. The skill of playing basketball demands that many other skills, such as running, jumping, and visual-motor coordination, all be integrated to function in a coordinated way. Integrated skills are not simply interdependent but interparticipatory. True integration means that the systems participate in one another’s functioning. Atomistic models allow for simple interdependence: The stones in an arch, the trusses in a bridge, the modules in a serial computer comprise atomistic systems in which parts are interdependent but do not obviously participate in each other’s functioning. In contrast, the components of living systems not only depend on one another but participate in one another. Although at first this concept may seem counterintuitive, there are many obvious examples in familiar processes such as human cellular or organ systems. Any
system in the human body is composed of multiple subsystems whose boundaries defy definition. The cardiovascular system, for example, participates in the functioning of every organ system, because every organ depends on receiving oxygenated blood. At the same time, the cardiovascular system includes components from the nervous system, the muscular system, and so forth, so that these other systems in turn participate in the circulatory system. It makes little sense to think of any of these systems as functioning outside the context of the other systems: Living systems die when cut off from the other systems with which they interparticipate. For living systems, conceptions of structure must reflect the interparticipation of one system in another.

Systems of activities are central parts of living systems, especially in complex systems such as human beings. Activities organize into skills, which have many interparticipating components. When Susan creates a story of social reciprocity between the positive actions of the doll Susan and her doll father, the actions of each character affect each other intimately and reciprocally—they participate in each other. Skills normally involve this interparticipation of components.

**Context Specificity and Culture**

Skills are context-specific and culturally defined. Real mental and physical activities are organized to perform specific functions in particular settings. The precise way a given skill is organized—its structure—is essential to its proper functioning, as well as specific to that skill at any moment. Good basketball players do not automatically make good baseball players; good storytellers in one culture do not automatically have their stories understood and appreciated in other cultures.

The context specificity of skills is related to the characteristics of integration and interparticipation because people build skills to participate with other people directly in specific contexts for particular sociocultural systems. In turn, people internalize (Cole, 1996; Wertsch, 1979) or appropriate (Rogoff, 2003) the skills through the process of building them by participating in these contexts; and as a result, the skills take on cultural patterning. Similarly, component systems such as memory, perception, emotion, and even physiological regulation all participate in the culturally patterned skills. The context specificity of skills thus implies more than simply a fit with an environment. Even systems like perception or memory, which are often thought of as being isolated from sociocultural systems, are linked to them through the skills in which they participate; research shows how pervasive and deep the connections are (Greenwald et al., 2002; Mascolo, Fischer, & Li, 2003).

**Self-Organization, Mutual Regulation, and Growth**

Skills are self-organizing. Part of the natural functioning of skills is that they organize and reorganize themselves. These self-organizing properties go beyond maintenance to include growth of new, more complex skills. One of the goals of developmental science is to analyze the processes of organization and change, which skills undergo with development and learning. Unlike mechanical systems that must be built and maintained artificially through an external agency, the agency that creates and maintains skills (and living systems in general) resides in the activities for both individual activity and social interaction. Construction and maintenance of skills involves both self-regulation and mutual regulation with other people, because components interparticipate. In an obvious example from human biology, as people increase their activity level, their increased use of energy and oxygen evokes increases in their rates of breathing and metabolism. No outside agency is involved in adjusting the controls for this interparticipation of motor systems with respiratory and metabolic systems. The living system actively adjusts itself to maintain its own integrity.

In skills, the components regulate each other in the same way. Susan’s and her father’s mean actions toward each other mutually affected the other’s mean actions, creating adaptations in content, organization, and emotional tone (quality and intensity). Skills are not fixed abilities but constantly adapting, regulated activity structures. As Susan, her father, and her counselor act together, they develop new skills together, coordinating activities that were previously relatively independent to form newly integrated wholes. Through coordination and mutual regulation, they organize their activities into qualitatively new, integrated systems, with sequences of coordinations and regulations that build on each other.

Dynamic structuralism provides concepts and tools for taking hold of this adaptive variability to uncover the order behind the variations. One of the central discoveries is a common scale of hierarchical complexity that orders the variations.

**A Common Ruler for Skill Development**

A key ingredient for advancing developmental science is common rulers (scales) for measuring change and varia-
tion in activity, similar to the Centigrade or Fahrenheit scale for temperature and the meter or foot for length. These scales should be grounded in properties of natural response distributions and applicable across tasks and domains. However, psychological measurement has produced mostly arbitrary scales based on one situation such as those for intelligence, achievement, and personality tests. They do not use naturally occurring response distributions but statistical models assuming stable normal distributions (van Geert & van Dijk, 2002; Wahlsten, 1990), and they assess behavior in one situation, the test. A more useful scale allows measurement of different skills in various situations and is not tied to one situation or assessment instrument. Temperature and length can be measured in many ways in virtually any situation.

Fortunately, the measurement problem has now changed with the discovery of a common scale for behavioral complexity that captures a central dimension of both long-term development and short-term change (Commons, Trueb, Stein, Richards, & Krause, 1998; T. L. Dawson & Wilson, 2004; Fischer, 1980b; Fischer & Immordino-Yang, 2002). Research with various methods has produced evidence for the same scale, marked by clusters of discontinuities such as sudden changes in growth patterns and gaps in Rasch scaling. Analysis of growth curves has documented these patterns (Fischer & Rose, 1999; van Geert, 1998), and Rasch (1980) scaling of interview and test data has shown remarkably consistent evidence of the same patterns of discontinuity (Dawson, 2003; Dawson, Xie, & Wilson, 2003), forming a scale of at least 10 levels of hierarchical complexity, as shown in Figure 7.3. The scale relates to the outline of developmental stages that Piaget (1983) described, but the levels on the scale are better grounded empirically, and performance varies across the scale instead of being fixed at one point at each age. The scale also has important similarities to those suggested by Case (1985), Biggs and Collis (1982), and others. Interestingly, discontinuities in growth of brain activity seem to follow the same scale, as described later in the chapter (Fischer & Rose, 1996).

Many developmental scientists have posited stages, some of which match some of the levels (Biggs & Collis, 1982; Case, 1985; Halford, 1982; McLaughlin, 1963), but these alternatives have not been based on clear empirical criteria for what constitutes a stage or level—and what does not (Fischer & Silvem, 1985). Typically, these investigators have merely described a sequence of  

Figure 7.3 Developmental cycles of levels and tiers of skills. Development proceeds through 10 levels of skills grouped into three tiers between 3 months and adulthood. The ages of emergence are for optimal levels, the most complex skill that a person can perform with social-contextual support, based on research with middle-class American or European children. They may well differ across social groups. There is some evidence for an additional tier of innate action-components in the first few months of life. Sources: From “A Theory of Cognitive Development: The Control and Construction of Hierarchies of Skills,” by K. W. Fischer, 1980b, Psychological Review, 87, pp. 477–531; and “The Big Picture for Infant Development: Levels and Variations” (pp. 275–305), by K. W. Fischer and A. E. Hogan, in Action in Social Context: Perspectives on Early Development, J. J. Lockman & N. L. Hazen (Eds.), 1989, New York: Plenum Press.

posited cognitive reorganizations without specifying empirical criteria for stages or levels, except for loosely defined “qualitative change” and an approximate developmental sequence.

The skill scale in Figure 7.3 begins with sensorimotor actions, which are coordinated through several complexity levels to eventually form representations, which are in turn coordinated through several levels to form abstractions, which continue to develop into adulthood. The larger growth cycles of actions, representations, and abstractions are called tiers (left column of the figure), and the specific changes marked by clusters of discontinuities are called levels (middle column). The ages in the right column indicate when skills at a level first emerge under conditions that support optimal performance. Each level has a characteristic skill structure, as shown in Figure 7.4, and similar structures recur in each tier, reflecting a dynamic cyclical growth process. The structures begin with single sets organized as actions, representations, or abstractions. A person coordinates and differentiates these sets to form mappings, which in turn are coordinated and differentiated to form systems.
Figure 7.4 Cycle of levels of development for a tier: cube models and skill structures. The fourth level marks the culminating structure for a tier and the formation of a new unit for the next tier, as shown by the two skill formulas for Level 4/1: Level 4 actions form Level 1 representations, and Level 4 representations form Level 1 abstractions.

In skill formulas, brackets mark a skill structure; and each letter denotes a skill component, with a large letter designating a main component (set) and a subscript or superscript a subset of the main component. A line connecting sets (—) = A mapping relation, a single-line arrow (↔) = A relation forming a system, a double-line vertical (≡) arrow = A relation forming a system of systems, and a greater than symbol (>) = A shift from one skill to another without integration. Such shifts between skills can occur at every level, although for simplicity a shift is shown only at the first level. For skill formulas in later figures and text, bold letters = Sensorimotor actions, italic letters = Representations, and script letters = Abstracts.

At the fourth level of each tier, the person coordinates and differentiates systems to form systems of systems, thus constructing a new unit that begins the next tier—a single set of a new type. At the tenth level, the person constructs single principles, and there is as yet no evidence for further levels marked by clusters of discontinuities beyond single principles (Fischer et al., 2003).

Contrary to static approaches to development and learning, the levels on the scale do not indicate the use of one psychological structure or module across domains, like one of Piaget’s (1985) generalized logical structures or Chomsky and Fodor’s (1983) modules. People do not use the same structure across situations, but they build skills along the same scale. The processes of growth and variation produce skills that fit a common scale across tasks and domains, but the skills used differ, being dynamically adapted to context, emotional state, and goal. The complexity of separate activities varies in similar ways for different contexts and states. Think of temperature, for which physicists discovered a common scale over the last several hundred years. The same scale can be used to measure the temperature in the sun, Antarctica, a refrigerator or furnace in New York, a person’s mouth, or the bottom of the ocean. Thermometers measure with a common scale across radically different situations and methods, even with great differences in the ways that heat and cold occur.

In this way, skills are organized in multilevel hierarchies that follow the scale in Figures 7.3 and 7.4. People construct skills through a process of coordination, as when 5-year-old Susan built stories about emotionally loaded social interactions that coordinated multiple actions into social categories and then coordinated social categories into reciprocal activities. Susan used a skill hierarchy in which individual pretend actions (Sm3 systems of actions) were embedded in social categories (Rp1 single representations), which were in turn embedded in socially reciprocal activities (Rp2 representational mappings). Existing component skills, controlling activities in specific contexts, were intercoordinated to create new skills that controlled a more differentiated and integrated range of activities. In the newly integrated skills, the component skills still functioned as subsystems in the new skill as a whole. They also could still be used alone, as when Susan dropped back to simpler actions with less contextual support or with emotional upset. We use representations of positive and negative social interactions to ground the explanation of dynamic skills and to illustrate how the skills in the diagrams both develop in the long term (macrodevelopment or ontogenesis) and vary from moment to moment (micromovement).
systems. As skills become integrated and differentiated at later levels, the component skills subordinate themselves to new forms of organization and mutual regulation. The very process of creating new skills through self-organizing coordination leads to a multileveled hierarchical structuring of living skills. Indeed, “hierarchy” in this sense has a special meaning. Computer programs, for example, can be arranged hierarchically in the sense that lower-level outputs feed higher-level procedures, but this organization does not typically involve interparticipation and self-organization.

Generalization through Construction

Susan built her skills for representing positive and negative social interactions in one context, but she naturally tried to generalize those skills across related contexts—for example, using the skills for representing interactions with her father to build representations of interactions with her counselor. The process of skill construction through coordination is closely related to skill generalization, and the complexity scale can illuminate both. Generalization of mental and physical activity involves specific building of generalized skills driven by the goal-oriented activity of an individual or ensemble (a few people working closely together), especially for socially constructed domains such as literacy, mathematics, and science. Generalization in these domains is not a predetermined, innate outcome waiting for development to catch up with it, as some nativists would have it (Baillargeon, 1987; Fodor, 1983; Spelke, 1988). Several mechanisms of generalization of dynamic skills through coordination, differentiation, and bridging from simple to complex have been specified with some precision (Fischer & Farrar, 1987; Fischer & Immordino-Yang, 2002; Siegler & Jenkins, 1989). Studying microdevelopment is an especially powerful way of analyzing processes of dynamic generalization, as we describe in a later section to illuminate how learning general knowledge takes a long time.

Building a Constructive Web for Positive and Negative Social Interactions

The complexity scale combines with the constructive web in Figure 7.2 to support analyzing psychological structure in dynamic terms. Unlike the traditional ladder of development, the web highlights integration, specificity, multiple pathways, active construction, and other central properties of skill development (Bidell & Fischer, 1992; Fischer et al., 2003). Building a web is a self-organizing process in which a person coordinates and differentiates various activities along the complexity scale. The strands in a web are the joint product of the person’s constructive activity and the contexts in which skills are built, including the other people who coparticipate in building them.

We use stories about nice and mean social interactions to illustrate properties of the constructive web and its relation to dynamic properties of cognitive and emotional development. Telling a story or narrative is a fundamental human activity. To produce a specific story or narrative, a child needs to organize activities in a scriptlike way, following specific patterns of sequencing of events (Bruner, 1990; Fischer et al., 1990; Ninio & Snow, 1996; Schank & Abelson, 1977). This organization helps impart meaning to the narrative, as with 5-year-old Susan’s stories about interaction between a girl and her father. Without this script organization, the story becomes a meaningless jumble; for example, it becomes unclear who is being nice to whom and why, or who is hurting whom and why. Yet the organization of the storytelling activity must also be flexible, so that a storyteller can create new versions for changing situations and people, thereby communicating different ideas and feelings, as Susan changed her stories in relation to her emotional state and to the contextual cuing and support she received from the adult interviewer.

Like other skills, the complexity and organization of story skills varies widely with the dynamics of the constructive activity, including story complexity, emotional state, and social-contextual support from other people. The skill scale illuminates this variation by providing a ruler for analyzing and comparing these variations. When 5-year-old Susan is in a positive mood and has support from her counselor, she organizes a complex positive story. A few minutes later when she is emotionally stressed, she no longer produces a complex positive story, even with support from the counselor, but instead tells an equally complex negative story. When the counselor does not provide contextual support, Susan can organize only a simpler positive or negative story. In addition, the form of narrative organization varies across cultural groupings and discourse communities because individuals construct different narrative skills to participate in different culturally patterned communicative activity. Susan’s
stories fit her cultural community, but would have to be reorganized to fit others.

Webs and Biases

Figure 7.5 shows a developmental web for stories about positive and negative social interactions in American children of diverse ethnicity and social class (Ayoub & Fischer, in press; Fischer & Ayoub, 1994). When children play, they commonly act both nice and mean to each other, and like 5-year-old Susan, they readily act out and tell stories about positive and negative interactions between peers. The web has three distinct strands

**Figure 7.5** Developmental web for nice and mean social interactions. The numbers to the left of each set of brackets indicate the step in complexity ordering of the skill structures. The words inside each set of brackets indicate a skill structure. The left column designates the first step at each skill level.
organized by emotional domains of different valence—nice on the left, mean on the right, and the combination of nice and mean in the middle. The tasks are ordered in steps by skill complexity, marked by the numbers next to each skill structure. There are normally multiple steps per level, marking the distinct points in the construction process that can be discriminated for a particular situation, which can vary in number. The levels are indicated in the left-hand column.

In the research, children between 2 and 9 years of age told stories about two or three boys or girls playing together, with each story reflecting one of the three emotional domains. One character usually had the name of the child telling the story, and the others represented his or her friends or siblings; in some studies, the characters had the names of unknown children. In a separate assessment, children also told similar stories about parent-child interactions.

Later steps generally involve more inclusive skills, constructed by the coordination and differentiation of lower-level components. For example, in step 3, the story involves a mapping between two instances of niceness (or meanness), similar to the reciprocity stories of Susan: One doll acted mean (or nice) to a second doll who because of the first doll’s action, acted mean (or nice) in return. In Figure 7.5, each diagram of YOU or ME acting NICE or MEAN represents a story with a certain skill structure, varying across the three skill levels of single representations, mappings, and systems. The structure

\[ \text{YOU}_{\text{NICE}} \longmapsto \text{ME}_{\text{NICE}} \]  

represents a mapping for reciprocity: If you are nice to me, I will be nice to you. Vertical arrows between specific story structures in Figure 7.5 indicate developmental sequencing for those stories, as when steps 3, 4, and 5 in the left column form part of a pathway along the strand for nice. The skill formulas focus on the central elements that children had to control in the nice/mean stories: roles (you or me), emotional valence (nice or mean), and relations between roles (shifts without coordination, mappings, and systems). Like structures in any living system, these elements subsume many additional components hierarchically within them such as actions, perceptions, feelings, goals, and social expectations.

Thus, each step in Figure 7.5 represents a different level of skill at conceptualizing relations among social interactions. Children’s stories develop along strands for each of the content domains of nice, mean, and nice-and-mean in combination. When stories are parallel from left to right, they emerge at approximately the same time in development. Their development also shows many connections among the strands.

In accord with the general tendency for researchers to neglect within-person variation and emphasize between-person variation, people sometimes misunderstand this developmental web, interpreting it to mean that different children are developing along each strand. To the contrary, each child develops simultaneously along each of the strands in the web in Figure 7.5. That is, each child is simultaneously developing understandings about positive valence (how nice interactions occur), negative valence (how mean interactions occur), and combined valence (how nice and mean can be combined in an interaction). When the three strands are all closely parallel, with no clear bias toward one or the other, then the web looks like Figure 7.5, with complexity as the primary determinant of developmental ordering. Steps of the same complexity are parallel in the web, independent of valence.

One characteristic of emotions, however, is that people typically show biases in their actions and thoughts. Biases toward certain action tendencies are one of the defining characteristics of emotions, as is discussed in the later section on Emotional Development. Emotional biases often have strong effects on a developmental web; they shift relations between strands, and they change developmental orderings. For the nice-and-mean web, one far-reaching emotional bias is a general favoring over time of one pole of evaluation—toward positive (nice) or negative (mean). One of the most strongly established findings in social psychology is that most people show positive biases in their activities and evaluations, especially for attributions about themselves (Higgins, 1996; Osgood, Suci, & Tannenbaum, 1957). Figure 7.6 shows a global bias toward the positive.

Although positive biases are pervasive, there are also many instances of negative biases. Powerful biases toward the negative can be produced by trauma such as child abuse (Ayoub, Fischer, & O’Connor, 2003; Westen, 1994) and by implicit attitudes (Greenwald et al., 2002). When children show a strong and persistent bias toward the negative and against the positive, their entire developmental web is shifted (biased) in the opposite direction than in Figure 7.6—toward the negative pole. That is, mean interactions are understood earlier than nice ones, and the combination of
nice and mean is delayed as well. A number of abused children and adolescents show an alternative developmental pathway based on this bias toward the negative (Fischer et al., 1997; Rappolt-Schlichtman & Ayoub, in press). Besides the long-term effects of experience, there are short-term within-person effects as a function of context, mood, and similar factors, as when being in a negative mood leads to a bias toward negative stories. In this way, developmental webs can be useful for representing variations in developmental pathways not only between people but also within a person over time.

**Modeling Nonlinear Dynamic Growth in a Web**

Besides the representations of weblike relations between steps and strands like those in Figures 7.2 and 7.5, various tools can be useful for analyzing different properties of development. One example that can be particularly powerful is mathematical modeling of growth functions (Singer & Willett, 2003). Each strand in a web
can be described in terms of its growth function, which in this case is represented by a nonlinear dynamic growth model (Fischer & Kennedy, 1997; van Geert, 1991, 2003). Figure 7.7 shows an example of growth curves produced by the model for each of the three strands.

The growth model includes a global positive bias like that in Figure 7.6, and under certain conditions, it also produces stagelike jumps in development, which are discussed in the next section. Complexity scaling provides the metric for quantifying growth of the strands, with scaling tools provided by dynamic skill theory. The graph clearly represents the bias toward positive valence and away from negative and combined valences, emphasizing the quantitative advantage of the nice strand over the others. The graph also highlights the fits and starts in growth and the relations between them—something that is not evident in the web diagram. However, this quantitative graphing de-emphasizes the ordering relations among specific story structures, which are clearly marked in Figures 7.5 and 7.6. Different tools for analysis of developing activity structures capture different properties of the structures, and no single tool captures all important aspects.

**How Dynamic Skills Explain Variability in Development**

The characteristics of skills, including the weblike process of skill construction, can help both explain and predict patterns of variability that have eluded traditional static accounts of psychological structure. In this section, we show how three basic forms of systematic developmental variability—(1) complexity level, (2) sequence, and (3) synchrony—can each be explained by the characteristics of dynamic skills. In a subsequent section, we consider issues of methodology and measurement used in the precise description and prediction of variability in development.

**Developmental Range: Optimal and Functional Levels**

Children (and adults) routinely perform across a range of skill levels, like Susan telling stories about nice and mean at two different levels with her counselor. A fundamental error stemming from static conceptions of psychological structure is that each individual is treated as “possessing” one fixed level of structure, either across domains or in a domain, as if cognition were a sealed bottle with a fixed level of liquid in it. From this point of view, an individual’s behavior is expected to be homogeneously consistent with the fixed level of cognition such as the number of items that a child can sustain simultaneously in working memory. Deviations from this fixed level then seem mysterious and appear to call for complicated explanations. Often the deviations are ignored, as researchers mistakenly use methods that sum across individuals, activities, and contexts and treat true variations in level as errors of measurement (Estes, 1956; Fischer, Knight, & Van Parys, 1993; Skinner, 1938; van Geert & van Dijk, 2002).

A person possesses different competences in different contexts and emotional states. The types and complexities of organization found in dynamic skills are always changing because (a) people constantly vary their activities as they adjust to varying conditions and coparticipants, and (b) people commonly reorganize their skills to deal with new situations, people, and problems. For instance, a tennis player plays at top level one day—after a good night’s rest, on an asphalt court, against a well-known opponent. The same player plays at a much lower level the next day, with a bad night’s sleep, on a clay court, against a new adversary. This reduction in the player’s skill level is a real change in the organization of activity, not a departure from some underlying stage or competence that is the “real” thing. The person unconsciously changes the actual relationships among the participating systems of perception, motor anticipation, motor execution, memory (for instance, of the other player’s strengths), and so on. These relations...
constitute the dynamic structure of skill. The level of organization of tennis skills varies because coordination among the systems is different on the 2 days. To posit any additional layers of abstract competence or stage structure to explain this variation is unnecessary, as it is accounted for by the dynamic properties of real activity systems.

Comparable variations in skill level occur in most skills, from playing tennis to interacting socially, planning a party, and reasoning about scientific or literary questions. Vygotsky (1978) spoke of the zone of proximal development (ZPD) and the variation between performances as a result of presence and absence of scaffolding by an expert. Our research has documented an important principle of variation in this zone: the developmental range introduced earlier, which is the interval between a person’s best performances with and without social contextual support in some domain. Susan showed a developmental range in her construction of stories about nice and mean interactions.

In a study of nice and mean stories, 7-year-old children telling stories under conditions of high and low social-contextual support showed a consistent developmental range, repeatedly changing to a high level with support and a lower level without it, as shown in Figure 7.1 and Table 7.1 (Fischer, Bullock, et al., 1993). A typical 7-year-old produced a highest story at step 3 (Level R2, representational mappings) under low-support conditions but achieved step 6 (Level Rp3, representational systems) under high-support conditions. The interval between these two developmental levels (a child’s developmental range for this domain) is indicated in Table 7.1, which is based on the data in Figure 7.1. The highest skill level when functioning independently (under low support) for a given domain is referred to as the functional level. The highest level with high-support conditions is the optimal level.

The interval of variation for a given skill can extend even farther, as suggested in Table 7.1. Social support often goes beyond prompting or modeling to actual coparticipation in a task (also called scaffolding), where, for example, an adult takes on acting out the role of one of the dolls in a story with a child. With scaffolding, the level of task performance can be extended several steps upward because psychological control of the activity is shared with an expert. In contrast, circumstances such as emotional stress, fatigue, distraction, or interference by a coparticipant can lead a person’s skill level to fall below his or her functional level.

Developmental range seems to characterize performance across most tasks, ages, and cultures, and it grows larger with age, at least through the late twenties (Fischer, Bullock, et al., 1993; Fischer et al., 2003). Most people experience the developmental range directly when they learn something new with a teacher or mentor. With the prompting of the teacher, they understand a new concept or control a new skill at a relatively high level. Without the prompting, their level of skill drops precipitously such as when they leave the classroom and try to explain the new concept to a friend who knows nothing about it.

A study of Korean adolescents’ conceptions of themselves in relationships illustrates the striking gap that commonly occurs between optimal and functional levels, as shown in Figure 7.8 (Fischer & Kennedy, 1997; see also Harter & Monsour, 1992; Kennedy, 1991). In this study, adolescents participated in the Self-in-Relationships Interview (SiR), which assessed developmental level under two conditions (described in more detail in the section on Methodology of Dy-

<table>
<thead>
<tr>
<th>Step</th>
<th>Skill Level</th>
<th>Performance Level</th>
<th>Social Support</th>
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<tbody>
<tr>
<td>1</td>
<td>Rp1</td>
<td></td>
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<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>Rp2</td>
<td>Functional level</td>
<td>None</td>
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<tr>
<td>4</td>
<td></td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
<td>Rp3</td>
<td>Optimal level</td>
<td>Priming through Modeling, etc.</td>
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<td>7</td>
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<tr>
<td>8</td>
<td>Ab1</td>
<td>Scaffolded level</td>
<td>Direct participation by adult</td>
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<td>9</td>
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Note: Functional and optimal levels are upper limits on performance, which show stability for a task. Scaffolded level involves a range of performance indicated by the vertical line on the left, with the specific step depending on the nature of the scaffolding in combination with the 7-year-old’s skill.
namic Structural Analysis). For the optimal-level condition, high support involved the construction by each adolescent of a detailed diagram of his or her own descriptions of self in several different relationships such as with mother, father, sibling, best friend, and teacher. The diagram as well as the interview questions supported optimal performance by prompting key components of skills. For the functional-level condition, low support involved a relatively open-ended interview that was similar to most traditional assessments of self for adolescents; they were simply asked to describe what they were like in each relationship and how their descriptions related to each other. There was no prompting of key skill components.

The constructive web provides another useful way of portraying variability in developmental level. Figure 7.9 represents a developmental web for an individual’s conceptions of self in two important relationships, mother and best friend. Among each strand the heavy solid line indicates a well-established, highly automatized skill for a given context. An individual’s performance drops to this level in circumstances of high stress, fatigue, or interference. The thinner solid strand represents the functional level of independent control under normal conditions for this context—a level of skill organization that is well established but less automatic. The optimal-level skills indicated by the dashed lines are still under construction, occurring when the person receives modest contextual support such as modeling or prompting. Finally, the dotted lines indicate a skill level that the individual has recently begun to construct, in which the person can hold the component skills in an integrated structure only if there is direct scaffolding, coparticipation of a more capable partner.

From this perspective, it is easy to see why skill levels vary over a wide range. The variation is a direct consequence of the active, constructive, and context-embedded nature of human activity. As Figures 7.8 and 7.9 suggest, adolescents’ conceptions of themselves in relationships are not fixed capacities but multilevel structures of dynamic skills under construction. Skills early in a particular developmental sequence are better integrated and more stable across time and conditions than skills more recently constructed or just starting to be constructed. Variability in the organization of a person’s skill at holding in mind and organizing the events and characteristics of a social relationship are a natural consequence of these constructive dynamics. There is no need to invoke explanations in terms of formal stage structures or hidden competences hovering over and guiding activities. Variability is explained by constructive dynamics. The task is to build theoretical models and methods for describing and analyzing these dynamics.

**The Dynamics of Stages and Developmental Synchrony**

Besides explaining sources of variability in level, the concept of dynamic skill also provides a framework for facilitating analysis of processes of change in constructive dynamics. Specifying the conditions that lead to
variability, as in developmental range, allows the control and use of the conditions to analyze patterns of change. We have employed this control of conditions to illuminate a classic argument about processes of change, the stage debate (Bidell & Fischer, 1992). Traditionally the dialogue about stage has not always been informative, amounting to assertion without accommodation:

**Stage proponent:** “There are stages of cognitive development.”

**Nonstage proponent:** “No, there are no stages.”

**Stage proponent:** “Yes, there are.”

**Nonstage proponent:** “No, there aren’t.”

Instead of arguing about whether stages exist, dynamic skill analysis provides tools for specifying the conditions for stagelike change and those for continuous, nonstagelike change. Stages both do and do not exist, depending on the dynamics of the conditions of activity!

In the study of Korean adolescents, dynamic skill theory was used to predict the conditions and age intervals when growth shows discontinuous jumps in level versus smooth change. High-support conditions were predicted to produce two discontinuities marking the emergence of two new levels of coordination of abstractions. Figure 7.8 shows the predicted difference in growth functions: Optimal-level growth spurted twice, at grades 11 and 13, which are comparable to the ages of optimal-level spurts found in research with American and Chinese samples (Cheng, 1999; Fischer & Kennedy, 1997; Harter & Monsour, 1992; Wang, 1997). Researchers using the skill theory framework have observed similar patterns in other types of skills, in age groups ranging from preschool to adulthood (e.g., Corrigan, 1983; Fischer & Hogan, 1989; Fischer et al., 2003; K. Kitchener, Lynch, Fischer, & Wood, 1993). In each case, the developmental spurt is associated with a major transition in skill level such as the transitions to abstract mappings and abstract systems under optimal conditions in Figure 7.8. When optimal and functional levels are lumped together, this discontinuity is masked because the developmental function produced is effectively an average of two different developmental functions, a process that inevitably masks the true growth functions. In addition, there is much evidence of other kinds of discontinuities such as gaps in Rasch scaling and changes in brainwave patterns at similar points along the hierarchical complexity scale (Dawson, 2003; Dawson et al., 2003; Fischer & Rose, 1996).

As this and many other examples demonstrate, the developmental level of behavior varies with assessment context, coparticipant, state of arousal, emotional state, and goal, just to name a few of the most obvious sources of variation. Some researchers have argued that these variations demonstrate an absence of developmental stages (Brainerd, 1978; Flavell, 1982; Thelen & Smith, 1994), but these arguments overlook the order in the variability. The organization of behavior develops systematically, and it also varies from moment to moment. These facts are contradictory only for overly simple concepts of stage and variation. Real behaviors—and real neural networks as well—function not at a single level but in a range or zone (A. Brown & Reeve, 1987; Fischer, Bullock, et al., 1993; Grossberg, 1987; Vygotsky, 1978). Research to test for stagelike change must take this range into account and analyze which parts of the variation show stagelike characteristics and which do not. Only then will the field move beyond endless arguments in which protagonists focus on only part of the variation and thus draw half-baked conclusions.

The separation of optimal and functional is one example of the way a dynamic skills framework permits the prediction and explanation of patterns of variability that have typically been ignored or explained away by theories relying on static stage or competence models of psychological structure. Although researchers may differ with the specific interpretation given to a phenomenon like the discontinuities in optimal level, the constructive-dynamic framework described here makes it possible to debate the issues empirically, by providing concepts and research methodologies to control and manipulate variations in the developmental process. (These methodologies are described throughout this chapter; see also the section on Methodology.)

An important part of “stage” is the expectation of high developmental synchrony. Stage theories predict high stability across contexts in the level of performance an individual will display. The idea of a “hard stage,” an underlying logical system pervading the mind at a given stage (Kohlberg, 1984; Piaget, 1985), implies that a given person should perform logically equivalent tasks at the same time regardless of state or context—say, Piaget’s tasks of conservation of liquid and classification of shapes in matrices. It is as if Piaget touched children’s heads on their seventh birthday, and instantly they were transformed into concrete operational thinkers. This strong “point synchrony” (simultaneous development of new levels across domains) is seldom empirically supported (Fischer & Bullock, 1981). Instead, children and
adults show a high degree of variability in levels across tasks and contexts, even with tasks that are logically similar. For example, children who understand tasks for conservation of number frequently fail tasks for conservation of liquid even when the procedures and questions are similar.

On the other hand, there is evidence of real developmental synchrony as well when dynamic concepts are used to analyze how and when synchrony does and does not occur. Equivalent concepts show what is sometimes called “interval synchrony,” appearing not at the same time but within a relatively short time interval of each other. Moreover, this interval is much smaller for concepts about closely related topics measured in similar tasks, especially when there is a clearly defined conceptual structure that is ecologically valid (T. L. Dawson & Gabrielian, 2003; K. Kitchener & King, 1990; Pirttilä-Backman, 1993). The disparity in intervals between concepts drops as differences in content, context, and concept are reduced. Case and his colleagues (1996) have even shown that, with a well-defined central conceptual structure, teaching the structure increases the degree of synchrony across domains to the point that it sometimes accounts for approximately 50% of the variability—a remarkably large effect indicating high interval synchrony. Lamborn, Fischer, and Pipp (1994) demonstrated that development of understanding of specific moral concepts such as honesty and kindness related closely to relevant social problem-solving skills but not to other problem-solving skills.

The combination of systematic variability and synchrony is hard to explain with static concepts of psychological structure such as stage or competence. Piaget and other hard-stage theorists initially waved away evidence by arguing that different tasks posed different forms of resistance to structures of logic. The resulting decalages (time gaps) were said to result from different kinds of resistance, but the processes by which resistance functioned were never explained (Kohlberg, 1969; Piaget, 1971).

The principles of constructive dynamics explain patterns of variation in stage patterns and synchrony in a straightforward manner:

- Skills are constructed hierarchically by integrating earlier skills into a more inclusive whole.
- Skills vary across multiple levels for each individual depending on context, goal, state, support, and other factors. An important example is the developmental range.
- Skills are constructed for participation in specific tasks and contexts and over time can be generalized to others through specific generalizing activity (Case et al., 1996; Fischer & Farrar, 1987; Fischer & Immordino-Yang, 2002).

Even in the simple diagram of two domains in Figure 7.9, it is obvious that among the functional, optimal, and scaffolded levels, some skills will be the same across domains, and others will be different for the same domain. Taken together, these principles help explain how interval synchrony occurs as well as how people build general skills. This process is elaborated later in the section titled: Building Structures: Transition Mechanisms and Microdevelopment.

The scale for hierarchical complexity in Figures 7.3 and 7.4 provides a metric for assessing greater or lesser synchrony, moving beyond all or none arguments. For many related skills, levels do not show complete asynchrony but are relatively close even when they differ. The growth functions for nice and mean in Figure 7.7 illustrate how the same growth curves can simultaneously show similarities and differences in the ages of change. Stepping back to look at the broad sweep of change makes the synchronies evident; stepping close to look at the details of change highlights the disparities. Each new skill at a higher level is built from similar lower-level skills: Each extension of a skill to a new level is a constructive generalization constrained by the component skills available. There is no need to invoke pervasive logical structures or innately determined formal constraints to account for interval synchrony in development. The dynamics of the construction of skills in context explain both the variability and the synchrony found in patterns of variation.

Variability in Sequence of Acquisitions

Another form of variation involves the sequence in which skills for a given task or context are constructed, often called developmental sequences or pathways. Although evidence of variation in specific developmental sequences has been taken as evidence against hierarchically constructed stages (Brainerd, 1978; Gelman & Baillargeon, 1983), a dynamic structural analysis illuminates when sequences occur and when they do not, whereas stage and competence theories are hard pressed to account for observed patterns of variability and stability in sequences.

An examination of the evidence shows a familiar pattern: There is high variability in developmental
sequences, but this variability is neither random nor absolute. The number and order of steps in developmental sequences vary as a function of factors like learning history, cultural background, content domain, context, coparticipants, and emotional state. In addition, the variability in steps appears to be contingent on the level of analysis at which the sequence is examined (Dawson & Gabrielian, 2003; Fischer, 1980b; Fischer et al., 2003).

Developmental sequences tend to appear mainly at two levels of analysis: (1) large-scale, broad sequences covering long times between steps, relatively independent of domain, and (2) small-scale, detailed sequences found within particular domains. Large-scale sequences appear to be relatively invariant. Children do not, for instance, exhibit concrete operational performances across a wide range of tasks, and then years later begin to exhibit preoperational performance on related tasks. On the other hand, small-scale sequences have often been found to vary dramatically (Ayoub & Fischer, in press; Wohlwill & Lowe, 1962).

Typically, variation in small-scale sequences is associated with variation in task, context, emotion, coparticipant, or assessment condition. For instance, Kofsky (1966) constructed an eleven-step developmental sequence for classification of objects based on Inhelder and Piaget’s (1964) concrete-operational thinking and used scalogram analysis to rigorously test the sequence. Her predicted sequence followed a logical progression, but it drew on an assortment of different tasks and materials to evaluate each step. The results showed weak scalability with several mini-sequences.

Other sources of variation in small-scale sequences include cultural background, learning style, learning style, and emotion. Price-Williams, Gordon, and Ramirez (1969), for instance, examined the order of acquisition of conservation of number and substance in two Mexican villages. The villages were comparable in most ways except that in one village the children participated in pottery making from an early age. Children of the pottery-making families tended to acquire conservation of substance (tested with clay) before conservation of number, while nonpottery-making children showed the opposite tendency.

Affective state can also powerfully affect developmental sequences (Ayoub & Fischer, in press; Fischer & Ayoub, 1994). For example, inhibited and outgoing children show different sequences in representing positive and negative social interactions, especially those involving the self. Inhibited children often show the positive bias in Figure 7.6. Extreme emotional experiences such as child abuse often lead to highly distinctive developmental sequences for representing self and others in relationships, as we discuss in the section on Emotions.

Furthermore, the failure to consider variation in sequences from factors such as learning style, disability, or cultural difference leads to combining undetected variations, with the result that task sequences erroneously seem to scale poorly (Fischer, Knight, et al., 1993). As soon as they are resolved into alternative sequences, they scale well. For example, a sequence of six tasks related to reading single words scaled weakly when tested on a sample of poor readers in first to third grades (Knight & Fischer, 1992). In each task, a child dealt with an individual word, reading it directly (Reading Production), reading it through matching it with a picture (Reading Recognition), producing a word that rhymes with it (Rhyme Production), recognizing a word that rhymes with it (Rhyme Recognition), naming the letters seen in the word (Letter Identification), or describing what the word means (Word Definition). Use of a scaling technique for detecting alternative sequences showed the existence of three different well-ordered sequences in the sample. Subsamples of poor readers showed sequences that reflected their specific reading difficulties.

The constructive web framework provides a tool for rethinking these patterns of variation in the constructive dynamics of skill development. Alternative developmental pathways can often be traced for different groups of children such as the three pathways for good and poor readers. When the standard metaphor of the developmental ladder is used, children are compared only in relative progress or delay on a single progression from low to high performance on a single sequence. As long as only a single pathway is considered, there seems only one remedial choice: to work to speed up the apparently delayed group along the “normal” pathway.

Figure 7.10 shows the three weblike pathways that the students take through the series of reading tasks. For each group, the order of acquisition for the six tasks was tested using partially ordering scaling, a statistical technique that is based on the logic of Guttman scaling (Krus, 1977; Tatsuoka, 1986). A line between two tasks means that the ordering is statistically reliable. A comparison of the three developmental pathways shows that the poor readers are not delayed with respect to a universal sequence, but actually follow different pathways of acquiring these skills. Normal readers all showed one
main pathway (a), but poor readers showed two other pathways different from the normal one (b and c).

This map of alternative pathways suggests a different remedial educational strategy. Instead of attempting to speed up development in poor readers, teachers can help channel children following divergent pathways into alternatives that converge on the goal of skilled reading (Fink, in press; Wolf & Katzir-Cohen, 2001). By providing environmental support, teachers can channel development, building bridges from the known to the unknown instead of providing frustrating repetitive encounters with the unknown. This approach is being realized most fully in educational efforts for children with learning disorders and handicaps (Fischer, Bernstein, & Immordino-Yang, in press; Rose & Meyer, 2002) and also in some work with maltreated and aggressive children (Ayoub & Fischer, in press; Kupersmidt & Dodge, 2004; Watson, Fischer, & Andreas, 2004).

From this perspective, the tool of mapping alternative developmental pathways is especially important for the study of development among children of differing socioeconomic groups, cultures, ethnicities, or races, and children with learning or psychological disorders. Against the backdrop of a developmental ladder based on White, middle-class norms, children from different social groups are frequently seen as exhibiting deficits in development. Within the web metaphor, many developmental differences become alternative pathways instead of deficits, and curricula, interventions, or therapies can be created based on these alternative pathways.

Research methods should allow detection of alternative sequences instead of forcing all children to either fit or not fit one sequence. Remarkably, much research on development has treated sequences not as variable phenomena to be explained but as fixed milestones in a ladder. In the early 1970s, Flavell (1971) and Wohlwill (1971) called for more research on variation in sequences, but this call has only recently begun to be taken seriously. Most neo-Piagetian developmental theories and domain theories still differentiate only gross stages, ignoring completely branches in sequences and variations among steps, with a resulting overgeneralization of the
uniformity and universality of cognitive and emotional development.

In summary, the organization of human action, thought, and emotion shows wide, systematic variation that can be measured, analyzed, and explained in hierarchically organized systems of contextually embedded activity. Patterns of variation in developmental level, synchrony, and sequence are all consistent with a constructivist, dynamic systems interpretation of psychological structure. In light of the pervasive evidence of cognitive variability, it seems surprising that the most prominent models of psychological structure have been and continue to be based on static conceptions such as stage, competence, and innate core knowledge. To understand why these static conceptions of structure continue to dominate and how dynamic views of psychological structure move beyond them, we consider the history and origin of static conceptions of psychological structure and their shortcomings as explanatory tools in the next section.

THE CRISIS OF VARIABILITY AND THE CARTESIAN SYNTHESIS IN DEVELOPMENTAL SCIENCE

The failure of developmental theory to recognize the dynamic and constructive nature of psychological structure has led to an explanatory crisis in developmental science. At the heart of this crisis is the problem of how to account for the tremendous variability in developmental phenomena, which during the past 30 years has increasingly moved from the background to the foreground of developmental research and theory (Bidell & Fischer, 1992; Damon, 1989; Siegler, 1994, Chapter 11, this *Handbook*, Volume 2; Telen & Smith, Chapter 6, this *Handbook*, this volume). The Cartesian method conceptually isolates mental systems from their natural context of interrelations with the biological and cultural systems of which they are a part. This intellectual methodology of isolating an object of study from interrelationships with other phenomenon was successful in the early history of the natural sciences, but it obscures the complexity and dynamism of mental activity. It leads to systematic distortions when applied to the question of mental organization or psychological structure.

In this section, we review the Cartesian framework and the empirical debate surrounding the concept of “stage structure,” showing how this debate led to the discovery of variability in level, synchrony, and sequence, and why the formal view of structure was unable to predict or explain this variability. We then argue that three major theoretical movements since stage theory—(1) domain specificity theory, (2) nativist competence theory, and (3) competence/performance theory—have also proved inadequate in accounting for variability in structural development because they too have failed to move beyond the Cartesian structure-
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as-form paradigm. In the subsequent section, we describe a set of methods for moving beyond these approaches to do research that deals with variability more powerfully within a dynamic structural framework, including an outline of how to turn theories about developmental process into specific mathematical models that can be tested against growth patterns of individual children and adults.

The Cartesian Dualist Framework

The debate over nature-versus-nurture explanations of the origin of knowledge assumes the Cartesian framework, which is accepted by both sides—nature/nativist and nurture/empiricist. Grounded in the dualism of mind and world, the two sides necessarily imply one another. The nativist-rationalist tradition and the empiricist-learning tradition are two sides of the same Cartesian coin. The nativist branch of the Cartesian framework explains the origin of psychological structure as preformed innate structures such as concepts. The empiricist branch explains it as experience stamping its shape on the natural mind. Psychological structure, conceived as innate form, implies some outside input to be stored and manipulated. Environmental information conceived as preexisting packets of knowledge requires some sort of preexisting receptacle or organizing structure in the mind to receive, contain, and organize them. In this framework, only two explanations for the origin of psychological structure seem possible—nature or nurture—and they become the basis for the two branches of Cartesian epistemology.

The Cartesian tradition in philosophy and science brings with it the methodologies of reduction and reification. These methods, which have been profitably employed in many areas of science, result in systematic misconceptions when applied to dynamic processes like development of action, thought, and emotion. The dynamic organization of human mental activity is abstracted from the living systems of which it is a property and treated as a separately existing “thing,” giving birth to the conception of static structure. The reification of psychological structure as a separately existing static form leads scientists down false paths in trying to understand the origins and development of psychological organization. Instead of seeking to understand the constructive, self-organizing processes by which children build new relations among contextually embedded mental activities, theorists have been led into the futile nature-nurture debate about whether statically conceived psychological structure is somehow insinuated in the genome or is built up through analysis of perceptual-motor experience. These reductionist assumptions support static views of structure and limit the explanatory power of developmental theories.

The Cartesian method, emerging in the seventeenth century philosophy of René Descartes (1960) and others, gave science a powerful analytical tool to sort out the complexity of the world and focus on one aspect at a time for study. This tool, known as Cartesian reductionism, derives simplicity out of complexity by isolating one aspect of a process from its relations with other aspects of the process or from related processes, to be studied independently. Descartes tried to extract mind from nature by creating a dualism in which a separately existing mental structure receives impressions from the outside world through the sensory apparatus. Descartes’s famous dissection of the cow’s eye, revealing the image projected on the retina, supported his view that innate structures are fed with sensory images from the environment. Similarly, in his logical empiricism the philosopher John Locke (1794) asserted that some preexisting logical structure is required to explain how environmental input leads to higher order knowledge. Locke saw that the simple mechanism of association of sensory impressions could not account for higher-order knowledge involving induction, deduction, and generalization. Like Descartes, Locke’s account of knowledge acquisition involved a dualist conception in which a preexisting psychological structure receives and processes sensory input from the outside.

Although Cartesian reductionism has been and will continue to be an indispensable tool of scientific analysis, its strength—the isolation of phenomena from complex relations—is also its weakness (Wilson, 1998). When Cartesian reductionism is used exclusively as an analytic method, it eliminates an essential characteristic that needs to be understood—the interrelations of psychological systems both internally among component processes and externally with other systems. Understanding relations is a requisite for understanding change and variation in developmental or historical phenomena. In the real world, it is the interrelations among systems and processes that effect movement and change. The gravitational relation between the earth and the moon is key to sustaining the moon’s orbit, which generates the changing cycles of the moon seen on earth. To ignore the gravitational relation between
earth and moon would preclude understanding the source of this pattern of variability, and in turn its explanation of an orbital system. The reductionist approach can be highly efficient for restricted scientific purposes such as isolating a particular strain of bacteria that causes a human disease. It is problematic in studying any complex phenomenon involving relations among elements and systems such as the problem of how some bacteria evolve more virulent strains in the modern context of changing natural and social ecology, growing poverty and hopelessness in many locales, and overuse of antibiotics. The structure grows dynamically out of the relations among varying systems, neither from a static innate structure nor a static environmental structure stamped on the mind.

The exclusive use of reductionism as an analytical method fosters the related problems of reification and dualism, both arising from the neglect of relations in theoretical constructs. Without an account of the relations among systems that can explain movement and change, abstractions such as mind, thought, and structure appear static and isolated from other constructs such as body, action, or function. These static abstractions reify the phenomena they refer to, treating dynamic processes as frozen objects. The self-organizing, goal-directed activity of the human agent is ruled out of the accounts of development.

Moreover, because the relations between such reified processes are lost, they seem isolated, separate, and even opposite to one another. This seeming opposition of reified abstractions is the basis for the classic Cartesian dualisms separating mind from body, thought from action, and structure from function. Since the time of Descartes, such dualist assumptions have become ingrained in the mainstream of Western scientific thought in general and psychological theories in particular. The result has been static accounts of psychological phenomena and their origins and sterile debates that explain mental processes by one or another reified abstraction such as faculties, associations, stimulus-response bonds, innate concepts, or stages. While such single-construct explanations have generated intense debate, they have been notoriously limited in accounting for a broad range of developmental data.

**The Tacit Modern Synthesis in Psychology: Nativism and Empiricism Together**

The result of the debate that has continued for more than a century between empiricist and nativist theories of development is the emergence of a tacitly shared model—a kind of modern synthesis in psychology—that is neither strictly empiricist nor strictly nativist but simply Cartesian in its assumptions. The emerging model is an amalgam of a sort of logical empiricism with a version of maturationism. According to this view, infants are supplied innately with core knowledge systems that provide them with predetermined representations of certain aspects of the world such as numerosity and object permanence (Carey & Spelke, 1996; Hauser, Chomsky, & Fitch, 2002; Spelke, 2000). However, these initial representations must be extended by learning processes. Learning processes typically are characterized through a logical analysis of perceptual-motor input leading to inductions and generalizations growing from core knowledge. Debate continues about whether core knowledge systems change qualitatively over time or simply remain in place into adulthood, which mechanisms lead from innate representations to new forms of knowledge, and what roles perceptual analysis and learning mechanisms play in such changes. Yet the framework of the debate remains firmly grounded in Cartesian assumptions.

With respect to the origins and development of knowledge, the debate between empiricism and nativism—and the emerging modern synthesis—starts with a core set of shared dualist assumptions: The mind is isolated from its environmental context, thought is divided from action, and the way the mind is organized (psychological structure) is separated from the way it operates in the world (cognitive function).

Early empiricists tried to explain the origins of knowledge in sensory impressions of the environment with little reference to the role of the active person and mind. In classic empiricist theories, the role of organization in the mind is minimal (a “blank slate” in the extreme), and it is shaped by environmental contingencies. Links or associations between ideas are generated by whatever happens to co-occur: A person sees red and apple at the same time, so she or he remembers red-apple. In the behaviorist version of associationism, the mind is reduced to almost no role at all, and behavior is organized directly by environmental contingencies through the stimulus-response bond (Skinner, 1969). Contemporary empiricist theories tend to rely on an information processing metaphor in which sensory information from the environment is parsed by perceptual analysis into basic knowledge units that can then be recombined into higher level knowledge (Newell & Simon, 1971). However, common to all empiricist theories of mental development is a dualist separation of
mind from environmental context, a concomitant reification of the mind as a container or mechanistic processor, and a dualist separation of mental structure from mental content.

Information processing theories, in the empiricist tradition, have focused on the input and storage of information, building the analysis of cognitive structure on a model of information flow in a computer. These theories came late to the problem of where cognitive structures come from and how they change over time. A few information processing theories have posited qualitative hierarchies of cognitive structures (Anderson et al., 2004; Klahr & Wallace, 1976; Pascual-Leone, 1970), but they have provided only sketchy accounts of the origins of these structures and the mechanisms of transition from one structure to another.

Despite years of vociferous debate with empiricists, nativists share this set of dualist assumptions but privilege them in different ways (Fischer & Bullock, 1984; Overton, Chapter 2, this Handbook, this volume). Nativists and the closely associated rationalists also start from an acceptance of mind-environment, mind-body, and thought-action dualisms. The difference with empiricists is that the structure of the mind is primary instead of the structure of the environment. Nativists accept the dualism of inner structure and outer sensory information, but they simply assign them different roles. Instead of filling up preexisting mental containers with experience, the nativist role for sensory information is to provide inputs, which trigger the emergence or activation of preexisting psychological structures such as the syntax of language or the properties of objects. The dualist separation of psychological structure from its contextual relations with human activity has led to the reification of psychological structure and the inevitable conclusion that the structure must be innate. The outside world provides grist for the cognitive mill, or sometimes a triggering stimulus to kick off a new level of maturational, but plays a minimal role in the development of the psychological structures themselves.

When a dynamic system is approached statically, the complex relations by which it is organized and by which it develops are lost. The inescapable fact that it is organized is abstracted and reified as static form. When psychological structure is conceived as static form, with no activity and no inter-systemic relations to explain its origin and development, it appears to have an existence of its own, separate from the reality from which it is abstracted. Therefore, psychological structure must be innate, according to this argument.

The reification of dynamic structure as static form in the Cartesian tradition has earlier roots in Western culture (Pepper, 1942) extending back at least to Plato (1941) 2,000 years ago. His doctrine of ideal, universal forms provides a particularly clear example of how concepts and ideas are seen as independent of the mind. These forms exist independently of the imperfect material world, which evolves toward them. They are transferred to each newborn infant, who gradually remembers them with maturity. In the eighteenth century, Kant (1958) argued that we inherit preexisting cognitive structures or categorical imperatives, which determine how we make sense of our experience. In recent times, Chomsky (1965) and Fodor (1983) have argued for pre-determined linguistic structures called modules that impose specific patterns on our learning of languages and concepts. Following Chomsky’s lead, contemporary neo-nativists have posited innate structures determining such developmental achievements as number concept, object concept, and Euclidian geometry (Baillargeon, 1987; Fodor, 1983; Spelke, 1988).

Because both the empiricist and the nativist versions of the Cartesian tradition share the same dualist, static conception of psychological structure, neither has really challenged the other on the nature of psychological structure. However, the debate over how much emphasis to place on innate structures versus learning has forced each side to examine, rethink, and revise its theories. As theorists on both sides of the empiricist-nativist debate have attempted to revise their models to meet these challenges they have naturally turned to models within their shared Cartesian framework, and thus have increasingly adopted elements of each other’s theories. While still emphasizing the importance of perceptual input, empiricism-based theories have come to rely on nativist conceptions about the origins of psychological structure to help explain how that input gets organized and how its organization changes over time. On the nativist side, theorists have increasingly come to depend on various functional-learning and perceptual-analysis mechanisms to explain how innate structures can lead to knowledge and conceptual change.

At first glance, bringing together two opposing tendencies into a more integrated model may seem like progress toward a more comprehensive theory. The resulting amalgamated model, however, does not take us beyond the Cartesian framework of dualism and therefore does not offer a way beyond the static conceptions of psychological structure—a way to explain how structure emerges from the interrelated activity of people...
with their world and each other. For this reason, the Cartesian synthesis is not any more successful in explaining the broad data of variability in cognitive development. Linking static conceptions of psychological structure to mechanistic information processing models does not provide us with better explanations for variability in cognitive performance than either tradition did on its own. Understanding why Cartesian models—whether empiricist, nativist, or a combination of the two—have trouble explaining variability requires considering in more depth the static conceptions of psychological structure inherent in this tradition and the explanatory limitations they carry with them. This analysis lays the foundation for understanding how dynamic structuralism provides a path to analyzing the dynamics of structure in development starting from activities in context.

The Structure-as-Form Paradigm

Because the Cartesian tradition has been the dominant framework for scientific theories in general and psychological theories in particular, reductionism and reification have been the rule rather than the exception in conceptions of psychological structure. The prominence of these modes of thought in the Western intellectual tradition has encouraged the confounding of dynamic structure with static form. Accordingly, the structure-as-form model has tended to serve as an unconscious foundational metaphor (Lakoff & Johnson, 1999; Pepper, 1942) or paradigm (Kuhn, 1970) for scientific accounts of the organizational properties of natural and social systems, especially in psychology (Overton, Chapter 2; Valsiner, Chapter 4, this Handbook, this volume).

It is no easy matter to move beyond the static metaphors for structure, which language and cultural practices strongly support and which people typically use unaware. A dramatic, pervasive example is the conduit metaphor for communication (Lakoff & Johnson, 1980; Reddy, 1979). In ordinary discourse about communication of knowledge, people use this metaphor, talking as if the mind is a container for knowledge and as if things that they know are discrete objects. They treat communication as the transfer of knowledge objects from one person to another, as if static objects are being sent through a conduit such as a pipe or telephone line. This metaphor often leads to the belief that telling someone an item of information (giving them an object) is sufficient to communicate it and even to teach it. If a course or a chapter covers a concept, for example, then the student or reader is assumed to have been given that object. If they fail to demonstrate the knowledge specified by that object, they are taken to be ineffective learners (stupid, inattentive, or lazy). Research shows that students do not learn effectively from such presentations, but they require experience with acting on and manipulating the material to understand it (Crouch, Fagen, Callan, & Mazur, 2004; Schwartz, 2000; Schwartz & Fischer, 2005). This static metaphor (and others as well) omits the constructive nature of learning, knowing, and understanding from the assumed structure of communication and education, and their social nature is minimized too.

The conceptualization of structure as form treats structure as a static property of knowing that can be separated from the knowing activities themselves, just as the conduit metaphor separates objects of knowledge from activities of knowing. Imagine trying to remove the structure from the Golden Gate Bridge, gather it up somehow, and ship it off to someone else, who would add it to a pile of steel, which would quickly arise to form a replica of the San Francisco landmark. Even more absurd would be trying to extract the structure from the tightly coordinated, self-organizing, physico-chemical processes of a living cell and then to apply it to a blob of inert chemical components in hope of generating a new cell. Structure is an inseparable quality of real dynamic systems, and it emerges as they develop (are constructed). In reality, structure cannot be separated from its role as the organizational property of dynamic systems.

In the study of development, three static conceptions of psychological structure have predominated, all of which have used static forms to explain dynamic structures. In many developmental theories, including Piaget’s (1983, 1985) stage theory, activities take the form of abstract logical structures. In many linguistic and cognitive theories, activities take the form of preformed quasi-logical rules, typified by Chomsky’s (1957, 1995) theory of innate linguistic competences and its corollary theories of innate cognitive competences (Baillargeon, 1987; Fodor, 1983; Spelke, 1988). In many traditional empiricist theories in Anglo-American psychology, activities take the form of linear input-output rules, as typified by linear models in statistics, information processing, and behavior genetics (Anderson et al., 2004; Horn & Hofer, 1992; Plomin, DeFries, McClearn, & Rutter, 1997). This linear form of theory is especially prominent in approaches that focus on domain speci-
ficity, the separation of knowledge into distinct parts tied to domains of experience.

Despite well-publicized disagreements among these three frameworks, they derive their core assumptions from the structure-as-form paradigm, portraying psychological structure in abstract forms existing separately from real self-organizing human activities. In stage theory, psychological structure is seen as a universal abstract logic imposing itself on the developmental trajectories of every person. Although Piaget believed that activity is the basis of knowledge and development, the base metaphor for his stage theory of cognition is successive stages of logic that determine specific cognitive performances across contexts and domains of knowledge and are relatively unaffected by the contexts of those performances. Similarly, nativist competence theories project a universal preformed code, blueprint, or set of instructions that somehow exists separately from the activities that it will someday engender. Like Platonic forms, these blueprints lurk among the genes, awaiting the right moment to impose order on behavior.

The experimental/psychometric framework also bases its core assumptions on structure as form, but there the structure is hidden behind standard methods and paradigms for explanation. The assumed linear combinatorial structures of dichotomies—person and environment, input and output, heredity and experience, domain x versus domain y—are embedded in research designs, statistical techniques, and theoretical concepts, but their implicit assumptions about structure are seldom acknowledged (Bronfenbrenner, 1979; Fischer & Bullock, 1984; Gottlieb, Wahlsten, & Lickliter, Chapter 5; Overton, Chapter 2; Thelen, & Smith, Chapter 6; Valsiner, Chapter 4, this Handbook, this volume; Wahlsten, 1990; Wittgenstein, 1953). Person and environment are partitioned into separate groups of factors instead of being treated as dynamic collaborators in producing activities. Much of modern biology has assumed similar reductionist, reifying notions of structure as form (Goodwin, 1994; Gottlieb, 2001; Kauffman, 1996).

The dominance of the structure-as-form paradigm in cognitive developmental theory has forced scholars to choose among these three inadequate notions of structure—stages, innate structures, and linear information processes. Instead, structure needs to be conceived dynamically. Psychological structure exists as a real organizational property of dynamic systems, just as the structure of the human skeletal system and the human circulatory system are real and distinguish humans from other animals. The structure is a property of the self-organizing systems that create it—the dynamic organization exhibited by self-organizing systems of mental and physical activity, not a free-floating ghost of competence or logic that dictates behavior to its human machine. Before we explicate concepts and methods of dynamic structure, however, we need to ground our argument with analysis of key problems with the static conceptions of structure that pervade developmental and psychological science.

The Stage Debate and the Discovery of Variability in Cognitive Development

The strength of the stage structure concept, as with all structure-as-form models, is its account of stability in development. Skills exhibit patterns of stability both in the ways they function and the ways they develop. What would account for such stable patterns in the functioning and development of cognition? Piaget’s (1983, 1985) conception of formal logical stages addressed this question with what seemed to be a powerful and reasonable explanation: Individuals construct logical structures that preserve the organization of their interpretive or behavioral activities to be applied again at later times or in different situations. The existence of these structures accounts for the ability to apply the same concept or skill across many situations. Similarly, the emergence of concepts in specific sequences is accounted for by the fact that the logical structures underlying the concepts are constructed gradually, so that a partially complete logic would give rise to one concept (e.g., one-to-one correspondence) and the later completion of the logical structure would give rise to a more extensive and logically complete concept (e.g., conservation of number). Piagetian stage theory places all human cognitive activities into a sequence of abstract logical forms, but it has proved incapable of explaining the vast array of deviations from stage predictions (Bidell & Fischer, 1992; Flavell, 1971; Gelman & Baillargeon, 1983).

However, the strength of the stage structure concept was also its greatest weakness: Whereas universal logical structures accounted elegantly for stability, they offered hardly any explanation for variability in the functioning and development of cognition. Because the stage concept equated psychological structure (the organization of dynamic mental activity) with static form (formal logic), it provided no model of the real psychological mechanisms that might lead to variability and change in development. The idea of a fixed logical structure underlying all of a
Departures from the consistency predicted by stage theory proved to be more the norm than the exception as proliferating replication studies introduced a myriad of variations on Piaget’s original tasks and procedures. On the one hand, opponents of Piaget’s theory, doubting the reality or usefulness of formal stage structures, focused their research on identifying conditions in which stage theory predictions failed. In contrast, supporters of Piaget’s constructivist view tried to validate the purported products of development—stage sequences, timing of cognitive achievements, and universality. These researchers focused a great deal of attention on demonstrating conditions in which stage predictions were empirically supported. Today, many researchers still continue along these independent paths, mostly ignoring or dismissing findings of people from the other camp.

The outcome of this protracted and often heated empirical debate has been the discovery of remarkable variability in every aspect of cognitive development studied. As researchers implemented variations in the nature of task materials, complexity of tasks, procedures, degree of modeling, degree of training, and methods of scoring across a multitude of replication studies, a consistent pattern of variation emerged (Bidell & Fischer, 1992; Case, 1991b; Fischer, 1980b; Halford, 1989; Lourenço & Machado, 1996). To the extent that studies closely approximated the assessment conditions used by Piaget, the findings were similar to those he had reported. When tasks and procedures varied greatly from Piaget’s, the findings also varied greatly within certain limits.

A classic example of this pattern of variation is found in research on number conservation. In Piaget’s theory, number conservation (the ability to conceptually maintain the equality of two sets even when one set is transformed to look much larger than the other) was seen as a product of an underlying stage of concrete operational logic. In the original number conservation studies, Piaget and Szeminska (1952) had used sets of 8 or 10 objects each and had identified 6 to 7 years as the typical age of acquisition for this concept. In one group of replication studies, Gelman (1972) showed that the age of acquisition for number conservation could be pushed downward from Piaget’s norms if the task complexity was simplified by (a) reducing the size of the sets children had to compare and (b) eliminating the requirement for verbal justification of conservation judgments. Under these conditions, Gelman reported that children as young as 3 to 4 years of age could answer conservation questions correctly. Fortunately, the debate about number eventually produced important new discoveries spelling out developmental pathways for the early construction of number actions and concepts (Case et al., 1996; Dehaene, 1997; Spelke, in press).

As replication studies proliferated, this seesaw debate over age of acquisition of logical concepts was extended to other dimensions of psychological structure where researchers produced similar patterns of variability as a function of assessment conditions. These included variability in the three central characteristics we have described (developmental level, synchrony in level across domains or contexts, and sequence of development in a domain or context).

The growing empirical documentation of variability in development posed severe problems for the concept of formal stage structures. If concepts such as conservation of number are supported by underlying logical structures, then why wouldn’t the logical structure manifest itself in most if not all situations? Why would a child show logical thinking one moment and in the next moment, appear to have lost it? If cognitive development consists of the emergence of successive forms of underlying logic, why wouldn’t developmental sequences remain the same across domains, contexts, and cultures? The formal concept of stage structure could offer no specific explanation for this pattern of variability, but only the label of decalage.

In one sense, victory in the stage debate went to the skeptical. By the mid-1980s, the inability to account for the dramatic departures from stage theory’s predictions of cross-domain, cross-individual, and cross-cultural consistency had resulted in a general flight from stage theory as an explanatory framework (Beilin, 1983). In a more important sense, however, there was no winner because neither side had offered a workable explanation of the patterns of variation the debate uncovered. What concept of psychological structure would explain the fact that cognitive performance varies so greatly with changing conditions and yet also exhibits great consistency under other conditions?

### Explaining Variability versus Explaining It Away

From the perspective of the history of science, one might think that the discovery of new patterns of variability would be met with excitement and theoretical ad-
vance. After all, a central task of science is to discover and account for variability. Theories are constructed and reconstructed to interpret the range of variation observed and to search for patterns of order within this range. Indeed, an essential criterion of sound scientific theories is that they account for the full range of variability observed in a phenomenon of interest.

However, change in scientific theories is rarely that simple. Evidence that threatens a prevailing worldview or paradigm can lead to attempts to assimilate the discrepant findings into the current paradigm, either by denying their relevance or by advancing alternative explanations within the dominant paradigm (Hanson, 1961; Kuhn, 1970). Responses to the discovery of variability in development have followed this pattern, returning to the prevailing Cartesian framework and building minor modifications to account for portions of the observed variability. Instead of attempting to fully describe the range of variability and explain the reasons for the observed patterns, responses have tried to explain away variability through a variety of theoretical maneuvers that include ignoring variability, accepting variability without explaining it, and focusing on selected effects of variability to support existing theory with minor adaptations. Each of these theoretical responses to variability has served to preserve some version of the Cartesian framework and the structure-as-form paradigm in the face of the new evidence and has led to the modern Cartesian synthesis, despite the fact that most of the evidence of variability remains unexplained.

Reasserting Stage Theory

Piaget, Kohlberg (1969), and other stage theorists at first mostly ignored variability, treating it basically as a nuisance or as error of measurement. Differences across domains, tasks, contexts, and coparticipants in phenomena such as age of acquisition, synchrony, and developmental sequence were said to represent varying forms of resistance to the operation of underlying logical structures. Although Piaget later acknowledged the inadequacy of this position and experimented with alternative logic frameworks (Piaget, 1985, 1987; Piaget & Garcia, 1991), he never found an alternative concept of structure that would predict and explain when and how performance varies. (The discovery of the scale of hierarchical skill levels, shown in Figure 7.3, came from analyzing patterns of variation in growth curves, demonstrating the usefulness of analyzing variation for understanding stages.)

Several scholars have emphasized Piaget’s belief in the importance of decalage and other forms of variation (Beilin, 1983; Chapman, 1988; Lourenço & Machado, 1996), but recognizing that phenomena need to be explained is not the same as explaining them. Piaget and other stage theorists have not specified the processes by which cognitive stage structures and environmental resistance interact to make one kind of task develop later than another in general. They have dealt even less adequately with variations across individuals in the order and timing of acquisition of skills and variations within an individual related to tasks, context, social support, and experience. In short, stage theory has provided no explanation for most observed patterns of variation in developmental level, synchrony, and sequence (Bidell & Fischer, 1992; Edelstein & Case, 1993).

Domain Specificity Theory

As evidence of variability grew and the inadequacy of the classic stage concept became clear, the theoretical crisis deepened. With stage theory losing its potential to generate interesting and credible research and with no clear alternative model of psychological structure available except for Chomskian nativism, some framework was needed as a basis for the continued empirical study of development. Domain specificity theory emerged as a way of freeing the field from its dependence on stage theory without demanding a new commitment to any particular model of psychological structure. According to domain specificity theory, psychological processes are not organized in universal structures, but within limited domains such as spatial, linguistic, or mathematical reasoning, or for groups of similar tasks such as problem solving, analogical reasoning tasks, and theory of mind (Demetriou, Christou, Spanoudis, Platsidou, 2002; Hirschfeld & Gelman, 1994; Turiel & Davidson, 1986; Wellman, 1990). The structures in these domains are often referred to as modules, indicating separate, distinctive structures of brain and behavior (Fodor, 1983). In education, domain specificity became a major theme through the influence of Howard Gardner’s (1983) theory of “multiple intelligences,” leading to curricular revisions in schools around the world.

Description of development and learning within important domains has great value for both developmental science and education, but many scholars have stopped with the domain description. They thus avoid having to explain patterns of variability—for example, the differences and similarities in age of acquisition across different logical concepts such as number and theory of
mind. Instead, they simply assert that cognition is organized locally and so cross-domain relations do not have to be explained. This theoretical stance simply acknowledges the fact of variability and sidesteps a systematic account of its origins.

In some ways, this acknowledgment has represented an advance for a field once dominated by stage theory with its assumption of a single logic that catalyzes change across all aspects of the mind. However, to the extent that domain specificity creates the illusion of having solved the problem of variation, it is an unfortunate theoretical detour. Developmental scientists need to explain why clusters of many (structurally equivalent) concepts emerge in different domains around the same time, showing interval synchrony (Case, 1991b; Fischer & Silvern, 1985). They need to explain how an individual who is working within a single domain and task exhibits one skill level when working alone, but a distinctly higher level when working with the support of a helpful adult (Fischer, Bullock, et al., 1993; Rogoff, 1990). Although domain specificity theory provides important recognition of developmental variability, it offers no explanation of variability across domains and within individuals.

**Neo-Nativism**

An important response to the evidence of variability has been the neo-nativist movement (Carey & Gelman, 1991; Fodor, 1983; Spelke, 1988), which represents a major theoretical alternative to stage theory within the structure-as-form paradigm. Researchers taking this perspective have used ingenious experiments to uncover surprising capacities of infants and young children and have led to the creation of the modern Cartesian synthesis. With the rejection of the concept of structure as stages of formal logic, the other predominant concept of structure—in innate formal rules—seems to be the only remaining alternative within the structure-as-form paradigm. Unfortunately, the concept of innate formal rules has the same fundamental limitation as its sister concept of formal logic: As a static conception of structure, it cannot adequately account for the variability that arises from dynamic human activity (Fischer & Bidell, 1991).

Neo-nativist researchers have focused on selected effects of cognitive variability that seem to support the existence of innate competences within prominent domains such as number, space, language, object properties, and theory of mind (Carey & Spelke, 1994). For the most part, they have not attempted to deal with the extensive variability found in performance. Indeed, the modern father of this movement, Noam Chomsky (1965, 1995), specifically rejects the evidence of variability in language, asserting that it is illusory and that all people “really” speak the same fundamental language. The Chomskian theory of linguistic competence accounts for human linguistic behavior on the basis of a set of innate rules, only a few of which have been specified. Despite almost 50 years of effort, nativism has been notoriously unable to account for either the variations of human languages (Chinese is different from English!) or the highly variable everyday communication skills that individuals develop in a language within and across diverse settings (Lakoff, 1987; Ninio & Snow, 1996; Slobin, 1997). Nevertheless, the nativist approach has had great appeal to many developmental scientists because of its important discoveries about children’s early abilities.

The basic paradigm for neo-nativist research is to design tasks that drive ages of acquisition much lower than traditional Piagetian norms (Baillargeon, 1987; Spelke, 1988, in press). Nativist researchers introduced techniques for simplifying Piagetian task materials and procedures, requiring only minimal activity from a child or providing modeling, training, and other forms of support for more complex activity. They have shown great ingenuity in discovering capacities of young infants and children, demonstrating strong violations of Piaget’s age norms for various logical concepts. Their neo-nativist argument is that cognitive structure must be innate because acquisition of certain concepts can be demonstrated at very young ages. However, this argument from precocity takes into account only half the evidence for variability—the downward half (Fischer & Bidell, 1991; Halford, 1989). It treats the earliest age as the “real” age for a concept’s emergence, ignoring evidence of wide variations in age of acquisition both upward and downward.

A good example of the focus on early age instead of variation is the extensive research on infants’ acquisition of knowledge of objects, especially object permanence (objects continue to exist even when they have been displaced and are not perceived) and object tracking. Researchers have used the procedure of dishabituation, which is designed to assess preferences for stimuli without requiring much behavior. Infants are shown a stimulus until they are used to it (habituated), and then they are shown an altered stimulus. If they show increased attention to the new stimulus (dishabituation), the conclusion drawn is that they have noticed the difference.
A well-known case is Baillargeon’s research on object permanence in young infants (Baillargeon, 1987, 1999). To appreciate the problems with focusing on only selective aspects of variability, it is useful to place this study in the context of Piaget’s (1954) original findings and interpretations regarding infant object permanence. Piaget described a six-stage sequence in infants’ construction of object permanence, which subsequent research confirmed with some revision and clarification (McCall, Eichorn, & Hogarty, 1977; Uzgiris & Hunt, 1987).

Piaget offered a constructivist interpretation of his observations: a simple activity-based mechanism to explain transitions from one stage to another. By coordinating early sensorimotor activities on objects to form new, more comprehensive action systems, infants gradually construct more inclusive understandings of what they can do with objects and therefore how objects can behave. For instance, by coordinating the sensorimotor actions for looking at and grasping objects at Stage 2, infants of about 5 to 6 months of age move to a new Stage 3 structure for dealing with objects—visually guided reaching, in which they simultaneously hold and observe an object. Piaget described an especially important transition at stage 4, when infants of about 8 months coordinate different visually guided reaching skills into a system for searching out objects that have been displaced or hidden. For instance, infants coordinate two skills (what Piaget called “schemes”): reaching for a rattle to grasp it, and reaching for a cloth that is covering the rattle to remove it. With this stage 4 coordination, they can begin to understand how objects come to be hidden by other objects and why hidden objects remain available to be retrieved. Later stages in this understanding extend to late in the second year of life, when infants become able to search exhaustively for hidden objects in many possible hiding places.

In contrast to Piaget’s model of gradual construction of object permanence, Baillargeon focused on the lower end of the age range and a simple looking task. Infants from 3 to 5 months of age were habituated to the sight of a small door that rotated upward from a flat position in front of them, tracing a 180° arc away from them to lie flat again on a solid surface. They were then shown two scenes with objects inserted behind the rotating door. In the possible event, the door swung up but stopped at the object. In the impossible event, the object was surreptitiously removed and the door was seen to swing right through the space the object had occupied, as if it moved through the object. Infants as young as 3½ to 4½ months dishabituated to the impossible event significantly more than they did to the possible, and Baillargeon took this behavior as evidence of object permanence. She concluded that infants acquire object permanence 4 to 5 months earlier than the age of 8 months that Piaget had reported.

This argument from precocity is straightforward: If behaviors associated with a conceptlike object permanence can be found much earlier than in prior research, then the concept in question must be present innately. Similar evidence has led to claims of innate determination for a growing list of concepts, including object properties, space, number, and theory of mind (Carey & Gelman, 1991; Saxe, Carey, & Kanwisher, 2004; Spelke, 2000). Based on the static Cartesian model, these claims have important limitations centered on the failure to consider the full range of variability involved in developmental phenomena.

The crux of the problem is a simplification that ignores the gradual epigenetic construction of activities that vary in complexity. Baillargeon’s task and procedure were dramatically different from the more complex method of assessment used by Piaget. In place of independent problem solving in which the infant must actively search for an object hidden in several successive places, Baillargeon substituted a simple look toward one of two displays. This procedure simplifies the task so greatly that it shifts from a conceptual task to one of perceptual anticipation. Indeed, on a computer a neural-network model of the situation can solve a similar task with a simple visual strategy and no coordination of object characteristics with spatial location (Mareschal, Plunkett, & Harris, 1999).

Baillargeon and other nativists claim that the object concept appears very early, even though the more complex behaviors described by Piaget still develop at the usual later ages, as shown by overwhelming evidence. The selective focus on one early age for one behavior obscures the constructive mechanisms of development and makes it seem that the concept of object permanence has suddenly leaped up, fully formed, at 3½ months of age. Within this framework, innate concepts emerge abruptly in the first few months of life, and development disappears. How could such early development arise except through innate concepts? The answer to this question is another question: How do skills develop through a long sequence of increasingly complex
object-related activities of which the looking behavior is only the beginning?

**Competence/Performance Models**

Nativists and many other cognitive scientists answer by distinguishing between competence and performance. The modern version of the competence/performance distinction was proposed by Chomsky (1965) in an effort to explain why his theory of innate linguistic rules could not predict the wide range of variability observed in actual language usage. Chomsky argued that innate language rules existed separately from the performance of specific acts of communication. The rules governed which communication practices are possible but not which ones will actually take place in a given situation.

Many developmental scientists, faced with the similar problem of explaining why formal Piagetian conceptions of logic do not predict observed patterns of variability in cognitive performance, adopted this distinction (Flavell & Wohlwill, 1969; Gelman, 1978; Klahr & Wallace, 1976; Overton & Newman, 1982).

Competence/performance theories based on the Piagetian and Chomskian models portray cognitive structures as fixed rule sets in the mind/brain that specify behaviors but are somehow impervious to or independent of the contexts of the behaviors. The structures exist somewhere in the background and serve a limiting function: They determine the upper limit on the range of actions possible at a given time, but they leave open the specific action that will take place. For example, in arithmetic, the counting behavior of a preschool child arises from a mathematical competence such as being able to directly perceive numbers of objects of 1, 2, or 3. When a child fails to count, say, three pretzels accurately, the failure is explained by some interference such as memory failure or distraction (Freeno, Riley, & Gelman, 1984; Spelke, in press). A skilled person can indeed mess up a performance here and there because of memory failure or distraction, but when the 3-year-old fails almost all tasks for counting three objects, what sense does such an explanation make?

These models dismiss variability in cognitive and language performance by asserting that fixed competence is differentially expressed because of intervening cognitive processes (vaguely specified) or as a result of unanalyzed environmental resistance to the competence, as Piaget suggested for decalage. Although most nativist theories assume such a framework, some competence/performance theories do not require that psychological structures exist innately, but only that they are firmly separated from the actions that instantiate them. The dynamics of construction of activities leading to wide variation are lost in the muddy mediators that somehow prevent competence from being realized in activity. Such conceptions of disembodied structure seem not too distant from the humorous idea of bottling up the structure of the Golden Gate Bridge. Why is it necessary to posit separate levels of structure, existing somewhere (it is unclear where) outside the real activity in question? Why not model the organization of the actual mental and physical activity as it exists in its everyday contexts?

In short, domain specificity, nativist, and competence/performance models share the same fatal limitations as the logical stage models they were meant to replace. Although the newer models do not make the cross-domain claims that stage models did, they retain a conception of psychological structure as static form existing separately from the behavior it organizes. Whether such static forms are seen as universal logics or domain-specific modules, they offer accounts only of stability in the organization of behavior while ignoring or marginalizing variability. The challenge for contemporary developmental science is not to explain away evidence of variability in performance. Instead, scholars need to build dynamic models of psychological structure, using concepts such as skill, hierarchical complexity, contextual support, and developmental web to build methods for analyzing and explaining both the variability and the stability in the organization of dynamic human activity.

**The Constructivist Alternative**

The constructivist alternative takes as its starting point what the Cartesian framework rules out: the constructive agency of a human being acting in the context of relationships among systems—biological, psychological, and sociocultural. As we have shown in the opening sections of this chapter, the dynamic structural framework provides a straightforward, comprehensive alternative to the conundrums created by the Cartesian synthesis and the related structure-as-form paradigm. Human knowledge is neither passively received from the environment nor passively received from the genome. Instead, people construct knowledge through the active coordination of action systems beginning with the earli-
est sensorimotor activities of newborns, influenced by environmental and genetic systems. By coordinating the systems of activity (including perceptual activities) through which they participate in the social and physical worlds, infants create new relations among these systems and thus new potentials for acting in and understanding the world. These new relations among action systems constitute psychological structures—the organizational aspect of human knowledge, which we refer to as skills. They exhibit both wide variations and patterns of order within the variations.

Dynamic systems research provides the framework for this alternative account, drawing on traditions that have developed outside of or as an alternative to the Cartesian tradition. Important concepts and methods come from epistemological constructivism and related sociocultural/sociohistorical theory (Cole, 1992; Rogoff, 2003), traditional systems theory (Dixon & Lerner, 1992; von Bertalanffy, 1976), dynamic systems theory (Thelen & Smith, 1994, Chapter 6, this Handbook, this volume; van der Maas & Molenaar, 1992; van Geert, 1991), and the developmental science group (Cairns, Elder, & Costello, 1996; Cairns, Chapter 3; Valsiner, Chapter 4, this Handbook, this volume). These traditions, while differing in many ways, share a constructivist focus on action, interrelatedness, and complexity of psychological, biological, and sociocultural systems. From this perspective, the person is the primary agent of cognitive change, constructing new kinds of relations among psychological systems with biological and cultural systems (Bidell & Fischer, 1996; R. Kitchener, 1986). These relations are organized in particular ways that give rise to specific patterns of performance, and they are complex and variable because they are living systems.

People construct the skills of human understanding and action through their diverse bodies, the variable physical world, different sociocultural relations, and distinct developmental histories, thus producing highly variable activities. If this variability is ignored, it acts as noise disguising the nature of developmental processes and thus misleads researchers and educators. However, if the tools of developmental analysis are used to control and manipulate conditions contributing to variability, then the systematicity of the variability can be uncovered and it becomes a key to understanding the nature of psychological structure. In the next section, we discuss some of the methodological tools by which developmental variability can be used to understand and describe the development of dynamic psychological structure.

**METHODOLOGY OF DYNAMIC STRUCTURAL ANALYSIS**

To overcome the limitations of structure as static form, we need to articulate a framework for dynamic development, which includes a set of methods that embody dynamic concepts. Classical research methods use static notions, indicating the age when a competence emerges (really, the mean or modal age for one context and one group), forcing growth into linear models, and partitioning analysis of activities into dichotomies such as heredity and environment or input and output (Anderson et al., 2004; Horn & Hofer, 1992; Plomin et al., 1997; Wahlsten, 1990). Most importantly, effective research needs to be designed so that it can detect variability and, in turn, use the variability to uncover sources of order or regularity in development.

Effective research should be built with designs, measures, analytic methods, and models that can detect variations in growth patterns. Research must be designed to deal with variability, or it is doomed to fail to provide an adequate analysis of development. This chapter focuses on activities in which people coordinate and differentiate lower-order components to form higher-order control systems, which encompasses most activities of interest to developmental and educational researchers. The components of these control systems range from neural networks to parts of the body, immediate contexts (including objects and other people), and sociocultural frameworks for action. Moment by moment, people construct and modify control systems, and the context and goal of the moment have dramatic effects on the nature and complexity of the systems. Frequently, people do the construction jointly with others. To go beyond static stereotyping of development and learning, research must deal directly with these facts of variation. Research must be designed to deal with the wide range of shapes of development that occur for different characteristics of action and thought in diverse contexts and conditions.

Developmental regularities can be found at several levels of analysis, from brain activities to simple actions, complex activities, and collaborations in dyads or larger groups. In analyzing these developmental regularities, it
is important to avoid a common mistake. No one regularity applies to all characteristics of developing activity or all levels of analysis. The same developmental regularities will not be found everywhere. That is an essential principle of the variability of human activity.

In one major realization of this principle, development has many different shapes! Some behaviors and brain characteristics show continuous growth, others show clusters of spurts and drops, still others show oscillation, and some show growth followed by decay (Fischer & Kennedy, 1997; Siegler, Chapter 11, this Handbook, Volume 2; Tabor & Kendler, 1981; Thatcher, 1994; Thelen & Smith, Chapter 6, this Handbook, this volume; van Geert, 1998). Ages of development likewise vary dynamically, even for the same child measured in the same domain: Assessment condition, task, emotional state, and many other factors cause ages to vary dramatically. There are no legitimate developmental milestones, stones fixed in the developmental roadway in one position. Instead, there are developmental buoys, moving within a range of locations affected dynamically by various supports and currents.

It is remarkable how pervasively researchers ignore or even deny variations in shape and age of development. Scholars committed to a continuous view of development typically ignore the spurts and drops in many developmental functions, insisting that development is smooth and continuous despite major evidence to the contrary. Physical and psychological development are both routinely graphed with smooth curves, as in the charts in a pediatrician’s office, even though research on individual growth consistently shows patterns of fits and starts in virtually all aspects of physical growth (Lampl & Johnson, 1998). The distortion is just as pervasive in psychological development. For example, Diamond’s (1985) findings of linear growth of memory for hidden objects in infancy are frequently cited, even though replications by others with the same tasks and measures show nonlinear, S-shaped growth (Bell & Fox, 1992, 1994). Many data sets show powerfully nonlinear individual growth as the norm in infant cognitive and emotional development as well as development at later ages (Fischer & Hogan, 1989; McCall, Eichorn, & Hogarty, 1977; Reznick & Goldfield, 1992; Ruhland & van Geert, 1998; Shultz, 2003).

In a similar manner, at the other pole of argument, scholars committed to stage theory often ignore the evidence for continuous growth, even in their own data. For example, Colby, Kohlberg, Gibbs, and Lieberman (1983) asserted that their longitudinal data on moral development showed stages in growth even in the face of clear evidence that growth was gradual and continuous (Fischer, 1983). In the same way for age, scholars routinely talk as if there are developmental milestones at specific ages, despite the massive evidence of variability in age of development with variations in conditions of assessment (Baron-Cohen, 1995; Case, 1985; Spelke, in press). Common claims, for example, are that object permanence develops at 8 months in Piagetian assessments, conservation at 7 years, and combinatorial reasoning at 12 years, although no such statement is tenable without more specification because the ages vary greatly with task, support, and so on. Classic research on reflexes in very young infants even demonstrates variability in the ages at which they emerge and disappear (Touwen, 1976).

Starting in the Middle of Things: Implications for Design

To study development in medias res—in the middle of things—research designs need to be broadened so that they capture the range of variation and diversity of human activities in real-life settings. If development is assessed with an instrument that places all behavior on a single linear scale, for example, then nothing but that linear change can be detected. The limitations of most classical research arise from assumptions that restrict observation and theory to one-dimensional analysis. When those assumptions are changed, research opens up to encompass the full range of human activity. By limiting developmental observation and explanation to one-dimensional processes, the static assumptions have stymied investigation of the richly textured dynamic variations of development. To do research that facilitates multidimensional-process explanation requires building research designs that go beyond one-dimensional assumptions to provide for detection of the dynamics of variability (Edelstein & Case, 1993; G. Gottlieb, Wahlsten, & Lickliter, Chapter 5, this Handbook, this volume; Lerner, 2002; Thelen & Smith, 1994, Chapter 6; Valsiner, Chapter 4, this Handbook, this volume; van Geert & van Dijk, 2002).

Here are four important one-dimensional assumptions that are typically incorrect and that are embodied in research designs that implicitly assume static structure. These all need to be avoided in designs for assessing the dynamics of change by addressing variability and diversity.
1. **Single-level, single-competence assumption—not.** At any one moment, a person functions at a single cognitive stage or a single level of complexity and possesses a single competence. Contrary to this one-level, one-pathway assumption, people function at multiple developmental levels concurrently, even within the same situation (Fischer & Ayoub, 1994; Goldin-Meadow & Alibali, 2002; Siegler, Chapter 11, this *Handbook*, Volume 2). In development, a person moves through a web of connected pathways composed of multiple strands (domains or tasks), each involving variation within a range or zone of developmental levels, as illustrated in the webs in Figures 7.2 and 7.9. Assessments must include multiple pathways and multiple conditions so that the full range of levels and competences can be detected.

2. **Single-shape assumption—not.** Each developmental pathway shows essentially similar linear or monotonic shapes. Contrary to this linearity assumption, developmental pathways or strands take many different shapes, which frequently include reversals in direction—not only increases but also decreases, as illustrated in Figure 7.11. Individual people normally grow in fits and starts and start both physically and psychologically, as we described in the introduction to this section. In development, these fits and starts seem to be especially prevalent and systematic when people are functioning at optimum or when they are building a new skill in microdevelopment. Developmental pathways or strands for individual activities move through nonlinear dynamic patterns of change, seldom showing straight lines. In long-term development, there are periodic movements to a lower level (regressions), especially after developmental spurts (Fischer & Kennedy, 1997). In microdevelopment, backward movement to a low-level skill is common before construction of a new skill (Granott & Parziale, 2002), as we discuss in the section on Microdevelopment.

3. **Single-person assumption—not.** People develop and learn individually, and they sometimes interact and affect each other. Contrary to this individualist assumption, people do not usually function solo, but instead from birth they act in a fundamentally social way, working together in ensembles that distribute a task across several collaborating partners (Bronfenbrenner & Morris, Chapter 14, this *Handbook*, this volume; A. Brown & Palincsar, 1989; Scardamalia & Bereiter, 1999; Vygotsky, 1978). Studying development socially is not only more realistic, but it can also make the processes of development more transparent. When people work together, communicating about what they are doing, the internal processes of learning and thinking become externalized, and the processes of social collaboration and interference become evident (Fischer & Granott, 1995).

4. **Single context assumption—not.** The most effective research typically focuses on one task and variations on it or one context for assessment. Contrary to this uniformity assumption, research needs to combine multiple tasks and assessment contexts so that it can capture the range of levels and competences, pathways, and social interactions that characterize development (Bronfenbrenner, 1993; Campbell & Stanley, 1963; Fischer, Knight, et al., 1993). To accurately describe people’s developing activities, research must be designed with an array of assessment conditions and an array of tasks within conditions.

### Figure 7.11

Three different growth curves based on the same growth model. The growth curves are all generated by the same nonlinear hierarchical model of development of self-in-relationships used in this chapter, but variations in the values of the parameters in the equations produce vastly different shapes. The same growth processes produce essentially monotonic growth (Gower 1), growth with stagelike spurts and drops (Gower 2), and fluctuating change (Gower 3).

### Guidelines for Developmental Research

To analyze and understand natural variations in development as well as consistencies across variations, research needs to move beyond these limiting assumptions. Analyzing the dynamics of change requires...
methods that allow detection of variations in development and learning:

- People develop along multiple concurrent pathways in a web.
- From moment to moment people function across a range of different levels and competences.
- People develop in the long run and learn in short time periods according to diverse shapes of growth, including the complex nonlinear fits and starts in many growth curves.
- People learn and develop in social ensembles, and research should reflect this fundamentally social nature of development.
- People act differently in different tasks and conditions, and so research needs to include a range of tasks and conditions to detect the full range of variability in action and thought.

Only through analyzing the natural variability in development and learning can researchers come to understand the consistencies inside the variation.

Putting together all these contributions to variation can seem daunting, but it need not be. A few straightforward guidelines in designing research and analyzing observations facilitate uncovering the variation and diversity of development. Investigators should focus on (a) using well-designed clocks and rulers to measure change and variation, (b) studying several tasks and domains to determine the generality and variation in pathways, (c) varying assessment conditions to uncover the range of variability in level and content, and (d) investigating diverse sociocultural contexts to discover the effects of different cultural groups on development. No one study can investigate all sources of variation at once, but investigators can make sure that several sources are evaluated in each study. Also researchers need to situate their findings within a conceptual map of the multiple sources of dynamic development, avoiding the pitfall of reductionist description, which assumes that one study captures the important sources of variation.

**Clocks, Rulers, and Repeated Measures**

Detection of variation in developmental shapes requires both good clocks and good rulers to measure change. To capture either smooth growth or fits and starts requires a clock that can detect the speed of change. Ages or events need to be sampled frequently enough to provide several assessments for each period of increase and decrease. Otherwise, the shape of growth cannot be detected. Also, the distribution of ages or times of assessment must be chosen carefully so that estimates of changes in item or response distributions are not distorted by biases in time sampling. Much developmental research uses clustered ages such as groups of 2- and 4-year-olds, clustered tightly around the mean ages of 2 and 4. This design assumes the importance of mean differences and provides a bad clock for development, because it represents only a few of the many points along the time scale from 2 to 4 years. If major reorganizations of activity are hypothesized to occur, for example, every 6 months in the early preschool years as Case (1985) predicted, then assessments must take place at least every 2 or 3 months to reliably detect the periods of reorganization, and the distribution of ages across 2- or 3-month intervals should be uniform, not clustered at the mean age.

Capturing the shapes of development requires a good ruler as well, one that provides a scale sensitive enough to detect the ups and downs of growth. The best assessments provide a relatively continuous developmental scale of increasing complexity, such as the Uzgiris-Hunt (1987) scales to assess infant development and the scales for nice and mean social interaction (Ayoub & Fischer, in press; Fischer, Hencke, & Hand, 1994). It is crucial to avoid scales that combine items in a way that forces growth into a particular function, as when intelligence tests force test data into scales that show linear increase with age.

A single task seldom makes a good ruler because it provides such a limited sample of behavior. Better is a series of tasks or a grouping of tasks that forms coherent developmental scales. A series of tasks can be used to assess either (a) a Guttman-type developmental scale measuring one linear pathway in a developmental web (Guttman, 1944), like the Uzgiris-Hunt scales, or (b) branching pathways like the tasks for nice and mean interactions and those for reading single words in Figures 7.5 and 7.10. Through analysis of profiles across tasks, a good ruler can be created for either pathway. A particularly useful method is Rasch scaling, which is based on a sensible, nonlinear (logistic) developmental model and allows detection of Guttman scales as well as branches (Bond & Fox, 2001; Dawson, 2003; Rasch, 1980). The discovery of the general ruler for hierarchical skill development came from research assessing performance profiles with these and related methods, as
Methodology of Dynamic Structural Analysis

Table 7.2 shows a set of profiles for defining the simplest developmental pathway in the development of reading words—Figure 7.10 (a), the pathway for normal readers, which includes only one simple branch (Knight & Fischer, 1992). The sequence is determined by the ordering patterns for every pair of tasks. For most profiles in this simple sequence, every task is passed up to a certain point in the table from left to right, and then all tasks are failed thereafter, which is characteristic of a Guttman scale. Branching is indicated by profiles that show variations in this simple pattern, such as Step 2b in Table 7.2, where there is a failed task in the middle of a string of passes. Based on analysis of performance across tasks for each word, a child is assigned a profile in Table 7.2, and therefore a step in the pathway, even when assessment is at a single time rather than longitudinal. The table shows pass/fail tasks for simplicity, but multistep scales can be used, with scaling tested by tasks earlier in a sequence having higher scores than those later.

Profile analysis can detect webs as simple as the one for normal readers in Figure 7.10 (a), or as complex as the one for nice and mean social interactions in Figure 7.5. The logic of analysis is the same for branched webs as for linear Guttman scales, and sequencing is determined by the ordering patterns of all pairs of tasks. Indeed, the same set of tasks can define different webs for different children. For example, different sets of profiles for the tasks in Table 7.2 define the unintegrated webs for poor readers in Figure 7.10 (b) and (c), such as the web in which the three domains of identifying letters, reading words, and rhyming words are all independent.

An important characteristic to keep in mind when devising tasks to build rulers for change is the similarities and differences among tasks. Simple ordering like that in Table 7.2 is typically eliminated by differences in content or procedure between tasks. When researchers have attempted to build scales using distinctive tasks to assess different steps, the task differences have wiped out scaling of steps (Kofsky, 1966; Wohlwill & Lowe, 1962). A good, simple Guttman-type ruler uses tasks that include only variations in complexity or difficulty, with minimal differences in content and procedure. Differences between distinctive tasks are captured by having separate Guttman rulers for each set of tasks (each domain). In a similar way, measuring the temperature of a refrigerator in New York requires a different thermometer from measuring the temperature of the surface of Mars. Rasch analysis can also facilitate using a common scale across tasks and domains (Bond & Fox, 2001; Dawson et al., 2003), as it has helped test the generality of the ruler for skill complexity, showing simultaneously the same scale across domains and large domain effects.

Another method for devising a ruler uses groupings of similar tasks to assess a scale. For example, in early language development, Ruhland and van Geert (1998) grouped words into syntactical classes based on Dutch children’s spontaneous speech to form a sensitive developmental scale. With pronouns, for example, they found a large growth spurt late in the second year, as shown in Figure 7.12. Other groupings that have proved useful in studies of development have included arithmetic problems of similar complexity (Fischer, Pipp, & Bullock, 1984) and explications of dilemmas about the bases of knowledge called reflective judgment (K. Kitchener et al., 1993). Scales based on such groupings of similar tasks can be used to specify the shapes of development in various domains and to compare relations among development across domains or levels in individual subjects or groups. Like scalogram analysis, they also provide a way of testing developmental functions with

### Table 7.2 Task Profiles for Normative Developmental Sequence for Reading Words

<table>
<thead>
<tr>
<th>Step</th>
<th>Word Definition</th>
<th>Letter Identification</th>
<th>Rhyme Recognition</th>
<th>Reading Recognition</th>
<th>Rhyme Production</th>
<th>Reading Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>1</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>2a</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>2b</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>5</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>6</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

*Note: Pass = +; Fail = −.*

cross-sectional designs. For example, this method can test for both spurts and bimodal distributions on emergence of developmental levels or growth of separate strategies for approaching a task (Siegler, 2002). The design must included separate groups of tasks for each level or strategy. The grouping method, however, does not provide a sensitive index of the intervals in a scale between points of discontinuity, or levels.

Rasch analysis fills this need, providing powerful tools for assessing the steps and intervals along a scale as well as discontinuities (Bond & Fox, 2001; Rasch, 1980). Only recently have researchers begun to realize its potential for assessing developmental scales and determining the distances between items along a scale. Most investigators have used it to determine whether items in a domain fit a single Guttman scale and what the distances are between items along that scale, and it can also be used to assess for several independent scales or branches in a web. Rasch scaling provides one of the most convincing sources of evidence for the scale for hierarchical complexity of skills shown in Figure 7.3 (Dawson, 2003; Dawson et al., 2003).

The three techniques for combining tasks to form developmental scales (Guttman scaling, groupings of similar tasks, and Rasch analysis) provide a repeated-measures assessment that has many of the desirable characteristics of longitudinal assessment, even when there is only a single session. Through analysis of task profiles and distributions, each person can be tested to determine whether he or she follows a particular developmental pathway or growth function. Contrary to the conventional wisdom that development can only be effectively assessed longitudinally over months and years, these repeated-measures assessments can provide powerful tools for describing and testing developmental pathways and growth functions. They can also be combined with longitudinal designs, where they provide even more powerful tools for assessing development.

**General Structure across Tasks in a Domain**

Task differences are typically controlled for and systematically manipulated in developmental scales. However, task differences are important in their own right. Task is one of the most powerful sources of variability in behavior, as documented by thousands of psychometric and experimental studies across many decades (Fleishman, 1975; Mischel, 1968). An accurate portrait of development requires assessment of different tasks and domains to capture patterns of variation in developmental pathways and growth functions.

One of the most common hypotheses in cognitive and developmental science is that behavior divides into domains, which are built on general psychological structures. That is the core of the domain specificity framework and of neo-nativist explanations. However, evidence for generality in a conceptual structure is relatively rare in the research literature, where careful tests of generalization are infrequent (Fischer & Immordino-Yang, 2002). Many abilities that have been described as general competences seem not to be coherent abilities at all but instead summary variables, with at best weak correlations among items. Examples include the hypothesized domains of theory of mind, metamemory, visual thinking, and ego resiliency, for each of which there is no clear evidence of a central generalized structure that generates common activity across a wide array of tasks. For example, ego resiliency has been posited as a broad characteristic of effective people and it has been subjected to extensive longitudinal study by Jack and Jeanne Block (Block, 1993). Research on this general competence in Dutch and American children indicates that ego resiliency does not affect relevant specific competences such as school achievement and social preference (Harter, 1999; van Aken, 1992). That is, it does not show a generalizing relation with specific skills, which would indicate a common structure applied across tasks. Ego resiliency may be a useful social construct, but it does not seem to be a central psychological structure that organizes various activities together in development.
One convincing case of a general structure in a domain is the central conceptual structure documented by Robbie Case and his colleagues (1996). It provides a model for defining a general structure and testing its generality. Assessment of the development of a general concept of number requires an array of tasks that all require the use of that concept. Case and his colleagues have constructed such a task array for the elementary number line, which represents number as quantitative variation along a line. This representation constitutes what they call a central conceptual structure for number in young children, a framework for thinking about number that facilitates numerical understanding across many situations. Tasks like reading the time on a clock, counting gifts at a birthday party, and doing simple arithmetic problems in school all make use of this same structure. Discovery of general conceptual structures like the number line would be a strong boon for educators, greatly streamlining their efforts to teach children the basic concepts and skills required by modern society.

From approximately 4 to 8 years of age, children build the central conceptual structure for number. When instructors and curriculum explicitly teach the structure, children evidence a major improvement in performance across a wide array of number tasks but not for tasks in other domains such as understanding social interactions. The change amounts to as much as 50% of the variance in test scores, which is a remarkably large effect. The use of many tasks allowed Case and his colleagues to determine how general the structure is—where children apply it and where they do not. Note also that along with the general change across number tasks, the researchers still found large task effects and considerable developmental variation in level. The generality of the structure operates within this substantial variability.

In the behavioral sciences, researchers commonly wish to generalize from their data to the development of a domain, but the two standard methods preclude legitimate generalization by artificially reducing variation instead of analyzing it. First, in the "psychometric method," commonly used in intelligence, education, and personality testing, many tasks are summed and only the summary scores are considered. A boy's IQ score is 116, or the college entrance test score for a young woman is 575. Most of the variation in each person's performances on the tasks is ignored. Second, in the "experimental method," commonly used in experimental psychology and neuroscience, a researcher analyzes one task by varying a parameter and calculating mean performance differences for specific values of the parameter. Variations in performance in the task other than the means are treated as error variance and not analyzed further. Also, variations among diverse tasks are ignored because only one task is examined.

The psychometric strategy is evident in ability theories, where researchers study some hypothesized general ability such as spatial intelligence or verbal intelligence (Demetriou et al., 2002; Sternberg, Lautrey, & Lubart, 2003). The evidence for the coherence of these supposedly modular abilities is modest in comparison to Case's evidence for a central conceptual structure for number. Most tasks or items that measure each ability or intelligence have only minimal variance in common, with correlations between pairs of items typically accounting for approximately 4% of the variance (an average correlation of .2 between individual items).

Educational researchers have regularly thrown up their hands in dismay that they have found so little generalization or transfer of concepts to tasks that are distinct from those taught (Salomon & Perkins, 1989). For example, when instructors teach a concept such as gravity, evolution, or working memory, they commonly find that even intelligent students have difficulty using the concept in tasks different from those explicitly taught in class. The reason for the difficulty of this far generalization (use of knowledge in tasks far from the original object of learning) is that the construction of generalized skills requires time and effort (Fischer & Immordino-Yang, 2002). Furthermore, even with a strong conceptual structure like Case's number line, generalization is not perfect. For a weak structure such as spatial intelligence or ego resiliency, generalization should not be expected. Learning is not a simple transmission of information through a conduit from one person to another or from one task to another.

Researchers using the second strategy, experimental manipulation of a task, typically restrict their investigations to one task and variations of it. Their intent is to control for extraneous sources of variability, such as task effects, but at the same time, they wish to generalize about broad abilities or concepts such as object permanence (Baillargeon, 1999), the concept of number (Spelke, in press), or working memory (Diamond, 1985). Unfortunately, the cost of restriction to a single task (or even two) is an absence of generalizability of results beyond that task.

When researchers use different tasks to assess a domain, they typically find very different portraits of development for each task. Indeed, many of the central
debates in the study of development center on issues of task difference. When do children really understand object permanence? When do children control the syntax of their native language? When can people think logically? Such questions cannot be answered without examination of many distinct tasks that index the domain of interest. Analysis of the dynamics of variability then becomes possible.

**Multiple Assessment Conditions and Social Support: Developmental Range**

Even for a single task, a person typically shows vastly different competence with variation in social-contextual support, as demonstrated by the developmental range. Other powerful sources of variation for an individual person in a single task include emotional state, coparticipant, and familiarity with the task and situation. To capture these sources of variation, research should include multiple conditions designed to evoke different levels of performance in each person. It is not legitimate to ignore these variations and claim broad application of a developmental analysis based on one assessment task and condition.

Recall the study of Korean adolescents’ conceptions of self-in-relationships, which documented the power of variation in developmental range—the contrast between conditions of unassisted performance (low support) and priming of a task (high support)(Fischer & Kennedy, 1997; Kennedy, 1991). The upper limit on individual performance under these two conditions changes powerfully, as shown in Figure 7.8. The gap is robust and cannot be removed by simply increasing training, practice, or motivation. The developmental range illustrated in Figure 7.1 documents this robustness for another domain—nice and mean stories. Performance on these stories shifted repeatedly up to optimal level with high support and down to functional level with low support, and the gap did not lessen with practice, instruction, and motivational manipulations (Fischer, Bullock, et al., 1993).

For a high-support procedure to produce optimal-level performance, it must be designed to sustain appropriate performance and minimize interference. Tasks should be straightforward and well defined, procedures should be familiar to participants, and there should be no incompatible emotional state. Most important, the context should prime high-level functioning, with social priming by a more knowledgeable person often proving especially effective. Successful priming procedures have included demonstrating a task and asking people to imitate it, explaining the gist of a task, and providing a prototype of an effective solution.

The Self-in-Relationships (SiR) Interview illustrates an effective, flexible high-support procedure. Participants built their own tool for priming themselves—a visual representation of themselves in relationships. In addition, an interviewer asked structured questions to prime high-level functioning. First, participants were asked to describe several characteristics of themselves in relation to each of a series of designated people (listed in Figure 7.13). They wrote each description on a Post-It paper and indicated whether it was positive, negative, or of mixed valence. Then they arranged the descriptions on an 18-inch circular self-diagram, placing each self-description within one of three concentric circles that ranged from most important (inner circle) to least important (outer circle). Each student grouped descriptions together on the diagram and indicated relations between groups or individual descriptions. Once the diagram was created, the interviewer asked specific questions to assess four distinct developmental levels from the skill scale. For example, the level of abstract mapping of self-understanding was assessed by asking each student to explain the relation (mapping) of two salient abstract self-descriptions to each other, such as attentive and overjoyed in Figure 7.13.

The SiR was designed to assess functional as well as optimal levels of self-understanding. The low-support condition was given at the start of a session and assessed a person’s functional level through the traditional “spontaneous” procedure (McGuire & McGuire, 1982). Without any diagram or supportive questions, participants were asked first to describe what they were like with each of the designated people, to indicate whether any characteristics seemed to go together, and to note those that were opposites. Then they moved on to the high-support condition.

Scholars have often claimed that the collectivist nature of Far Eastern cultures leads people to have no clear self-concept, in contrast to people in the West (Fischer, Wang, Kennedy, & Cheng, 1998; Markus & Kitayama, 1991). Research with traditional Western low-support assessments has seemed to show that the self-descriptions of people in Far Eastern countries are indeed primitive and simple, and that there is little developmental change in concepts of self during adolescence.

This claim illustrates the limitations of one-condition assessments, which ignore the effects of contextual sup-
Figure 7.13  Self-in-Relationships diagram constructed by a 15-year-old Korean girl.

Because Eastern cultures typically discourage a focus on self in conversation, people are likely to show low levels of self-description unless they are given strong social-contextual support for describing themselves. That explains why the difference between optimal and functional levels was so dramatic in the Korean study (see Figure 7.8). Under low-support conditions, Korean adolescents did indeed show simple, primitive self-descriptions, which they presumably also show in much of their public conversation. High-support conditions, on the other hand, produced complex self-descriptions, comparable in
developmental level to those of U.S. adolescents, although emerging about a year later. The gap between optimal and functional levels appears to be larger in Korean youths than in their U.S. counterparts, probably because of the Korean devaluation of focusing on self.

**Sociocultural Variation and Frames of Meaning**

A powerful source of variability in developmental pathways is sociocultural context, as reflected by differences across nations, ethnic and racial groups, and social classes (Cole, 1996; Rogoff, 2003; Valsiner, 2001; Whiting & Edwards, 1988). To capture the range of variation in human development, researchers need to assess developmental pathways in distinct cultural groups. Doing research in a different culture usually requires working with a native of that culture to ensure that the research engages the meaning systems of the culture instead of misrepresenting them.

One major dimension of disagreement in developmental science involves generalizing findings to all human beings versus emphasizing cultural differences. Dynamic structural analysis requires analyzing this source of variation instead of assuming either universality or cultural difference. Diverse social groups value different activities, teach different contents, prescribe different roles and norms, and practice different child-rearing practices. A method of raising children that is common in one culture (e.g., Western parents’ placing their infants in a separate bedroom to sleep) may be more than unusual in other cultures (the Gusii of Kenya consider Western sleeping arrangements abusive; LeVine, 1988).

Yet some characteristics turn out to be universal or at least common across many cultures, and others vary greatly (Fischer et al., 1998). The optimal skill levels in development of self-in-relationships, for example, look similar in China, South Korea, Taiwan, and the United States. Also, people tend to view themselves in predominantly positive terms across the same cultures, as is evident with the Korean girl in Figure 7.13 (note the distribution of pluses and minuses). On the other hand, the emotion of shame differs greatly across cultures. Fundamental in Chinese and many other Asian cultures, it develops early in children’s speech, is highly differentiated with many different words for shame situations and reactions, and pervades adults’ discourse and emotion concepts. That same emotion is treated as being much less important in the United States and Great Britain, where it develops late in children’s speech and is minimized in the emotional concepts of most middle-class adults (Li, Wang, & Fischer, 2004; Shaver, Wu, & Schwartz, 1992).

Developmental researchers need to explain such similarities and differences by examining major sources of variation, such as task, assessment condition, emotional state, and culture. Then they need to characterize the variations effectively, relating their findings explicitly to concepts about development and variation. Traditionally, theories of development and learning have been replete with complex conceptions of change and variation processes, but there has been no way to test adequately the process claims, to determine whether the processes specified actually produce the growth patterns predicted. That deficit no longer exists.

**Building and Testing Models of Growth and Development**

Developmental theories require complex, sophisticated tools for analysis, going beyond the models of linear main effects that have dominated the behavioral sciences. Methods based on nonlinear dynamics, including both dynamic growth models and neural networks, provide powerful ways of representing and analyzing the dynamics of change. These dynamic methods mesh naturally with developmental theories to allow developmental scholars to begin to capture the complexities of human development (Fischer & Kennedy, 1997; Shultz, 2003; Thelen & Bates, 2003), and they can be easily programmed on computers with common software such as Excel.

With these new tools for building models of change, the claims of virtually any theory can be explicitly tested in what van Geert (1994) calls “experimental theoretical psychology.” Developmental or learning processes can be represented in equations, and computers can be used to run experiments by varying parameters to test whether the growth functions that the models produce fit theorists’ predictions and empirical findings. A model of growth defines a basic growth function or set of functions for each specified component, which is called a “grower.” These growth models can simulate not only quantitative growth, such as complexity level, frequency of an activity, or preference but also qualitative developments such as emergence of a new stage, coordination of two strands into one, or splitting of a strand into branches.

One important kind of nonlinear dynamic model represents networks in the brain and nervous system. Re-
searchers have built many neural network models to depict and analyze processes of learning and adaptation that involve coordinating and differentiating activities at one or two levels of complexity (Bullock et al., 1993; Elman et al., 1996; Grossberg, 2000; van der Maas, Verschure, & Molenaar, 1990). For example, word inputs are compared to infer how to make a past tense verb in English. Visual scanning and object characteristics are integrated to infer how an infant looks for objects of a particular type following a specific path. Or visual input and arm-hand control are integrated to produce visually guided reaching.

An important characteristic for evaluating the models is whether they reflect the real architecture of the activities that they represent. Many models use global, generalized programs to analyze the development or learning of an activity. Although these generalized approaches make models easier to design, their structure typically does not closely match the architecture of the real activities. Models that have been constructed specifically to fit the real architecture of the behavior, social interaction, or nervous-system network being modeled have been more successful. For example, the adaptive resonance theory of neural networks has been used to construct models that carefully match the architecture of the nervous system, the body, and the senses (Raizada & Grossberg, 2003). A model of eye-hand coordination is based closely on how eye, hand, and related cortical networks are actually built (Bullock et al., 1993). Many models have paid much less attention to the specific architecture of the activity being modeled. A question to ask in evaluating a model is whether it plausibly reflects the architecture of the activity of interest.

Nonlinear Dynamic Models of Growth and Development

For decades, systems theory and nonlinear dynamics have been popular as broad theoretical interpretations of development (Sameroff, 1975; von Bertalanffy, 1976), but the tools needed for precise developmental analysis were missing. When the computer revolution began to produce a powerful array of new dynamic modeling tools, investigators began with models of a few tractable psychological problems, especially involving motor coordination (Bullock et al., 1993; Thelen & Smith, 1994).

Now there is an explosion of dynamic systems research, including diverse models for analyzing activity and its development (e.g., Case et al., 1996; Fischer & Kennedy, 1997; Hartelman, van der Maas, & Molenaar, 1998; Shultz, 2003; van Geert, 1998). Our focus in this chapter is on models of hierarchical growth of action, thought, and emotion. We define basic growth processes for psychological growers and how they are connected in a developmental process.

An important consequence of these new tools is that they lead to more powerful and precise definitions of growth, development, and learning. Traditionally, these three terms for patterns of change have been defined restrictively in terms of directional change, usually, linear increase (Willeit, Ayoub, & Robinson, 1991; Wohlwill, 1973). In dynamic structural analysis, they are defined instead by specific models of change processes—any systematic mechanism of change, resulting in not only linear increase and decrease but also complex patterns such as increase occurring in successive jumps and dips, or oscillation between limits. Equations specify these growth processes systematically and predict a family of growth curves, often of many different shapes. In common usage, growth is the most general term, development tends to be used for systematic increase over long time periods, and learning typically means short-term increase based on experience. We expect the meanings of the terms to be revised over time as a result of the more precise definitions of change in dynamic models. The most important point for our purposes is that growth, development, and learning are no longer identified by the shape of any one particular curve. There is no need for restrictive definitions such as monotonic increase.

Logistic Growth

The best starting point for growth models is usually logistic growth because most growth processes in biology show this kind of growth. Figure 7.14 shows three examples of logistic growth, all produced by the same basic equation, which generates the S-shaped curve that typifies much simple growth. Note that even this simplest curve is not linear. The model is called logistic because the equation includes log values (squares or higher powers of the grower’s level).

Many basic growth processes involve this form of growth, where the change at a given time is derived from three parameters: (1) the prior level of the grower, (2) the growth rate of the system, and (3) a limit on the system’s growth, called the carrying capacity. The term level refers to some quantity that a grower has reached, potentially involving a wide array of different characteristics such as developmental level, frequency of response, or amount of activity. In many of our
examples, level \((L)\) refers to the complexity of an activity along the skill complexity scale in Figure 7.3, as applied to the development of self-in-relationships (Fischer & Kennedy, 1997). Models have also been built for other domains such as King and K. Kitchener’s (1994) reflective judgment, which develops through seven stages that show growth curves similar to those for self-in-relationships (K. Kitchener & King, 1990; K. Kitchener et al., 1993).

By itself, without connection to other growers, the equation produces mostly S-shaped growth, as with Growers 4 and 5 in Figure 7.14. Even without connection, however, there is significant variation in the growth curve, as illustrated by the turbulence in Grower 6 as it nears its carrying capacity. The three growth curves in Figure 7.14 all derive from the same equation, and only values of the growth parameters differ.

Logistic growth equations can take several different forms, and van Geert (1994) recommends the following as the best starting point for modeling hierarchical growth for an action, thought, or emotion, designated as Grower B:

\[
L_{B_{t+1}} = L_B + R_B \left( \frac{L_B^2}{K_B^2} - \frac{L_B}{K_B} \right)
\]

\(L_{B_{t+1}}\) is the level of Grower B, with subscript \(t\) indicating the previous trial, and \(t+1\) indicating the current trial. \(R_B\) is the rate of growth of B, specifying the amount of change that occurs in each trial. \(K_B\) is the carrying capacity of B, which is the limit on growth that is characteristic of this particular system in this situation.

The equation is divided into three terms, which together produce the level of B in the current trial. The first term is the level in the previous trial. Next is the growth term—the growth rate times the square of the level in the previous trial divided by the square of the carrying capacity. With modest growth rates, this factor produces an increase on each trial. Level is divided by carrying capacity to base growth on a ratio with the system’s capacity instead of its absolute value, because of an assumption that the level operates as a function of the capacity.

The growth term in this logistic equation squares the ratio of level to carrying capacity, in contrast to a simpler form of the equation, which uses the ratio without squaring. The squared form of the equation seems to represent psychological growth processes more accurately, and that growth depends on the person’s prior level in two simultaneous ways: (1) current understanding is built on earlier understanding, and (2) level affects the probability of encountering situations that promote growth. Van Geert (1994) elaborates this argument and shows that this form of the growth equation fits individual growth curves better than the squared equation. The growth curve for pronoun use by the Dutch child Tomas in Figure 7.12 fits this version of the equation well, but not the nonsquared version (Fischer & Kennedy, 1997; Ruhland & van Geert, 1998).

The third term provides a form of regulation based on the limits of the system. Without some limit, the level will eventually explode to ever larger quantities. In real biological systems, there is always some limit, based on the availability of food, space, energy, and the like. The regulation term subtracts an amount to limit the system based on its carrying capacity and keeps it from exploding. The amount subtracted is the product of the growth term (the second term in the equation) multiplied by the ratio of the level to the carrying capacity. The result is the cubing of level, which leads to this equation being called the cubic logistic equation. (The simpler equation is called the squared version.) When the current level is low in relation to carrying capacity, little is subtracted; but when the current level rises, the amount subtracted becomes larger. As the level approaches the carrying capacity, the amount subtracted becomes large enough to cancel out growth, and thus the level approaches the carrying capacity as a limit. This growth process does not always produce smooth S-shaped growth, however. When the growth rate is high, the level can show turbulent fluctuations as the level approaches the carrying capacity, illustrated by Grower 6 in Figure 7.14. Note, in
Figure 7.12, that Tomas’s development of pronoun use also evidenced this turbulence as his use grew rapidly to a high level. Turbulence is a common property of dynamic systems when they grow very rapidly.

Growth can be characterized with other kinds of equations, most obviously with differential calculus instead of the difference equations that we are using. Differential equations assume that feedback for change is instantaneous and continuous in time, whereas difference equations assume that feedback occurs between discrete events such as social encounters or learning situations. The assumption of discrete events seems appropriate for most psychological development and learning. Also, differential equations are mathematically complex and difficult to work with, whereas difference equations can be used easily in any computer spreadsheet program by using recurrent trials (similar to what is required for calculation of mortgage payments). Van Geert (1994) provides step-by-step guidelines on how to use a spreadsheet program to build a dynamic model. Singer and Willett (2003) describe another class of growth models based on linear assumptions, and they also provide step-by-step guidelines for use.

**Connections among Growers**

Any single activity is affected by many different components and influences coming together. In a growth model, each component (grower) is represented by a growth function, and all growers can be connected within the set of growth functions. Modeling a grower starts with a growth function like the first equation, and connections are built around that function. The connections range from strong to weak to nonexistent, and the ways that they affect growth take many different forms. Connections between growers can involve aspects of the person acting alone, or they can be between people, as in a teacher-student relationship (van Geert, 1998).

Different combinations of components can produce different growth curves. With dynamic systems, however, even the same combinations can produce widely different growth functions. Shapes as diverse as monotonic growth, successive stagelike change, and chaotic fluctuation can all arise from the same set of equations. Growth curves 1, 2, and 3 in Figure 7.11 all arise from the same nonlinear hierarchical model of development of self-in-relationships for five relationships, each with five developmental levels (Fischer & Kennedy, 1997). Despite the great differences in their shapes, only the values of the parameters in the equations differ. The same growth processes produce virtually monotonic growth (Grower 1), growth with stage-like spurts and drops (Grower 2), and fluctuating change (Grower 3).

The strongest form of connection among growers is hierarchical integration, where each successive step within a strand in the developmental web builds on the previous step. In one example of such integration, two strands come together to form a new single strand such as when an adolescent girl compares herself in two relationships. The 15-year-old Korean girl represented by the diagram in Figure 7.13 compared what she was like at school (being attentive, enjoying school) with what she was like with her best friend (feeling valuable, being overjoyful). She built a mapping for those characteristics of the two relationships. The model of the strand for each relationship uses a skill scale of five hierarchical growers built successively on each other—Growers A, B, C, D, and E. A grower later in the sequence starts only after the level of the immediately prior grower, the prerequisite, has become sufficiently strong and frequent for a person to begin to build on it. When the girl coordinates her characteristics at school with those relating to her best friend, she is coordinating two strands, each with five hierarchical growers forming a five-level scale.

In this prerequisite connection, the prior grower must reach some specified level $P$ before the later grower can begin to change:

$$L_{B, t+1} = L_{B, t} + P_{B} \left[ \frac{R_{B}}{K_{B}} - \frac{L_{B}}{K_{B}} \right]$$

$P_{B}$ is the precursor function for Grower B at time $t$ based on the level of the prerequisite Grower A:

$$\text{If } L_{A, t} < p, \text{ then } P_{B, t} = 0; \text{ if } L_{A, t} > p, \text{ then } P_{B, t} = 1$$

Before Grower A has reached its prerequisite level $p$ at time $t$, such as .2, precursor $P_{B}$ is 0, and Grower B does not grow. When Grower A reaches .2, precursor $P_{B}$ becomes 1 and Grower B starts to grow. Specification of the precursor function can be more complex than simply one trial at .2. For example, Grower A might need to stay at .2 for some number of events or trials before Grower B starts to grow; or two different prerequisite Growers, $A_{1}$ and $A_{2}$, might both have to reach a specified level.
In addition to strong hierarchical connections among growers, there are also weaker connections, both within and between strands. These weak connections can be difficult to detect at any one moment, but in growth models they often cumulate, either from repeated action over many occasions or from multiple connections working together at the same time. These weak connections then become powerful determinants of the shapes of growth.

One common kind of weak connection is competition, in which growth in one component or strand interferes with growth in another. For example, trying to relate two opposing characteristics of the self, such as feeling comfortable and feeling uneasy, may interfere with earlier understandings of the characteristics themselves. Another common connection is support, in which growth in one component or strand promotes growth in another. Understanding how the real me is shy can facilitate the girl’s understanding of why she is awkward with a boyfriend (Rom for Romantic in Figure 7.13). Connections of competition and support occur both between successive growers (levels within a strand) and between domains (relationships or strands). We use within-strand between-level connections to illustrate the processes. Fuller explications are available from van Geert (1994) and Fischer and Kennedy (1997).

As grower C begins to grow along the strand, it competes with grower B, as with feeling comfortable and feeling uneasy. In this model, the competition process is the product of a competition parameter times the change in grower C on two successive trials divided by the level of C on the prior trial. This term is subtracted from the growth equation for grower B:

\[-Cb_{C\rightarrow B} \frac{L_{C_t} - L_{C_{t-1}}}{L_{C_t}}\]

where \(Cb_{C\rightarrow B}\) is the parameter specifying the strength of the competitive effect of grower C on grower B. The competition parameter specifies the strength of the competition effect. Large values of parameters of competition and support can cause major perturbations in growth, including crashes and explosions. Ordinarily, the values are small, which reflect the weakness of these connections.

In this model, the competition is a function of the change in the level of grower C relative to its prior level, not the level by itself. The rationale for this form of competition is that the amount of change involved in growth is posited as the major source of competition, not the absolute level of skill. For example, when an adolescent is working to construct an abstract mapping for comparing her feelings of being comfortable with her mother to her feelings of being uneasy, her new understanding is likely to disrupt her prior understandings temporarily until she can work on the understanding for a while. In addition, the time and effort she spends on building that understanding competes with further learning of her skill at the prior level because that time is used up. That is how grower C competes with grower B as a function of the change in level, not the absolute level itself.

Support of grower B by grower C in this model takes a different form—the product of a support parameter times the level of grower C divided by the carrying capacity of C. This term is added to the growth equation for grower B:

\[+Sb_{C\rightarrow B} \frac{L_{C_t}}{K_C}\]

where \(Sb_{C\rightarrow B}\) is the parameter specifying the strength of the supportive effect of grower C on grower B. For example, when an adolescent relates the shyness of her “real me” with her awkwardness with a boyfriend, the relating of the two characteristics can facilitate the separate lower-level understandings of the shyness and the awkwardness. This support from higher growers turns out to be important in producing developmental spurts in growth curves. For many parameter values, it promotes the occurrence of growth patterns like the succession of spurts seen in Figures 7.7 and 7.11 and thus helps explain empirical findings of successive spurts in growth curves like that for the self-in-relationships study.

Addition of the between-level support and competition processes to the second equation provides this connected growth model for grower B:

\[L_{n_{t+1}} = L_n + P_n \left[ R_n \frac{L_n}{K_n} - R_s \frac{L_s}{K_s} + Sb_{C\rightarrow B} \frac{L_s}{K_C} - Cb_{C\rightarrow B} \frac{L_s - L_{s-1}}{L_s} \right]\]

Each successive level in the hierarchy involves a similar growth equation, and together the equations for the five levels constitute a growth model for one strand of self-in-relationships. The complete model includes five separate relationships (strands), each with connections of support and competition among them as well, and the between-
strand competition and support are defined differently from those within level (Fischer & Kennedy, 1997).

These various connections among growers have powerful dynamic effects on the shapes of growth and development. The confluence of multiple types of connections turns out to be important for determining the many shapes of development.

**Equilibration, Disturbance, and the Shapes of Development**

If the self-in-relationships model is correct, it should produce growth curves like those obtained in the self-in-relationships study for optimal and functional levels, as well as a number of other kinds of growth curves of interest to generate questions for further research. Processes such as equilibration, disturbance, regression, and turbulence can be explored with the model.

The empirical results for development of self-in-relationships in South Korea include a striking difference between optimal and functional levels, as shown in Figure 7.8, where the measure is the highest level obtained for the entire interview. Under optimal conditions, students showed relatively rapid growth as well as two successive spurts in understanding. Under functional conditions, they underwent very slow, monotonic growth.

The model produced growth patterns similar to the empirical ones, with analogous differences between the levels and shapes for high- and low-support assessments. Figure 7.15 presents growth curves generated by the model under high- and low-support conditions. Note that the contextual support referred to in high and low support is different from the support between growers in the model. Contextual support is not included directly in the model, but is varied through the parameter of growth rate. All parameter values for the curves in the figure are the same, except that high-support growers have a high rate and low-support growers have a low one. With differences in rate alone and no other differences among the equations, the shapes shift from strongly stagelike hierarchical growth to more monotonic and variable growth. All the high-support curves approximate the empirical curve for self-in-relationships under high support. The low-support curves for relationship 3, which has the slowest growth rate, approximates the empirical curve for low support. Included in the variability of some of the low-support curves is a jump or drop, which presumably represents likely growth patterns when the growth rate is a little higher than it was in the Korean sample. In general, low rates produce relatively monotonic growth, and high rates produce a series of discontinuities (spurts and drops).

This change from growth through a series of discontinuities to growth that is variably monotonic defines a broad set of the growth patterns for the model, but the model also produces other patterns. For example, in Figure 7.11, which shows curves generated by the same model, Growers 1 and 2 represent similar variation from discontinuous to more monotonic growth. However, Grower 3 represents a more unstable pattern, which is common when the growth curves are less stable or equilibrated.

According to Piaget (1985) cognitive development is usually equilibrated—regulated to produce a series of successive equilibria (times of stability) marking the stages in his developmental hierarchy. Spurt-and-plateau growth patterns like those for high-support growers in Figure 7.15 show an equilibration process, in that the growers for different domains tend to seek the same levels—what is referred to as an attractor in nonlinear dynamics, because there seems to be something pulling the curves toward a common place. For example, when one grower moves higher than the others, which can be construed as a disturbance from equilibrium, it is pulled back toward the common level. At the same time, the growers for functional level do not show any clear attractor—no tendency to seek the same level.

This pattern is also called U-shaped growth because of the decrease after each spurt—which scholars have often puzzled about (Strauss with Stavy, 1982). The U
shape is especially dramatic in Grower 2 in Figure 7.11. In these dynamic growth models and in empirical research on optimal levels, peaks of growth are often followed by drops. By experimenting with the full range of possible values of the parameters in the model, Fischer and Kennedy (1997) determined that the support among multiple domains (relationships) in the model caused this pattern through growers catalyzing each other’s growth and thus producing an overshoot beyond the carrying capacity of the system. Such complex effects from connections among growers are one of the hallmarks of dynamic systems.

Orderly equilibration is a quality of one class of hierarchical growth curves, but there are many forms that show no such order. Besides curves like those for low support in Figure 7.5, many growth functions spread disturbances throughout a system of growers. Sometimes, these disturbances lead to growth patterns like the one shown in Figure 7.16, which we call the Piaget effect. When Piaget (1950) criticized efforts to speed up children’s early development, he suggested that pushing them beyond their natural levels was like training animals to do circus tricks. Instead of contributing to their normal growth, it could lead to stunted long-term development like what happens in some circus animals. The model and growth parameters in Figure 7.16 are the same as those for optimal levels in Figure 7.15, except that Domain 2 was given a special one-time boost to its growth rate at the second level, analogous to special training to produce precocity. The boost caused Domain 2 to immediately grow to higher levels than the other domains, but over time the other domains grew more and Domain 2 ended up at a much lower level. Also, the five domains stopped showing equilibration with each other and instead spread out across a wide range of levels. In this way, a short-term boost in one grower disturbed the entire system, changing the growth patterns of all the growers it was connected with.

The Piaget effect is still an orderly pattern. Sometimes, the growers in this and related hierarchical models show much wilder disturbances, including crashes, explosions, and turbulent vacillations, analogous to the turbulence produced by the simple logistic growth formula with Grower 6 in Figure 7.14. In this way the same growth processes produce a full range of shapes of development from monotonic growth to stagelike equilibrated growth to disturbed growth and turbulent variation. Some of the growth functions of these hierarchical growth patterns even seem to fit the properties of catastrophe and chaos (van Geert, 1994). These are truly nonlinear systems, and they provide a powerful tool for facilitating description and analysis of the many shapes of human development.

Van der Maas and Molenaar (1992) hypothesize that developmental reorganizations marked by shifts to a new skill level reflect an especially important property of change according to catastrophe theory—hysteresis, in which during a time of major change the point of jumping to a higher or lower level shifts depending on the direction of variation in a control parameter. For example, the temperature at which water freezes when heat is removed differs from the temperature at which ice melts when heat is added. Candidates for hysteresis effects in psychological development include contextual support and emotional state. With changes in these factors, shifts to higher or lower levels would vary more dramatically during a time of transition between levels than later when the level had been consolidated.

A wide array of nonlinear dynamic tools is available for tying down developmental processes and analyzing change, and much work remains to be done to apply them to analysis of development and learning. Many of them were devised in biology to deal with the ecology of species interactions and the dynamics of long-term evolution (Holland, 1992; Kauffman, 1996; Wolfram, 2002). A few scholars have even begun to apply nonlinear concepts to social phenomena such as how people work together to construct their own development (Fogel & Lyra, 1997; Nowak, Vallacher, Tesser, & Borkowski, 2000). A particularly promising area for advancing
methods and theories of development is the study of transition mechanisms in microdevelopment of both individuals and social ensembles.

BUILDING STRUCTURES: TRANSITION MECHANISMS, MICRODEVELOPMENT, AND NEW KNOWLEDGE

Because the study of development is the study of change, any adequate account of the development of psychological structures must provide credible explanations of the transition mechanisms by which a constructive agent develops from structures at a given level to more complex, inclusive, and differentiated structures. Recent advances in methods for task analysis in general and microdevelopmental analysis in particular have moved the field beyond the vague descriptions of transition mechanisms of the past. The outlines of a constructivist model of task- and context-specific developmental transitions are emerging. This methodology promises to provide answers to a key question that cognitive scientists have puzzled over: How do people construct new knowledge, building novel understanding out of existing skills (Granott et al., 2002; Gruber, 1973)?

The study of transition mechanisms is closely associated with the concept of microdevelopment (also called microgenesis). Microdevelopment is typically defined as the study of developmental change over short time periods, spanning minutes, hours, days, or weeks rather than months or years. Studying processes of change over short periods produces fine-grained data about the course of transitions as they occur (Granott & Parziale, 2002), which is not possible with the widely spaced observations of traditional cross-sectional and longitudinal developmental studies.

Relations between Micro- and Macrodevelopment

An important advantage of dynamic structural analysis is that it provides a way of relating short-term and long-term change. Past approaches have tended to take either long-term development or short-term microdevelopment (learning) as central, either reducing one type of change to the other or emphasizing one and neglecting or dismissing the other (Piaget, 1950; Skinner, 1969). They have been caught in the problematic unidimensional assumptions about developmental methods and concepts that we outlined earlier.

Microdevelopment is the set of short-term processes by which people construct new skills for participation in specific contexts, which Vygotsky (1978) called “proximal processes.” Macrodevelopment describes the larger-scale processes in which many local constructive activities in different contexts and domains are gradually consolidated, generalized, and related to form the big, slow changes of development over long periods.

The image of the developmental web in Figure 7.9 illustrates this approach to micro- and macrodevelopment. The microdevelopmental processes by which specific skills are constructed in specific contexts are represented by the strands of the web shown under construction (dashed and dotted lines). At any given time, many strands are under construction, and the strands follow different developmental pathways for different contexts and with different coparticipants. The shifts from optimal to functional and from functional to scaffolding levels begin at different developmental points along the scale on each strand and span several levels in the developmental range for that strand, as shown in Figure 7.9 as well as Table 7.1 and Figures 7.1 and 7.8.

Stepping back a bit, scanning across the developmental web presents a broad picture of macrodevelopment. Whereas each small piece of each strand entails microdevelopment, the collection of processes involved in constructing the web as a whole constitutes macrodevelopment, which is not simply an atomistic heap of many microdevelopmental processes but the cumulative process in which all the micro processes participate. In this sense, micro and macro processes are intrinsically related and interdependent in a way that is analogous to the molecular and subatomic worlds. Neither can exist without the other, but neither can be reduced to the other. At the microdevelopmental level of analysis, we find some phenomena that do not appear at the macrolevel, and vice versa.

An important macrodevelopmental phenomenon is the clustering of discontinuities with developmental levels, the intervals in which jumps, drops, and reorganizations in skills co-occur across strands (domains), labeled “emergence zones” in Figure 7.17. This phenomenon captures the kernel of truth in stage theories—what allows people experienced with children to predict accurately, before they have ever met a child, most of the skills the child will be able to use. Examined up close (microdevelopmentally) the web shows enormous variability in performance, but examined from a distance, there is relative
consistency in emergence of a level. For example, understanding of self-in-relationships spurs in individual adolescents at approximately 15 to 16 and 19 to 20 years in macrodevelopment, but microdevelopmental analysis of changes over hours, days, and weeks shows each individual gradually constructing these new skills.

The clustering of discontinuities in macrodevelopment arises not from a mysterious underlying stage structure but from the dynamics by which people build skills through the integration of earlier components in a gradual process with constraints. The constraints include sociocultural meanings and settings (Rogoff, 2003; Whiting & Edwards, 1988), biological changes in neurological and anatomical supports for skills (Carey & Gelman, 1991; G. Dawson & Fischer, 1994; Fischer & Rose, 1996), and the limits that available time places on the speed and scope of skill construction. These same dynamics also cause the opposite pattern—major disparities in ages of skill emergence in some domains under some circumstances, as shown in Figures 7.10, 7.15, and 7.16.

Developmental clustering is a macrodevelopmental phenomenon that does not appear directly in microdevelopment. Yet it arises from the combination of microdevelopmental processes in many contexts leading to clusters of discontinuities for each developmental level. Conversely, macrodevelopmental constraints limit microdevelopmental processes at any given time because people build on skills they have accumulated over time and have upper limits on complexity reflected in functional and optimal levels. Full understanding of developmental transitions thus requires studying the relations between micro- and macrodevelopment.

**Construction Processes: From Micro to Macro**

A major obstacle to studying the relations between micro- and macrodevelopment has been an absence of research methodologies for including both levels of analysis in one study. Conceptual frameworks and research methodologies for the study of short- and long-term change have grown up independently. On the one hand, macrodevelopment has been studied mainly in terms of the broad structural models of Piaget (1983, 1985), Werner (1948), and the experimental/psychometric approach focusing on input and output (Horn & Hofer, 1992; Klahr & Wallace, 1976). Typically, research has used cross-sectional or longitudinal methods to describe the successive forms of psychometrically scaled performance or mental structure at widely spaced points over the life span. Such approaches make no reference to the everyday short-term functional adaptations that lead to long-term changes.

On the other hand, microdevelopment has been studied as a process of relatively immediate functioning in adaptation to specific environments. Whether such adaptations are conceived as individual learning (Bandura, 1977; Skinner, 1969) or as internalization of between-person control (Rogoff, 1990; Vygotsky, 1978), researchers taking functional approaches have done little analysis of long-term structural change.

Contemporary task-analytic methods make it possible to overcome this methodological divide and study the ways that short- and long-term reorganizations relate within a common framework (Goldin-Meadow, 2003; Granott & Parziale, 2002; Miller & Coyle, 1999; Siegler & Crowley, 1991). Common scales and concepts make it possible to describe psychological organization in terms of executive control structures for specific tasks, contexts, and collaborations, thus relating micro- and macrodevelopment. The skill complexity scale makes it possible to use the same scale (Figure 7.3) to analyze both microdevelopment and macrodevelopment. Researchers can relate changes in children’s short-term performance on a task, such as problem-solving efficiency, strategies, and errors, directly to
shift in hierarchical organization of control structures for performance.

This research has led to advances in our understanding of (a) the central transition mechanism of co-occurrence or shift of focus, (b) gradual construction of new structures through building, repetition, and generalization as evidenced in the shapes of growth curves, (c) microdevelopment from novice to expert in a domain, and (d) the process of bridging by which people bootstrap themselves to higher-level new skills.

**Shift of Focus in Transitional States**

A fundamental mechanism of transition in hierarchical integration is co-occurrence or shift of focus (Fischer, 1980b). Research across dozens of different tasks in several laboratories have converged on this common microdevelopmental phenomenon: When individuals are beginning to develop a new skill, they shift between two different representations or two different strategies, each of which is only partly adequate to the task (Bidell & Fischer, 1994; Goldin-Meadow, 2003; D. E. Gottlieb, Taylor, & Ruderman, 1977). Piaget (1952) and Baldwin (1894) described transitions as involving *groping*, in which children search intuitively for ways of combining and differentiating skills in a new form. For example, just before coming to understand conservation of liquid in containers of different shapes, children often represent the height of the liquid verbally while simultaneously representing the width in gesture (or vice versa). A few days or weeks later, they have integrated the two dimensions to form a skill for conservation, taking a major step in an important macrodevelopmental achievement. Goldin-Meadow and her colleagues (1993) have shown that such dual representations dependably indicate a transitional state in the development of skills such as conservation and mathematical equivalence. This transition process occurs in emotional development as well where opposites such as nice and mean routinely co-occur in children’s activities when they are working on integrating these opposites (Fischer & Ayoub, 1994; Harter & Buddin, 1987).

Many transitions involve such construction of new skills from co-occurring components, although many also involve a change in the mixture of skills or strategies applied to a task (Siegler & Jenkins, 1989). The diverse studies of co-occurrence provide a new before-and-after picture of transitions: At first, a person concurrently uses less adequate skills for a given task, and that co-occurrence instigates groping to differentiate and integrate the skills to form a new hierarchically inclusive skill that is more adequate to the task.

**Shapes of Growth Curves in Construction and Generalization of New Skills**

Microdevelopmental analysis illuminates the real-time process of coordination and differentiation of the co-occurring skills to form a new skill. Individual growth curves are analyzed, not combinations of standardized data from many students (Estes, 1956; Fischer, 1980a; Granott & Parziale, 2002; Siegler & Crowley, 1991; Yan & Fischer, 2002). Changes in learning and generalization can be analyzed and compared across skills and tasks, tracing, for example, the progress of generalization of new knowledge to different tasks and contents by individual students or ensembles. Commonly, the progress of learning can be directly detected, including the nature of construction of a skill and the generalization of that skill to new situations. The skill complexity scale in Figures 7.3 and 7.4 greatly facilitates the research by providing a common scale for comparison of growth of diverse skills.

A key tool for analysis is the shapes of growth curves. In everyday learning activities, people produce complex growth patterns, with activities that differ widely in complexity, varying from moment to moment within a range that does not show simple upward progression. With the insights of dynamic systems theory, many cognitive scientists recognize that complex trajectories capture the true shapes of learning and development. Real-time trajectories do not move along a straight line, but instead they typically fluctuate up and down within a range that reflects constraints.

Analysis of growth curves shows a prototypic pattern for building and generalizing a new skill: People build a skill and then repeatedly rebuild it in a wavelike pattern of construction and reconstruction, not in a straight line or monotonic upward progression. Encountering a new task or situation, people first move down to a low level of complexity as illustrated in Figure 7.18, using basic skills similar to those of young children. They then gradually build a more complex skill for coping with the task by repeatedly rebuilding it with variations (Fischer et al., 2003; Granott, 2002). That is, when they encounter some change in the narrow context, their skill collapses and they regress back to a low level and then rebuild the skill again in this new context. With naturally occurring changes in context or state, their skill collapses over and over, and they adapt and rebuild it each time in a different way. This pattern is often called
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Figure 7.19 Microdevelopment of understanding a Lego robot: Repeated reconstruction of skill. A dyad, Ann and Donald, worked together to understand a Lego robot that changed movement in response to light. Their joint problem solving involved repeated reconstruction, as shown in Figure 7.19, starting from primitive egocentric actions that confused the robot’s properties with their own actions and moving to complex representational systems that specified the robot’s concrete characteristics.

Instead of a single upward trend toward a more adequate understanding, Ann and Donald’s skill was fragile, building and collapsing several times, as illustrated by the panels marked by dashed vertical lines in Figure 7.19. Seemingly small changes in the situation led to collapse of their skill to low levels, marked by egocentric actions that confused their own activities with properties of the robot. After each collapse they rebuilt their understanding again. After their initial growth of skill (first panel: Start), a wire fell out of the robot, and they unknowingly placed it back in a different socket, producing a different response in the robot. With this change in the robot, their skill level plummeted, and they began again (second panel: Redo Wire 1). Then someone else joined them and asked what they were doing. In response to the need to explain their actions, their skill collapsed to a low level again, which they gradually built up again over several minutes (third panel: Summary). After finishing their explanation they purposely removed a wire from the robot and placed it...
in a different socket. Once again their skill collapsed and had to be rebuilt (fourth panel: Redo Wire 2).

Notice that this study involved a dyad working together, not separate individuals solving a problem. Many studies of microdevelopment benefit from analyzing learning in such social situations. Not only is the social setting more natural and ecologically valid, but it provides a richer source of data for analyzing learning. Collaboration makes the learning process more visible, as students communicate in ways that externalize the learning process (verbal exchanges, gestures, joint activities). Individuals working by themselves do much less externalization of learning, making it more difficult for researchers to study how they learn.

In summary, repeated building and collapse with changes in the situation show the fragility of new skills, which are usually difficult to generalize (Fischer & Immordino-Yang, 2002; Salomon & Perkins, 1989). Minor changes in the situation cause the skill to fall to a low level and require reconstruction, as shown in the scalloping model in Figure 7.18. We propose that this process of repeated rebuilding is an essential mechanism for creating a generalizable skill.

Learning Takes a While: Growth from Novice to Expert

Building new, generalizable skills usually takes a long time, especially for domains that are taught in school and valued in society such as literacy, mathematics, science, and art. Becoming an expert in a field typically requires 5 to 10 years of learning (Ericsson & Charness, 1994; Gardner, 1993; Hayes, 1985). Creating new general knowledge in a field likewise takes a long time, as when Darwin built the outline of the theory of evolution over a period of 8 years (Gruber, 1981), and then spent the rest of his life generalizing and differentiating it for dozens of topics in biology. Becoming an expert on a task or in a smaller domain may be accomplished in weeks or months, but it still takes time.

Novices and experts show distinct patterns of microdevelopment in their approach to a task, and as people move from novice to expert they produce an intermediate pattern that is equally distinctive. In a microdevelopmental study of graduate students learning to use a computer to calculate simple statistical operations such as the mean of a data set, students showed the three patterns in Figure 7.20 (Fischer et al., 2003; Yan, 2000; Yan & Fischer, 2002). Novices produced erratic, chaotic growth curves, shifting frequently between high and low skill levels as shown in the top row. Students with intermediate skill showed the scalloping pattern, building and sustaining a more complex skill for more than one interchange, as illustrated in the middle row, as well as Figures 7.18 and 7.19. Experts often began at a low level but moved quickly to a skill level appropriate for the task at hand and mostly remained there except for occasional brief drops with mistakes or confusions.

Across four assessments during the one semester course, approximately 40% of the students progressed from novice to intermediate patterns or from intermediate to expert. (Some of the students also showed backward movement from intermediate to novice patterns, apparently becoming confused as the course progressed from simpler to more challenging tasks.) Patterns of growth curves in learning and problem-solving situations thus provide straightforward ways of assessing how people build skills in the short term as well as how those skills relate to long-term development and expertise.

Multiple Dimensions of Learning and Development

Uncovering patterns of microdevelopment like those in Figure 7.20 requires observing the strands along which people are learning new skills. Growth commonly occurs along multiple concurrent strands and threads within strands, some of which show learning and some of which do not (Fischer & Granott, 1995). A given activity does not occur only on one dimension or at one developmental level but at different levels along different cognitive and emotional strands.
In the robot study, for example, Ann and Donald showed two separate but related strands intertwined in the same activity—understanding the robot and verbal communication with each other—which produced strikingly different patterns of growth. In contrast to the scalloping pattern for understanding the robot, the verbal strand showed a consistently higher level of skill and no systematic change over the course of the session, as shown in the top, dashed line in Figure 7.21 (which shows interchanges for only the first panel from Figure 7.19). Ann and Donald maintained effective representational communication during their joint problem solving but showed no systematic growth in the complexity of that communication. At the same time, their understanding of the robot (which was evident through their communication) did show systematic change, forming a scalloping pattern. A superficial analysis of the verbal interactions between Ann and Donald would have missed the process of understanding the robot and showed a relatively flat, stable trajectory in their representational communication, with some fluctuation but no learning. Activity involves multiple, simultaneous strands (dimensions) that are genuinely distinct aspects of the same activity, and in a learning situation only some of these strands demonstrate systematic change.

An important ancillary point is that these students were capable of higher levels of skill than they showed in either strand. Based on their performance in graduate courses and their ages, they were capable of using complex abstract skills, at least mappings at Level Ab2 and systems at Level Ab3, but they did not show these levels in their activities with the robot. People use the skill levels that are required for a task and do not employ the higher levels of which they are capable unless the situation demands it.

Detecting the dynamic nature of learning in microdevelopment requires (a) finding the strands or threads that are growing and (b) distinguishing them from the ones that are merely varying without growing. Methods that recognize the multiple levels of functioning in an activity facilitate distinguishing these different threads and thus uncovering microdevelopment. With such methods, it becomes possible to see how people build skills from low levels and how they rebuild them repeatedly to generalize and consolidate them. Generally, the complex webs of macrodevelopment derive from these microdevelopmental strands, which grow, join, and separate to produce nonlinear long-term development of skill and understanding.

Bridging: A Process of Building New Knowledge

One of the mysteries of learning has been that people somehow build knowledge that is new for them. That is how different people end up with very different knowledge. The origins of new knowledge have puzzled philosophers for centuries (Kant, 1958; Plato, 1941) and continued to puzzle twentieth-century scholars (Fodor, 1975). When people appear to have no knowledge of, say, a Lego robot’s functioning, how can they build new knowledge of the gadget? How can they build new knowledge out of nothing?

The reason for this dilemma lies (again) in the limitations of the paradigm of structure-as-form. People do not build new knowledge from nothing! It only seems that way because scholars assume that people function at only one level of knowledge. In fact, people function at multiple levels, and so they can use one level of functioning to direct their activities at another level. They can build up new knowledge by using old knowledge from other contexts to bootstrap themselves (Dunbar, 2001; Kurtz, Miao, & Gentner, 2001).

One important way that people do such bootstrapping to build knowledge is the process of bridging in which people direct the construction of their own knowledge by functioning at two levels simultaneously (Case, 1991a; Granott et al., 2002). They unconsciously establish a target skill or understanding, which lies unconstrued beyond their current level of functioning, and
they use it as a shell for constructing understanding. The shell functions like a grappling hook for mountain climbers, pulling activities up toward the target level. Often the shell is based on an analogy or metaphor, like the frameworks for meaning that Lakoff (1987) and other cognitive linguists have described. Teachers and other people can also provide bridging shells for learners such as Case’s number line metaphor as a central conceptual structure for arithmetic in young children (Case et al., 1996).

In the process of bridging, the target shells that people build are often partial and fuzzy, but they provide a framework that directs the search for new knowledge. People then use their activities to gradually fill in components of the shell until they have moved themselves to a higher level of understanding for the new task in context. Experts presumably use bridging shells, too, but ones that are less fuzzy and more articulated for relevant domains and that facilitate rapid skill building and problem solution, as in the third row of Figure 7.20.

An example from a second dyad working with a Lego robot illustrates how bridging works (Granott et al., 2002). Kevin and Marvin did not know that their robot responded to sound. When they began their explorations of the robot, they played with it for a few minutes, exploring what happened. After a few minutes, they showed their first case of bridging—a vague reference to undefined cause and effect that provided an outline around which to build a skill: Marvin placed his hand around the robot in different positions to see what would happen, and Kevin said, “Looks like we got a reaction there.”

The term reaction suggested cause and effect, action and re-action, but Kevin gave no specifics because he did not yet know enough. It was not clear what in Marvin’s action (or in something else) was the cause or how the robot’s movement changed in reaction. The two students did not know even that the robot responded to sound, and they had not yet detected relevant patterns in the robot’s movements. Still, the idea of reaction did imply a causal connection, content unknown. Through it, Kevin and Marvin set up a bridging shell that effectively posited two unknown variables, \( X \) and \( Y \), related to each other:

\[
\begin{align*}
\text{Reaction} \\
\begin{array}{c}
(X) \\
(Y)
\end{array}
\end{align*}
\]  
(2)

Parentheses around the letters in the formula indicate that the components were unknown for Marvin and Kevin. This shell linked action \( X \) with response \( Y \) as a reaction to \( X \). The shell was still devoid of content, but it marked an existing unknown causal relation. Bridging follows the basic structures of skill development except that some components of the shell start out unknown or partially known, like algebra in action. The number and nature of unknown components differ with developmental level.

Through construction of a shell, bridging operates like the pillars on an overhead highway that is under construction. The pillars have been put in place, but they do not yet carry the roadway that will eventually be built on top of them. Just as the horizontal beams and the concrete between the pillars are still missing, the content—the specific cause and effect—in Kevin’s brief statement is missing. Like the empty pillars, the bridging shell traces the target causal mapping and prepares a frame for building it. Although the bridging shell is currently hollow or empty, Kevin and Marvin will organize new experiences with the shell and thus introduce meaning to it.

After Kevin and Marvin introduced the reaction shell, they continued to play with the robot and observe how it reacted. A few minutes later, they had built a causal relation, saying: “When it comes over here and as soon as it gets underneath part of the shadow there, it starts changing its behavior.” This statement specified an elementary causal connection between the robot’s coming under the shadow and its change in behavior and thus filled in the first instances of \( X \) and \( Y \) in the skill shell:

\[
\begin{align*}
\text{Reaction} \\
\begin{array}{c}
\text{UNDER} \\
\text{SHADOW} \\
\text{CHANGES} \\
\text{BEHAVIOR}
\end{array}
\end{align*}
\]  
(3)

The bridging shell defined by reaction guided Kevin and Marvin to formulate a first causal relation or hypothesis indicating that a shadow produces a change in the robot’s behavior. After this beginning use of the bridging shell, Kevin and Marvin elaborated it to grope their way to what eventually became a relatively sophisticated, partially stable understanding of the robot.

In overview, microdevelopmental analysis richly captures the dynamics of activity, development, and learning. When people construct skills at new levels of complexity for a given task or situation, the more complex skills are initially tenuous and only become relatively stable gradually over long periods. Working socially as well as individually, people juxtapose or shift between relevant component skills, and they move
gradually through processes of coordinating these components to form higher-level skills. To facilitate their own skill construction, they build shells at higher levels to bridge or bootstrap themselves to new knowledge. Over time, they build and rebuild each skill again and again with each small change in task and context until they consolidate their performance to form a skill of some generality. Once new skills are consolidated, people can use them as bases for further constructive activity, including generalizing to new situations and building additional coordinations. Even when skills are consolidated, of course, they are not uniformly available at will. They remain subject to the many dynamically interacting factors that make up human activity.

Microdevelopmental analysis of learning and problem solving makes especially evident the great variability in the structures of human activity from moment to moment. Another traditional domain in which variability is prominent is emotional development. Traditionally, emotion has been treated as separate from cognition (another instance of reductionist distortion), but the revolution in emotion research in the last 25 years has radically changed that view. Emotion and cognition are not in fact separate but are two sides of the same coin. Indeed, microdevelopment and emotion are two of the domains leading the way in moving beyond the structure-as-form paradigm to create dynamic structuralism.

EMOTIONS AND THE DYNAMIC ORGANIZATION OF ACTIVITY AND DEVELOPMENT

Emotions show powerfully how dynamic structural analysis illuminates human activity and its development. In the past 25 years, emotions have reclaimed center stage in the study of human action and thought, after decades of neglect in the mid-twentieth century during the eras of behaviorism and cognitivism (Damasio, 1994; Frijda, 1986; Lazarus, 1991; Scherer, Wranik, Sangsue, Tran, & Scherer, 2004). Scholars have constructed a new framework for understanding emotion that belongs in the center of the new dynamic structuralism, combining traditional concerns about both structure and function in a single analytic system. The general framework is typically referred to as the “functional approach” because of its emphasis on the adaptive (functional) role of emotions in human activity. Consistent with dynamic structuralism, however, the functional focus is combined with structural analysis, so a more appropriate label would be the functional-structural or functional-organizational approach to emotions (Fischer et al., 1990; Mascolo et al., 2003; Sroufe, 1996). We illustrate the use of several interrelated kinds of structures to analyze emotional functioning, including information flow, script, categorical hierarchy, dimensional split, developmental level, developmental web, and dynamic growth curve. No single analysis by itself can capture all the important aspects of the organization and functioning of emotions—which is typical of dynamic phenomena.

Emotion and Cognition Together

Contrary to common cultural assumptions, emotion and cognition operate together, not in opposition to each other. The official journal of the International Society for Research on Emotion is entitled Cognition and Emotion to reflect this point. Cognition generally refers to the processing and appraising of information, and emotion refers to the biasing or constraining effects of certain action tendencies that arise from appraisals of what is beneficial or threatening to a person (Frijda, 1986; Lazarus, 1991; Russell & Barrett, 1999). Thus, cognition and emotion are two sides of the same coin as characteristics of control systems for human activity. Emotion is together with cognition at the center of mind and activity.

Analysis of emotion highlights the role of the body and social world. Minds are not merely brains that happen to be in bodies. People’s minds are parts of their bodies, and their mind-bodies act, think, and feel in a world of objects and other people. This ecological assumption is fundamental to the dynamic structural framework and applies to analysis of all human activity. Emotions are one of the most important organizing influences on people’s mind-bodies in context—fundamental biological processes that shape action and thought. Contrary to common parlance and much classic theory, emotions are not merely feelings or inner experiences of individuals but integral parts of human activity, shaping action and thought, and founded in social interactions.

In the history of psychology, a distinction has often been made between emotion and affect, with emotion referring to biologically driven reactions and affect emphasizing individual experience and meaning (T. Brown, 1994). By these definitions, modern functional/structural analysis deals with affect rather than emotion, but recent researchers’ emphasis on biological factors has led to general preference for the term emotion. In this modern meaning, emotion is used in a broad sense to include the classical meaning of affect. We use emotion
and affect interchangeably to refer to the broad ways in which activities are organized by action tendencies arising from people’s appraisals.

Adaptation and appraisal are two fundamental concepts in emotion. They are captured in the basic definition of emotion process: People act in contexts where their activities are embedded in events (in medias res). Emotions arise from appraisals of the events based on each person’s many specific concerns (goals, needs). An emotion is an action tendency (constraint, bias) that arises from an appraisal and molds or structures a person’s activities to shift the state of affairs toward his or her goals and needs. The central process in emotion is the action tendency, the way that an emotion organizes activity. Actions, thoughts, experiences, physiological reactions, and expressions of body and voice are all organized by the action tendency of an emotion.

When people feel ashamed, for example, they want to be evaluated positively in some context, but instead someone judges them negatively for something they did or said or for some characteristic of theirs, especially something that indicates a serious flaw (Tangney & Dearing, 2002; Wallbott & Scherer, 1995). They typically lower their eyes, conceal their face, blush, and stay quiet. They try to escape or hide, and they may try to blame others for the event or characteristic. Subjectively, people feel uncovered, small, or heavy, and they focus on their shameful flaw. Emotion refers to this entire process, including appraisal, social context, physical reactions, activities, and subjective experiences, but especially the action tendency that organizes the shame reaction.

The processes of emotion are diagramed in Figure 7.22, which presents a schema for the information processes that many emotion theorists propose (Fischer et al., 1990; Frijda, 1986; Lazarus, 1991). For the situation in which people are acting, they detect a notable change (first box on the left in Figure 7.22), involving some difference in the situation or some violation of expectations. For a case of shame, people may notice that they have acted poorly or broken some rule, or they may observe someone expressing contempt or disgust toward them.

They then appraise the situation for its affective meaning—its significance in their own specific concerns (second box). Despite the cognitive, conscious, deliberate connotations of the word appraisal, this process typically occurs unconsciously and quickly. One result of the appraisal is a general positive or negative evaluation of whether the situation promotes or hinders goal attainment or wish fulfillment (promoting accomplishments or preventing troubles) according to Higgins and his colleagues (1996). Situations that compromise people’s concerns produce negative emotions such as shame, fear, sadness, and anger. Those that promote people’s concerns produce positive emotions such as pride, joy, and love or affection.

A person also appraises the situation for coping potential, how well he or she can deal with or change the emotion-producing aspects of the situation. When circumstances are desirable, a person may try to sustain or further them or may simply enjoy them. When circumstances compromise a goal or need, a person assesses what can be done to change the situation—undoing, altering, or escaping from the negative circumstance. Appraisal that a negative situation can be undone or altered leads to emotions such as anger or guilt. An appraisal that it cannot be undone or changed leads to sadness or shame. Appraisal that it can be escaped leads to fear or shame.

Each appraisal produces an action tendency (third box in Figure 7.22), a pattern of activity based on evaluation and coping potential that is an unconscious plan of action for the situation. Each emotion has a prototypic, often preemptive, action tendency, which takes over control of activity. People tend to act in a certain way and to perceive and interpret events according to specific biases, and their bodies change physiologically to prepare for the planned actions.

Beyond early infancy, people also engage in self-control efforts in which they try to alter their own perceptions and actions. For shame, action tendencies include trying to hide or escape from observation, lowering the head or covering the face, feeling small and exposed, and becoming preoccupied with the negative action or characteristic. Self-control efforts include...
trying to change the negative action or characteristic, deny or disguise it, or blame someone else for it.

The boxes in Figure 7.22 suggest an approximate order for these emotion processes, although they typically occur in parallel and cannot be separated as fully as the boxes may imply. The implications of separateness and sequentiality are a limitation of information-flow analysis. After a person has fully developed an emotion, the processes become seamless and automatic. Emotions appear to occur unconsciously, washing over us autonomously, despite the fact that the processes are complex and derive from a long period of development. The heart of the emotion is the action tendency, which is indicated with darkened lines in Figure 7.22.

In addition to the sequence of processes from left to right, there is a feedback loop in which older children and adults appraise their own affective reactions and move back through the entire set of emotion processes, reacting emotionally to their own emotion and exerting efforts at self-control. This loop often results in an emotion about an emotion, as when a person becomes angry about feeling ashamed or becomes afraid about feeling love or affection.

Organizing Effects of Emotions

The ways that emotions organize activities are powerful and pervasive. Among the structural descriptions used to characterize these organizing influences are: (a) scripts for prototypical organizations for particular emotions, (b) categorical hierarchies, and (c) dimensions for relating emotions to each other.

These empirically derived descriptions of the organizing effects of emotions illustrate especially well how biology and experience work together in human development (Damasio, 2003; Fischer et al., 1990). Nativist theorists often emphasize the constraints or biases that genes place on human action and thought (Carey & Gelman, 1991; Spelke, 2000). At the extreme, nativist researchers look for the early or “first” emergence of some piece of knowledge or emotion, and then claim that this early development shows that the knowledge or emotion is innately present from an early age. Such an approach neglects the developing organization of human activity, reducing analysis to description of a few innate elements, as we discussed earlier. Emotions and emotional development show powerfully how biological constraints dynamically affect the developing organization of activities as they are constructed through experience and culture. Emotions are a paradigm of how the dynamics of development can produce simultaneously both “basic” categories and complex behavioral organizations (Camras, 1992; Russell & Barrett, 1999).

Scripts

A useful way of describing the organization of emotions is with prototypical emotion scripts—descriptions of the prototype or best case of the antecedent events and reactions involved in a common emotion such as anger, fear, love, or shame (Mascolo et al., 2003; Shaver, Schwartz, Kirson, & O’Connor, 1987). These kinds of scripts have been used extensively in cognitive psychology to describe a standard sequence of events that many people share—the prototype or best instance of a certain category (Schank & Abelson, 1977). Prototypic emotion scripts are inferred from stories that people tell about emotions, characteristics that people attribute to emotions, and reactions that people show in emotion-inducing situations.

In a standard format for scripts, antecedents describe the notable change in the situation that evokes an emotion, responses describe the action tendencies that the emotion produces, and self-control procedures describe the ways that people attempt to change or limit the emotion. Tables 7.3 and 7.4 present prototypes for the nega-

### TABLE 7.3 Prototypical Script for Adult Shame

| Antecedents: Person’s Flaw, Dishonorable or Deplorable Action, Statement, or Characteristic |
| A person acts in a dishonorable way, says something deplorable, or evidences a characteristic that is disgraceful or flawed. Someone witnesses this action, statement, or characteristic and judges it negatively. |
| Responses: Hiding, Escaping, Sense of Shrinking, Feeling Worthless |
| The person tries to hide or escape from observation or judgment, feels small, exposed, worthless, and/or powerless. The person lowers the head, covers the face or eyes, or turns away from other people. Sometimes he or she strikes out at the person observing the flaw. He or she is preoccupied with the negative action, statement, or characteristic as well as with negative evaluation of self more generally. |

| Self-Control Procedures: Undoing and Redefinition |
| The person may try to change the negative action, statement, or characteristic, or deny its existence, or disguise it. |

The individual finds another person attractive, physically and/or psychologically.
The other person meets some of the individual’s important needs.
The two communicate well, which fosters openness and trust; they have spent much time together and shared special experiences.

Responses: Feeling Happy and Secure, Wanting to Be Close, Thinking about the Other Person

The individual feels warm and happy and tends to smile, especially when thinking of the other person or being with him or her.
The individual thinks about the other person, wants to be with him or her, to spend time together (not be separated), to make eye contact, to hold, kiss, and be intimate (psychologically and/or sexually), and to express positive feelings and love to the other.
The individual feels more secure and self-confident, and accentuates the positive side of events.

Self-Control Procedures: Not a Salient Issue

(Suppression of love is possible in the interest of decorum or the avoidance of embarrassment, guilt, or rejection, but such self-control efforts are not prototypical, at least in the United States.)


The main organizing influences (action tendencies) for shame are to hide, escape, feel exposed, and become preoccupied with the cause of the shame. The main organizing influences for love are to feel happy and secure, to want to be close to the loved one, and to think about the loved one. Control procedures are typically important for negative emotions such as shame but minimal or nonexistent for positive emotions such as love, because in the prototypic situation there is no desire to avoid or eliminate the positive emotion. Real-life occurrences of emotions are inevitably more complex than simple prototypes, and control procedures do occur with positive affects as well, depending on the variable circumstances of the specific occurrence.

Families of Emotions, Dimensions, and Cultural Variations

Human beings experience many different emotions, and scholars have sought to find an organization underlying all these variations, relying on facial expressions, emotion words, personality types, and various other data to infer relations among emotion types or categories. In general, most categories function through prototypes, forming family resemblances related by similarities to best instances (prototypes). The study of knowledge was revolutionized in the late twentieth century by the realization that most categories function in terms not of exclusive logical definitions but of overlapping prototypes, which organize categories into basic families (Lakoff, 1987; Rosch, 1978; Wittgenstein, 1953). Emotions fit this organization just like most other categories.

One of the striking findings about emotion categories has been the similarity of basic families for emotion words with those for emotional expressions in face, voice, and action. The convergence across these components of human activity is remarkable, as illustrated by the prototypic families for emotion words in English, Indonesian, Italian, and Chinese shown in Figure 7.23 (Shaver, Murdaya, & Fraley, 2001; Shaver et al., 1992). The six emotion families of anger, sadness, fear, shame, love, and happiness also appear in many analyses of facial expressions for basic emotions (Ekman et al., 1987), along with a few additional emotion categories such as disgust and surprise. (The additional categories are not basic families but subordinate items within one of the families in Figure 7.23.)

Besides the basic categories of emotion families, there are higher degrees of abstraction in which families and emotions are related through superordinate categories or dimensions such as positive-negative evaluation. There are also lower degrees of abstraction, in which families divide into subordinate categories, and then the subordinate categories subdivide further into lower-level categories and eventually specific emotion words. For example, in Figure 7.23 clusters of Chinese emotion words form the subordinate categories of sorrowful love and unrequited love in the Sad Love family and the subordinate categories of guilt/regret and shame in the Shame family.

At higher degrees of abstraction, emotion categories fall along several dimensions defining an emotion space. The most prominent dimension is usually evaluation of positive-negative or approach-avoidance. That is why evaluation appears in the emotion process model in Figure 7.22 as part of people’s first appraisal—whether an event is good or bad for them. This superordinate dimension represents one of the three dimensions that have been found in many different research traditions going back to the beginnings of experimental psychology in the nineteenth century, long before the framework for prototype
Figure 7.23  Hierarchy of emotion categories. This hierarchy represents the organization of emotion families in Chinese based on the findings of Shaver and his colleagues. Results for the United States, Italy, and Indonesia are also represented. For subordinate categories, the diagram lists only the largest categories from the Chinese sample. Dashed lines indicate findings that held for only the Chinese sample; dotted lines those for only the United States, Italian, and Indonesian samples. Source: From “Structure of the Indonesian Emotion Lexicon” by P. R. Shaver, U. Murdaya, and R. C. Fraley, 2001, Asian Journal of Social Psychology, 4, pp. 201–224; “Cross-Cultural Similarities and Differences in Emotion and Its Representation: A Prototype Approach” (Vol. 13, pp. 175–212), by P. R. Shaver, S. Wu, and J. C. Schwartz, in Review of Personality and Social Psychology, M. S. Clark (Ed.), 1992, Newbury Park, CA: Sage.

The classic dimensions have been replicated with similar findings across many different methods, data sets, and cultures, although there are some important variations in the exact nature of the dimensions. The three general dimensions are (1) evaluation of positive-negative or approach-avoidance, which usually accounts for approximately half the variance and is shown in Figure 7.23, (2) activity or active-passive, and (3) engagement or self-other. Although dimensions (2) and (3) are not shown in Figure 7.23 because of graphical limitations, they are nevertheless present in the hierarchy as additional superordinate categories.

The basic emotion families and the dimensions of emotions are similar across cultures, probably because they reflect fundamental characteristics of the human species. In this sense, nativist arguments are correct: Emotion categories have an important species-general (hereditary) component (Ekman et al., 1987). In the studies that produced the hierarchy in Figure 7.23, Shaver and his colleagues began with a standard dictionary in each language, asking informants to pick words that involved emotions (Shaver et al., 1992, 2001). Then they used the selected words with another set of informants, who sorted the words into categories. Hierarchical cluster analysis of the sortings produced the dimensions, basic families, and subordinate families. Chinese, Indonesian, Italian, and American/English showed five common emotion families—anger, sadness, fear, love, and joy—as well as the three affective dimensions. Other researchers examining different cultures have found groupings of emotions in similar families and dimensions (Fontaine, Poortinga, Setiadi, & Markam, 2002; Heider, 1991). Claims that emotions differ fundamentally across cultures do not take these broad family groupings into account.

Alongside cultural similarities, however, cultural differences are strong and important. The hierarchies for China, Indonesia, Italy, and the United States illustrate those differences. First, the Chinese organization of love was substantially different from the Ameri-
can/Italian/Indonesian one. In the latter languages, love was categorized as a fundamentally positive emotion; while in Chinese love was sad and negative, as shown by the two main subordinate categories of sorrowful love and unrequited love. In contrast, the American subordinate categories were primarily positive, including words such as fondness and infatuation. The Chinese and American constructions of the basic family of love are clearly different.

An even greater difference was that the Chinese showed a sixth emotion family, shame, which existed in the U.S. study as only a small subordinate cluster in the sadness family, not as a separate basic family. This finding demonstrates a powerful cultural difference—an entirely different emotion family, presumably reflecting important cultural experiences (Benedict, 1946; Kitayama, Markus, & Matsumoto, 1995; Li, Wang, & Fischer, 2004). Shame is much less salient in the United States (and in many other Western cultures) than it is in China and some other Eastern cultures.

Li et al. (2004) followed up this finding by analyzing the categorical organization of the shame family in Chinese, using a method similar to Shaver’s. They worked with Mandarin speakers from mainland China to identify 113 words clearly involving shame. Hierarchical cluster analysis of subjects’ sortings of these words produced the hierarchy outlined in Figure 7.24. The primary superordinate dimension was self/other (one of the three common dimensions of emotion), and there were six families of shame words, with several subordinate categories for most of the families. The English names for each family and subordinate category were chosen carefully to portray the Chinese meanings, but it is difficult to capture in English the connotations of many of these Chinese emotion concepts. Interestingly, one of the families that seems familiar to U.S. culture is guilt, but it was the least differentiated shame family in Chinese, showing no clear discrimination of subordinate categories despite including an ample number of words (13).

Generally speaking, the organization of emotion concepts seems to have broad similarities across cultures, but cultural experiences simultaneously lead to powerful differences in specific emotion concepts and important variations in basic emotion families. Emotion concepts—and emotions more broadly—are not simply innate or entirely variable across cultures. Emotion organization is constrained by broad species characteristics at the same time that it involves very different

Figure 7.24  Hierarchy of shame categories in Chinese. This hierarchy shows the organization of shame categories in Chinese. For subordinate categories, only the first degree of categories is shown. Source: From “The Organization of Shame Words in Chinese,” by J. Li, L. Wang and K. W. Fischer, 2004, Cognition and Emotion, 18, pp. 767–797.
structures across cultures and individuals. Techniques that focus on the variations in emotion facilitate not only description of individual variability and cultural diversity but also detection of shared characteristics of emotions across individuals and cultures.

**Emotionally Organized Development**

The action tendencies produced by emotions shape activities not only at the moment they occur but also as they develop. Emotional experiences have powerful effects on the shapes of developmental webs, whether they are governed by cultural norms or by more individual life events such as trauma. Research on emotional development has mostly focused on these consistent, one-way effects of emotional experiences. Frequent affective experience of a given type shapes development of a person or ensemble along a particular pathway. The general positive bias illustrated in Figures 7.6 and 7.7 is one example: People generally are biased toward the positive, particularly for attributions about themselves (Greenwald et al., 2002). Other repeated affective experiences such as recurring feelings of shame, consistent love from a caregiver, or recurring abuse lead people to develop along a globally different pathway shaped by these affective organizations. Dynamic research tools facilitate the analysis of ways that these emotions shape development.

**One-Way Effects on Developmental Webs for Shame and Honor**

In one broad persistent effect, people develop a strand in their developmental web that would have been minor or nonexistent without the emotional experiences. The development of a distinct sixth family for shame in China illustrates how cultural shame experiences can lead to development of an additional major branch in people’s developmental web for emotions (Mascolo et al., 2003). In China and in many other Asian cultures, children experience shame and shaming repeatedly as a normal part of their socialization (Benedict, 1946; Heider, 1991; Shaver et al., 1992). As a result, they learn many shame words, they develop well-differentiated scripts and categories for shame, and they represent shame as an essential part of their everyday life. In U.S. culture, in contrast, many children experience much less shaming while having other negative experiences as part of their socialization. As a result, most U.S. children do not use shame words in their early vocabulary, nor do they develop well-differentiated scripts and categories for shame. Instead, they develop other negative affective scripts and categories such as ones for anger, aggression, sadness, and depression (Ayoub & Fischer, in press; Luborsky & Crits-Christoph, 1990; Noam, Paget, Valiant, Borst, & Bartok, 1994; Selman, Watts, & Schultz, 1997).

In the web metaphor for the structure of development, the American experience with shame promotes little growth of this branch of affective development. The shame family develops minimally, at least for concepts and conscious experiences of shame. (Scheff & Retzinger, 1991, argue that in America, shame continues to shape activity and experience, operating unconsciously because of its fundamental biological nature in human beings.) The Chinese experience with shame, on the other hand, produces rich growth of the shame branch of affective development, with differentiation of many subsidiary branches to form the multidimensional hierarchy in Figure 7.24.

Along with shame also goes highly differentiated development of honor and respect, which are the opposites of shame in China, unlike U.S. culture, where pride is considered the opposite of shame. This elaborate development of shame and honor leads to developmental pathways not seen in most people in English-language cultures such as the Chinese emotions of self-harmonization and social honor. Chinese children focus on succeeding in their efforts in school and other activities but always remaining modest about their achievements. The goal is to bring social honor to their family through their achievements: “My family is honored even though I am unworthy of your praise.” Development of the strand for self-harmonization and social honor in China contrast with development of the strand for pride in the United States, where the focus is on the child as the achiever rather than on the family (Mascolo et al., 2003).

**Attachment, Working Models, and Temperament**

Two domains where emotional-development research has been extensive are attachment and temperament. In both cases, the model of emotions is that they have a persistent, one-way effect on developmental pathways. According to attachment theory, children’s and adults’ relationships, curiosity, and general emotional security depend on the nature of their early close relationships with caregivers, usually mothers and fathers. According
to traditional temperament theory, babies are born with emotional constitutions that produce a specific pattern of emotional reaction, which pervasively affects their development and tends to remain similar from infancy to adulthood.

Attachment theory characterizes three major developmental pathways based on babies’ affective experience in close relationships: secure (type B), insecure avoidant (type A), and insecure anxious/ambivalent (type C; Ainsworth, Blehar, Waters, & Wall, 1978; Shaver & Clark, 1996). A fourth pathway is sometimes added—disorganized (type D), which is associated with abuse and trauma (Cicchetti, 1990; Lyons-Ruth, Alpern, & Repacholi, 1993; Main & Solomon, 1990). For each pathway, children develop a working model of close relationships founded on their early experiences with their mothers or other caregivers (Ayoub et al., 2003; Bretherton & Munholland, 1999; Sroufe, 1996). Each child’s internal working model follows a straightforward emotion script for interactions in a close relationship, with one or two emotions dominant in the script.

According to the theory, the working model pervades children’s later development, especially in close relationships but also in many other aspects of life. Babies who grow up in a secure relationship build their working models primarily around the emotion of love, trusting that their mothers will be present to take care of them when needed and will allow them independence to explore and learn about the world. Babies who grow up with an avoidant attachment build their working models primarily around a combination of love and fear of rejection, learning that although their mothers usually take care of them, they often reject their babies’ affection or closeness. Babies who grow up with an ambivalent attachment build their working models primarily around a combination of love and anger, learning that although their mothers usually take care of them, they often restrict their actions severely or behave inconsistently, making their infants hypervigilant about attachment and angry at restriction. Babies who grow up with a disorganized attachment respond inconsistently with their caregivers and frequently have a history of maltreatment, which we analyze in a later section. Several longitudinal studies have found some stability in attachment pathways, with moderate correlations in attachment type over years as well as clear evidence of changes in many children (Cassidy & Shaver, 1999; Fraley & Shaver, 2000; Schore, 2003; Waters, Merrick, Treboux, Crowell, & Albersheim, 2000).

Only a few studies have examined the development of children’s working models directly, perhaps because attachment theory treats working models as relatively fixed after infancy. Luborsky analyzed pretend stories created by 3- and 5-year-old middle-class Anglo-American children in response to story stems about emotionally loaded situations with family or friends (Luborsky et al., 1996). In this privileged sample, the dominant working model (which Luborsky calls “core relationship theme”) was positive and secure: A child wished to be loved and understood or to feel good and comfortable. The other people in the child’s stories understood the child and were helpful when help was needed. The child responded confidently and was, in turn, helpful and constructive.

Some research has examined working models of relationships in adult psychotherapy patients, defining how people build on dominant emotions to form an unconscious script about relationships. The script is like a working model, but it has major negative elements connected to the patient’s psychological problems, and so it is called a core conflictual relationship script (Luborsky, 2001; Luborsky & Crits-Christoph, 1990; Noam, 1990; Selman & Schultz, 1990). Scripts include key wishes or concerns, typical responses by others to those wishes, and one’s own actions in response to the others. For example, depressed patients often wish to be loved and close with others, to be accepted and understood, but they see others as rejecting and opposing them more often than loving and accepting them. Their response to the rejection is to feel depressed and helpless (a dominant emotion of sadness), as shown in the script for depression in Table 7.5. Fischer and Ayoub have also analyzed working models in maltreated children, which

### TABLE 7.5 Core Conflictual Relationship Script for Depression

<table>
<thead>
<tr>
<th>Wish or concern:</th>
<th>A person wishes to be accepted, loved, and understood in a close relationship.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other’s response:</td>
<td>Someone else who potentially could be in a close relationship with the person rejects or opposes him or her while intermittently showing some love and acceptance.</td>
</tr>
<tr>
<td>Self’s response:</td>
<td>The person reacts with depression, disappointment, and a sense of helplessness. The dominant emotion is sadness, accompanied by various other emotions in the sadness family.</td>
</tr>
</tbody>
</table>

are discussed in the section on Emotional Splitting and Dissociation.

Research on temperament shows a similar pattern to attachment: modest long-term stability from the school years through adulthood in several dimensions of temperament, especially introversion/inhibition and anxiety/neuroticism (Costa & McCrae, 1997; Kagan & Snidman, 2004). The most extensive research involves introversion/inhibition in which a person is wary of novel situations, especially new people; it contrasts with extroversion or outgoing social behavior. This dimension demonstrates moderate correlations from infancy through childhood and during adulthood, which includes moderate stability on average as well as clear evidence of changes in many children (just like attachment style).

Theories of attachment and temperament mostly posit persistent, one-way influences of emotions, shaping development along one emotion dimension. Structural analysis provides powerful tools for capturing these one-dimensional effects, as illustrated in Figures 7.6, 7.7, and 7.13. These tools also point the way to going beyond one dimension to examine dynamic, complex effects, which typify most of emotional development.

**Dynamic Shifts of Positive/Negative Biases in Webs**

The tools for dynamic structural analysis facilitate moving beyond one-emotion analyses to more differentiated, textured depictions of the organizing effects of emotions on development. Emotional development involves multiple emotions, and emotional biases shift in different situations and at different points in development. Children change their understandings of themselves and their social world, and families, communities, and life situations shift in values and expectations over time.

The pervasive positive bias in development related to self illustrates well the possibilities of a more dynamic, multidimensional analysis of affective biases. Positive and negative emotions act dynamically in development, pulling this way and that—not always in the same direction. In research on development of emotions in self-concepts and social relationships, for example, children have shown developmental shifts in their orientations toward positive and negative (Fischer & Ayoub, 1994; Hand, 1982). In one longitudinal study, 3-, 4-, and 5-year-olds told stories about themselves and other children in nice and mean social interactions, as in Figure 7.5 (Hencke, 1996): Most 3-year-olds showed the opposite of the positive bias in older children and adults—a clear negative bias. At age 3 stories about $ME_{\text{MEAN}}$ were understood better than $ME_{\text{NICE}}$ and preferred. As one 3-year-old said, “Can we do more of these mean stories? They’re more fun!” Within a few years, however, the children’s negative bias disappeared and was replaced by the usual positive bias, which gradually became stronger. This dynamic shift from a negative bias to a positive one is represented in the growth model in Figure 7.25.

**Developmental Shifts in Emotions about Self in Family Roles**

Such shifting affective biases are pervasive in development. In a general developmental principle, each new level brings with it specific emotional reactions and distortions, and many of these emotions change as children develop to higher levels. For example, the research literature illustrates transient emotional defensiveness in early development, based on children’s developing (mis)understanding of themselves and their social roles. For the behavioral role of baby, $ME_{\text{BABY}}$, preschoolers show early skill at acting out the baby role in pretend play, even before the role of mother, $ME_{\text{MOTHER}}$ (Pipp, Fischer, & Jennings, 1987). As they reach the age of 3 years or so (and firmly identify as not a baby), however, many of them become unable to act out the baby role, even though they are now capable of acting out many other simple roles such as mother, child, doctor, and patient (Watson, 1984). Other cases of emotional defensiveness affecting performance in 3-year-olds include African American children categorizing themselves as White even though they can accurately categorize other people as Black or White (Clark & Clark, 1958; Fischer,
Emotions and the Dynamic Organization of Activity and Development

Knight, et al., 1993; Spencer, Brookins, & Allen, 1985) and young boys categorizing themselves as large (old) even though they can accurately categorize other children as small or large (Edwards, 1984). These biases seem to be early versions of the self-promoting bias that pervades human mental life and that changes in form as children’s understandings and emotions grow (Greenwald et al., 2002).

Generally, children participate in the social relationships and roles that they experience in their lives, and various emotional implications of those relationships and roles emerge for them depending on their skill development. A classic example of such emotion effects is the Oedipus conflict, which Freud (1955) originally described but which has been the subject of little developmental research except for global cultural comparisons (Spiro, 1993). According to Freud, preschool children develop a desire to replace their same-sex parent in order to assume a romantic relationship with their opposite-sex parent. Freud built a large theoretical edifice around this emotional conflict in the nuclear family.

Watson and Getz (1990), who studied the Oedipal phenomena empirically in middle-class White U.S. families, found that children did show a surge of Oedipus-type emotionally organized behaviors from 3 to 4 years of age. For example, one 4-year-old girl said to her father, “Daddy, kiss me a hundred times more than you kiss Mommy.” Oedipal behaviors then declined sharply at ages 5 and 6. The researchers explained the emergence and decline of Oedipal activities, in terms of not castration anxiety and similar violent fantasies that Freud attributed to young children, but developing understanding and emotions about family roles. The first understanding of the special love relationship defined by husband and wife roles emerges at age 4 when children map representations of mother and father into a relationship concept. This new skill leads them to want to assume the special role with their opposite-sex parent. As a girl named Johanna comes to understand the special roles of her parents’ (Jane and Walter) as partners,

\[
\text{JOHANNA} \quad \text{MOTHER} \quad \text{WALTER} \quad \text{FATHER}
\]

That is why she says things like, “Daddy, kiss me a hundred times more than you kiss Mommy.”

This understanding gobs together or condenses parental and spousal roles, treating the mother role as including the wife role and the father role as including the husband role. When the roles are differentiated and coordinated in a representational system, children see that they cannot assume the parental role for themselves (becoming their own father or mother), and they see other limitations as well such as that they are too young to marry their parent and that people are not supposed to marry other family members. This emerging, more complete understanding of role relationships in the family leads the child mostly to lose the wish to replace the same-sex parent, unless there are role confusions in the family such as incest (Fischer & Watson, 2001). She comes to understand the intersection of spousal and parental roles in practice in the family:

\[
\begin{align*}
\text{JANE} & \quad \text{MOTHER} & \quad \text{WALTER} & \quad \text{FATHER} \\
\text{WIFE} & \quad \text{HUSBAND} \\
\end{align*}
\]

\[\text{(6)}\]

Development of Emotional Splitting and Dissociation

Emotions powerfully shape development, and one of the most pervasive effects on developmental pathways is emotional splitting, in which people routinely split positive and negative into separate elements that can be combined (Ayoub et al., 2003; Fischer & Ayoub, 1994; Harter, 1999). The positively biased web for development of nice and mean in Figure 7.6 illustrates one instance of splitting: Two-year-old children commonly split self and other, representing themselves as nice and someone else as mean, ME_{NICE} and YOU_{MEAN}. They have difficulty putting the two opposite representations together to see that each person (self and other) can be both nice and mean.

With time, children develop from splitting toward integration in particular domains. By the grade school years, most children become able to coordinate affects across the positive-negative split in many social situations, as when they represent themselves and other people as simultaneously nice and mean in the stories at steps 6 and 7 in Figures 7.5 and 7.6. For example, in one story, Jason comes up to Seth on the playground, hits him on the arm, and says, “I want to be your friend. Let’s play” (a combination of mean and nice actions).
Seth responds with appropriate reciprocal nice and mean actions: “I would like to be your friend, but I don’t play with kids who hit me.” Younger children who are asked to act out or explain stories of this kind commonly split them into two separate stories, one about being nice and a second about being mean. The skills in the middle column (Nice & Mean) in the webs involve various steps in integration across the positive-negative split.

Splitting is a special case of the more general category of dissociation in which activities are separated even though they should be coordinated by some external criterion. Emotional splitting involves separation along the positive-negative dimension, or more generally, between affective opposites (e.g., smart and dumb, grown up and child). Dissociation typically refers to a stronger separation of elements along dimension(s) besides positive-negative evaluation. The mind is naturally fractionated, as represented by the separate strands in developmental webs. Consequently, splitting and dissociation are pervasive in human activity.

The terms dissociation and splitting are often used narrowly to refer to motivated separation in psycho-pathology such as dissociating the self into multiple personalities, or splitting family and friends into good and bad people (Breuer & Freud, 1955; Putnam, 1997). Yet splitting and dissociation occur normally and routinely as a result of lack of coordination of skills or experiences that are naturally separate (Feffer, 1982; Fischer & Ayoub, 1994). There need be no pathology. People normally split their world into good and bad, smart and dumb, or us and them. In many instances, they strongly dissociate themselves from people, beliefs, and feelings that they disapprove of. Experimental research has established clearly that various forms of active dissociation occur normally, especially during dreaming, hypnosis, and extreme religious experiences (Foulkes, 1982; Greenwald et al., 2002; Hilgard, 1977). Splitting and dissociation are normal parts of human development.

Tools for dynamic analysis of development provide insights into both normal and pathological splitting and dissociation. The development of positive and negative shows natural positive-negative splitting, as shown in the nice/mean webs in Figures 7.5 and 7.6 and the SiR Interview in Figure 7.13. In severe emotional trauma, splitting and dissociation are magnified and play an important role in adaptation to the trauma.

Children subject to severe abuse frequently cultivate skills of dissociation to adapt to their horrendous situations (Putnam, 1997; Terr, 1991). For example, 8-year-old Shirley used dissociation to cope with her father’s abuse of her (Canadian Broadcasting Corporation, 1990). Shirley’s father repeatedly raped her in her bed in the basement of their home, and he beat her up if she ever resisted his advances. To cope during the rape, she concentrated on a small hole in the wall above her bed, dissociating from her body and feeling that she put herself into the hole. Inside the hole, she could get through the trauma without major distress and without angering her violent father. One day, her father raped her upstairs in the main house instead of in the basement. Without the hole in the wall to support her dissociation, she began screaming and fighting her father. He lost his temper, knocked her unconscious, and then continued with the rape. (Although the father was never arrested for his crimes, Shirley did eventually find help, and she became a competent adult crusading to stop child abuse.)

In a situation like Shirley’s, dissociation was an adaptive achievement in which she created a coordination to actively dissociate, building skills to keep herself from experiencing the full pain of the trauma. By 4 to 6 years of age, children first demonstrate active dissociation of a few components from one another, as when Shirley put herself in the hole in the wall (Fischer & Ayoub, 1994):

\[
\text{ME-SHIRLEY IN HOLE} \quad \text{SHE-SHIRLEY RAPED}
\]

The block on the line relating the two Shirley roles denotes that the coordination is dissociative. With development, people can construct more complex, sophisticated dissociative coordination, actively separating multiple components.

Although research is still young on the developmental pathways of abused children, available data guide an initial sketch of the pathways, including disorganized attachment—(type D) described earlier. In severely abused or neglected children, the organization of development along the positive-negative dimension is powerfully affected. For many maltreated children, the normal positive bias in representations disappears at a young age to be replaced by the opposite—a negative bias, in which the tilt in Figures 7.6 and 7.7 is shifted to the negative side. Instead of focusing their representations of self and important relationships toward the positive, many maltreated children characterize the self in
pervasively negative terms, endlessly acting out and talking about negative events and interactions.

The findings from one study demonstrate how powerful this reversal can be. It creates an alternative developmental pathway based on a negative self bias. A group of adolescent girls hospitalized for depression and conduct disorder (acting out) described themselves in the SIR Interview (Figure 7.13), which was designed to produce rich self-descriptions (Calverley, Fischer, & Ayoub, 1994; Fischer et al., 1997). In one part of the interview, they indicated the importance of various self-characterizations, and in another part they indicated whether the self-characterizations were positive or negative. Instead of the usual positive bias shown by adolescents in this interview, the girls who had experienced severe and prolonged sexual abuse showed a pervasive negative bias in their feelings about themselves in relationships, as shown in Figure 7.26. Depressed girls in the same hospital who had not been sexually abused showed no negative bias but a clear positive bias instead. Contrary to many clinical claims, the abused girls did not function at low developmental levels in their self-representations; they produced levels comparable to those of the nonabused girls and to adolescents of similar ages in other populations. Their self-descriptions were negative, but not primitive. The abused girls were developing along a distinctive pathway, not failing to develop.

These traumatic environments produce distinct developmental pathways that are powerfully shaped by the experiences of abuse and trauma (Ayoub & Fischer, in press). Children growing up in such environments often produce remarkably sophisticated dissociation, which like Shirley’s dissociation, demonstrate great developmental complexity. Figure 7.27 describes an early developmental pathway for a boy named John, who was growing up in a situation of hidden family violence where there is a rigid, socially maintained dissociation between public good and private violent worlds. In private, his father treated him tyrannically, abusing him physically whenever he disobeyed. In public, his father treated him as a good child whom he was proud of. In general, the parents maintained a consistent public image as good citizens and neighbors and model members of the community, but at home they were violent and abusive.

As John developed working models of close relationships, he constructed his own version of the private-public dissociation that his family maintained. He built increasingly complex and generalized representations of tyrant-victim relationships in private and model-family relationships in public (Ayoub et al., 2003; Fischer & Ayoub, 1994). Figure 7.27 illustrates three major levels in this development between 2 and 7 years of age for the first three levels of the representational tier (Rp1 to Rp3). At the first level, John represented himself in his private and public roles with his father, but did not maintain a firm dissociation between the two (as indicated by the permeable line dividing the domains). At the second level, he built role relationships, connecting his own and his father’s roles and dissociating public and private more firmly. The third level brought a

![Figure 7.26](image_url) Importance of negative self-representations in abused and nonabused depressed adolescent girls. Source: From “Complex Splitting of Self-Representations in Sexually Abused Adolescent Girls,” by R. Calverley, K. W. Fischer, and C. Ayoub, 1994, Development and Psychopathology, 6, pp. 195–213.

![Figure 7.27](image_url) Development of dissociated representations (Rp) of private and public relationships in hidden family violence. The double line between columns indicates dissociation of the private and public pathways.
clear generalization of those roles beyond his relationship with his father—relationships with other adults and children.

These results do not mean that only abused or traumatized children show emotional splitting and dissociation. These are normal processes that everyone shows under many circumstances. Abuse produces different developmental pathways in which the person’s working models of relationships are organized powerfully by the abuse, yielding characteristics such as a negative bias and a sharp dissociation between public good and private violent relationships. Tools for dynamic analyses of development provide ways of detecting these distinctive pathways and avoiding the common error of characterizing complex forms of dissociation and splitting as developmentally primitive.

In summary, emotions act as biasing forces that shape development along particular pathways, including normative emotional splitting of positive and negative in representations of self and others. When children have severe emotional experiences such as abuse, their emotional reactions contribute to shaping their development along unusual pathways that are built on their emotion-laden relationships. Developing understandings affect emotional reactions through changing appraisals, which lead to consequences at certain points in development, such as emotional reactions in 4-year-olds similar to those that Freud attributed to the Oedipus conflict. Emotions thus constitute a prime example of the usefulness of dynamic structural concepts and methods for analyzing how different components work jointly to produce development.

Emotion and cognition work together, affecting each other’s development so extensively that they are difficult to separate. In the big picture of macrodevelopment, many of the large developmental reorganizations occur concurrently for emotion and cognition. Through dynamic structural analysis, it has become possible to build the first detailed models of how these changes in emotion and cognition relate to brain development.

JOINING NATURE AND NURTURE: GROWTH CYCLES OF PSYCHOLOGICAL AND BRAIN ACTIVITY

The dynamic structural framework provides powerful tools for detecting regularities in development. Without these tools, regularities are often swamped by the variability of human activity. Dynamic analysis has been especially useful in dealing with variability in the search for relations between psychological and brain development, producing the first specific models of relations between brain and activity in development—hypothesized growth cycles linking developmental levels of cognition and emotion with growth of cortical functioning (Fischer & Rose, 1994; Thatcher, 1994). Using dynamic analysis, researchers have uncovered rich new findings and built the first detailed models of relations between brain and psychological development.

Most developmental research fails to deal with the facts of variability, but neglecting those facts is especially perilous for research on relations between brain and behavior. Development has many different shapes! Some activities and brain functions show continuous growth, while others show various discontinuities. Research on relations between brain and behavior needs to start with analyzing different growth patterns to find relations amid all the variability. The varying shapes provide tools for unpacking growth processes in brain and activity. If the variations are left out, the research is doomed to become swamped by the combined variability in brain and behavior development.

Epigenesis of Action, Feeling, Thought, and Brain

Today, scientists assume that growth of the brain relates closely to growth of action, thought, and emotion; yet the empirical basis for this belief remains limited because there are few studies that directly assess relations of brain and behavior development. In a few narrow domains, research on neural systems has uncovered close relations between particular brain components and developing behaviors, especially for the visual system (Hubel & Wiesel, 1977) and some aspects of language (Deacon, 1997). For connections between brain changes and development of action, thought, and emotion more generally, speculation is rampant, but evidence is missing.

Happily, research is beginning to change this situation, with new epigenetic analyses of the dynamics of brain-behavior development. Research shows complex patterns of nonlinear, dynamic growth instead of monotonic growth (Fischer & Rose, 1994; Rakic, Bourgeois, Eckenhoff, Zecovic, & Goldman-Rakic, 1986; Shultz, 2003; Thatcher, 1994; Thelen & Smith, Chapter 6, this Handbook, this volume; van Geert, 1998). The tools for
dynamic growth analysis open ways to illuminate the epigenesis of brain-behavior relations.

Between behavior and brain, there are important commonalities that facilitate the search for regularities, including patterns of epigenetic change. Epigenesis is development through qualitative changes like those from egg and sperm to fertilized cell, embryo, newborn infant, and, eventually, adult human being. After the historical debate about the nature of embryological development was settled in favor of epigenesis, as opposed to quantitative growth of a preformed human being, the epigenetic conception was extended not only to brain development but also to cognitive and emotional development (Erikson, 1963; Hall, 1904; Piaget, 1983; Werner, 1948). The analysis of growth functions suggests a straightforward correspondence between patterns of epigenesis in brain and behavior.

From a dynamic perspective, each structure in epigenesis emerges as a result of the self-organizing activity of previously developed systems through coordination of component processes, as described in the earlier section on Dynamic Structure. Such systems are hierarchically organized, with the component systems fulfilling both separate functions and functions that are part of the larger system. The key for developmental science is to unpack the specific principles and cycles in this epigenesis that illuminate the development of brain, action, thought, and emotion.

The growth cycles of brain and behavior involve a long sequence of epigenetic coordinations, extending from before birth well into adulthood. Cognitive and emotional development combine with brain development in a collaboration connecting neural networks with actions, feelings, and thoughts. There is no separation of nature and nurture, biology and environment, or brain and behavior but only a collaborative coordination between them. “Between nature and nurture stands the human agent whose unique integrative capacities drive the epigenesis of intelligence and organize biological and environmental contributions to the process” (Bidell & Fischer, 1996, p. 236).

**Principles for Understanding Growth Patterns of Brain and Behavior**

Analyzed in terms of dynamics of growth and especially discontinuities, developmental curves for many characteristics of brain and behavior show remarkable similarities that seem to relate to their common foundation in hierarchical, epigenetic growth shared by neural networks and optimal levels in behavior. Investigation of these common growth patterns in both psychological and brain activity gives evidence for two recurring growth cycles. We first explicate five principles described by Fischer and Rose (1996) to describe their model of brain/behavior growth cycles, which was strongly influenced by the work of Thatcher (1994) and van Geert (1991, 1994).

Both brain activity and optimal cognitive functioning show nonlinear dynamic growth, often developing in fits and starts, which is characteristic of human physical growth in general (Lampl & Johnson, 1998). Growth speeds up and then slows down, demonstrating spurts, plateaus, drops, and other discontinuous shifts in growth patterns. For some types of growth, the fits and starts are systematic, and for others they are disorderly, showing the variability that is typical of dynamic systems affected by many different factors, as illustrated in Figure 7.11. For certain properties of brain activity and for the optimal levels of cognition and emotion, the fits and starts are systematic and form clusters of discontinuities at particular age intervals. Understanding the systematicity, however, requires understanding the variability. The principles for the dynamic structural framework range from clusters of discontinuities to processes of variability and regularity in growth functions.

**Principle 1: Clusters of Discontinuities in Growth of Brain and Behavior.** Development of both brain activity and psychological activity moves through a series of clusters of discontinuities (spurts, drops, and other forms of abrupt change) indicating levels of reorganization of control systems for action, thought, and feeling. An important focus for analyzing discontinuities is the leading edge of change such as the onset and peak of a spurt.

A broad array of evidence indicates a sequence of discontinuities in development of brain and behavior marking a succession of levels and reflecting basic growth processes, as was discussed in the section on the Common Ruler for Skill Development. The growth patterns for different variables are not identical but variable, showing the normal diversity of dynamic systems. At the same time, the processes of development (what Piaget, 1985, called “equilibration”) produce important regularities across growth curves, as shown by the dynamic model for linked growers in Figure 7.15.
Principle 2: Concurrence of Independent Growers. Developing behaviors and brain activities that are mostly independent (belonging to different domains or strands and localized in different brain regions) commonly show discontinuities that are approximately concurrent. The dynamics of the person’s growing control systems produce concurrent changes across a number of independent psychological and brain activities.

In the web for multiple developing domains, discontinuities occur in concurrent clusters across domains, as marked by the clusters for optimal level in Figure 7.15 and the emergence zones in the web in Figure 7.17. Note, however, that the same growth curves also show relative independence of the growers. When small portions of the curves are viewed up close, as in Figure 7.27, the same growers that show clustering in Figure 7.15 are evidently independent, because the short-term concurrence across growers is not strong. Most developmental research takes this up-close, short-term view, instead of the distanced, long-term perspective. Clusters of discontinuities coexist with relatively independent growth in dynamic systems, with the (weak) linkages among growers often evident only in the long-term perspective.

A frequent error in the study of development is to assume that clusters of spurts or other discontinuities reflect a single coherent mechanism such as growth in a memory module that controls all the growers in common. Many traditional cognitive theories posit such a single mechanism of working memory or short-term memory, which acts as a bottleneck limiting development in all domains (e.g., Case, 1985; Halford, 1982; Pascual-Leone, 1970). Such single-process explanations do not fit the evidence. Growers that cluster can be independent of each other, with the clusters produced by dynamic regulatory processes, as in Figure 7.15. For example, synaptic densities in diverse cortical regions in infant rhesus monkeys develop through approximately concurrent spurts and drops, even though the regions are clearly separate and function mostly independently (Bourgeois & Rakic, 1993; Rakic et al., 1986).

Because of the many ways that a dynamic system can produce concurrent discontinuities, analysis of the processes underlying concurrence requires research designs for analyzing growth processes and dynamic variability. Growth must be investigated under diverse conditions that incorporate assessment of variability, and growth processes should be represented in explicit dynamic growth models (Fischer & Kennedy, 1997; Thelen & Smith, Chapter 6, this Handbook, this volume; van Geert, 1991, 1998). For investigations of relations between brain and behavior, these designs should include analyses of domain specificity of behavior and localization of brain function. Contrary to common assumptions, concurrence does not at all contradict domain specificity or localization.

Principle 3: Domain Specificity of Activities and Localization of Brain Functions. Relations between growers in various domains and brain regions can be analyzed through comparison of individual growth functions for those domains and brain regions. The complex shapes of the growth functions provide a tool for determining which growth functions vary together and thus which skills and brain regions grow together.

For example, many activities in distinct domains exhibit concurrent growth at approximately 8 months of age, including spatial skills such as search and locomotion, verbal skills such as imitation and intonation, and social skills such as recognizing familiar caregivers and striving to stay near them—shown by separation and stranger distress (Ainsworth et al., 1978; Bertenthal, Campos, & Kermoian, 1994; Campos et al., 2000; Uzgiris & Hunt, 1987). Many infants start to search effectively for toys or cookies hidden successively under different covers, imitate simple intonation contours and syllables that they hear spoken by their caregivers, and show consistent distress at their mother departing and at strangers appearing. These three different sets of activities belong to distinct domains and involve distinct cortical networks. They show globally parallel changes, but determination of whether they are tightly connected requires dynamic analysis of growth patterns.

Growth functions can differentiate which of these activities go together with development of specific brain regions. Bell and Fox have compared growth functions for these behaviors with those for cortical activity as measured by the electroencephalogram (EEG; Bell, 1998, 2001; Bell & Fox, 1992, 1994). Individual infants showed strongly overlapping concurrence for some domains and regions, but only loose and imprecise concurrence for others. For example, infants who demonstrated a spurt in search skills between 8 and 12 months produced a concurrent spurt in EEG activity (power) in the frontal cortex, but not elsewhere; they also showed growing connections between frontal and occipital/parietal cor-
Principle 4: Emergence of Neural Networks and Action Control Systems. With each developmental level, a new kind of control system for action emerges, supported by growth of a new type of neural network linking several brain regions and built on lower-level skills. Across different brain regions and skill domains, similar (independent) networks and control systems emerge concurrently. They produce clusters of discontinuities in characteristics of cortical activity and optimal level. Careful analysis of growth functions allows detection of correspondences beyond global concurrence between cortical regions and skills.

After emergence, the new systems undergo a lengthy period of consolidation during which they are tuned gradually to form efficient behavioral-neural control systems. Eventually, another new type of control system starts to grow, and another developmental level and cluster of discontinuities begins. In this way, the growth cycle creates the hierarchy of psychological and brain development.

Principle 5: Cycles of Discontinuities Forming Levels and Tiers. The development of a series of increasingly complex networks and control systems forms two dynamic cycles, one forming developmental levels, and the other, higher-order one, grouping levels into tiers and thus forming a cycle of cycles.

The cycles comprise a cascade of growth changes that move through brain areas and psychological domains systematically and cyclically—a growth process systematically altering neural networks as it moves. There are no all-or-none changes, occurring everywhere at once as suggested by classical conceptions of stage. The cycles may involve a number of different neural processes such as synaptic growth and pruning across cortical regions (Huttenlocher, 2002; Rakic et al., 1986), dendritic growth (Marrs, Green, & Dailey, 2001; Scheibel, Conrad, Perdue, & Wechsler, 1990), the formation of myelin to insulate neurons and thus produce faster neural impulses and improved coordination (Benes, 1994; Yakovlev & Lecours, 1967), and diverse other processes that improve communication among brain regions.

Cycles of Reorganization in Development

These principles specify a model for growth along the developmental scale for psychological activity in relation to brain activity—10 levels between 3 months and 25 years of age, as shown in Figure 7.3 for optimal levels. (An additional three levels are hypothesized for the first 3 months of life, Fischer & Hogan, 1989.) The levels on the scale are supported by an array of evidence of discontinuities and growth cycles for both behavior (action, thought, and feeling) and brain (anatomical growth and cortical activity). The ages for appearance of each level are highly variable, except under optimal assessment conditions. At the age of emergence, most people can first control several skills at the new level of complexity, and by hypothesis they are growing a new kind of neural network in diverse brain regions, evidenced by clusters of discontinuities in neural activity. Even under optimal conditions, however, exact age of emergence varies across individuals and domains (see Figure 7.28).
Development takes place in three different grains of detail—step, level, and tier. At the finest grain at which developmental ordering can be detected, skills form a sequence of microdevelopmental steps, separated by relatively short time intervals and small differences in complexity. In dynamic skill theory, the steps are predicted and explained by a set of rules for transforming skills via coordination and differentiation such as the shift of focus rule discussed in the section on Microdevelopment. Most steps are simply points along a strand in a developmental web of skill construction and do not involve discontinuities.

The intermediate grain of detail is developmental level, with each level emerging in a cluster of discontinuities in behavior and brain activity, marking emergence of a new kind of control system and network, and therefore a capacity to construct a new kind of skill. Assessment of fine-grained steps greatly facilitates detection of levels by providing detailed rulers and clocks for amount and speed of change, as described in the section on Methodology.

At the broadest grain, levels form the cycles of reorganization called tiers, defined by a cycle of four increasingly complex levels, as shown in Figure 7.3. With the start of a tier, skills are simplified by being reorganized into a new unit of activity: actions, representations, or abstractions, respectively (as well as reflexes, by hypothesis, in early infancy). Skills within a tier grow through four levels, from single units to mappings to systems and finally to systems of systems, which initiates the next tier. Development of a new tier brings an unusually strong form of discontinuity, producing radical alterations in brain and psychological activity. For example, late in the second year, children move into the representational tier, beginning to show complex language, independent agency (as in representing MENICE and YOUMEAN), and a plethora of other radical behavioral changes, as well as major spurts in frontal and occipital-parietal activity. Likewise, at 10 to 12 years, children combine multiple concrete representations to form the first abstractions and begin another new tier.

A new tier requires melding together complex systems to forge a new unit—an achievement that necessitates neural glue to cement the components together. We hypothesize that the prefrontal cortex provides much of this glue, in consonance with the general functions of frontal cortex (Damasio, 1994; Gray, Braver, & Raichle, 2002; Thatcher, 1994).

Hierarchical skill growth has a characteristic pattern of spurts and plateaus (sometimes drops), illustrated for the growth model in Figure 7.15. Research on cognitive development commonly shows this specific pattern of growth, as illustrated for a study of reflective judgment in Figure 7.29 (Fischer & Pruyne, 2002; K. Kitchener et al., 1993). The Reflective Judgment Interview, devised by K. Kitchener and King (1990), elicits arguments about knowledge for complex dilemmas such as determining the truth based on conflicting news reports. In an optimal-level assessment, students showed general increases in level between 14 and 28 years, with spurts centered at approximately 16, 20, and 25 years of age. Many other findings, such as the evidence for discontinuities in the development of self-in-relationships for Korean adolescents in Figure 7.8, manifest similar patterns for optimal conditions.

Besides hierarchical growth, correlations among behaviors also show discontinuities with the emergence of skill levels. For example, longitudinal analysis of infant
test performance at three ages in infancy from the Berkeley Growth Study showed sharp drops in correlations among test items at approximately 8, 13, and 21 months of age, as well as a rise from low stability at 4 months, as shown in Figure 7.30 (McCall et al., 1977). These changes match other evidence for discontinuities at similar ages (for instance, Fischer & Hogan, 1989; Ruhland & van Geert, 1998; Uzgiris & Hunt, 1987).

The clear evidence for discontinuities must be understood dynamically: Most activities do not exhibit clear discontinuities at these ages because level varies dynamically with optimal support, emotional state, task demands, and many other factors. Discontinuities occur consistently only in activities that at a minimum (a) increase in complexity with development and (b) are assessed under conditions that support optimal performance (the person’s optimal level). Subtler measures of discontinuity tend to show gaps in scales at the same points even without high support, but the relations with age are then highly variable (Dawson-Tunik, 2004).

**Growth Cycles in Brain**

One of the most remarkable characteristics of the evidence for brain development is the similarity in growth curves with cognitive development. Brain growth shows the same series of discontinuities, fitting the hierarchical growth curve for psychological development. Many of the data have been reviewed by Fischer and Rose (1994) and Thatcher (1994), especially for cortical activity, synaptic density, and head growth. They find that the majority of studies provide globally supportive evidence, but are limited by age sampling that is too infrequent to provide precise estimates of growth functions. The studies with more frequent sampling of age show clear, strong cyclicity of brain growth, with a series of discontinuities at specific age periods, listed in Figure 7.3. Here are a few strong examples involving the EEG, which measures electrical activity in the cortex. The measures showing the clearest developmental change involve the amount of energy in electrical waves, which is called power. Relative power is assessed for a region and wave band by dividing its energy by another measure of energy such as the total energy in the EEG.

In infancy, discontinuities in EEG power appear at ages similar to those for psychological development—approximately 3 to 4, 6 to 8, 11 to 13 months, and 2 years (Hagne, Persson, Magnusson, & Petersen, 1973). For example, a study of relative power for occipital EEG in Japanese infants found spurts at approximately 4, 8, and 12 months, as shown in Figure 7.31 (Mizuno et al., 1970). During childhood and adolescence discontinuities cluster at approximately 2, 4, 7, 11, 15, and 20

![Figure 7.30](image-url)

**Figure 7.30** Changes in stability of infant behavior scores for girls in the Berkeley Growth Study. Source: From “Transitions in Early Mental Development,” by R. B. McCall, D. H. Eichorn, and P. S. Hogarty, 1977, Monographs of the Society for Research in Child Development, 42(3, Serial No. 171).

![Figure 7.31](image-url)

**Figure 7.31** Development of relative power in occipital EEG in Japanese infants. Relative power is the ratio of power for the band from 7.17 to 10.3 Hz to power for the band from 2.4 to 3.46 Hz. Source: From “Maturation of Patterns of EEG: Basic Waves of Healthy Infants under 12 Months of Age,” by T. Mizuno et al., 1970, Tohoku Journal of Experimental Medicine, 102, pp. 91–98.
years (Somsen, van 't Klooster, van der Molen, van Leeuwen, & Licht, 1997; Thatcher, 1994). Figure 7.32 portrays development of relative power from a classic Swedish study, with spurts at approximately 2, 4, 8, 12, 15, and 19 years (Hudspeth & Pribram, 1992; John, 1977; Matousek & Petersén, 1973).

Thatcher’s (1994) massive study of development of EEG coherence illustrates not only the existence of discontinuities at appropriate age regions, but also other shapes for growth curves with different forms of discontinuity. Coherence is a measure of correlation between wave patterns in different cortical regions, so that high coherence indicates that two regions have similar EEG wave patterns and are therefore connected and communicating with each other. With development, coherence for any pair of EEG sites typically oscillates up and down, and these oscillations show growth cycles, moving through cortical regions in a regular pattern. In addition, the oscillations evidence discontinuities that relate to developmental levels, in which the oscillation pattern abruptly shifts to a different period. At approximately 4, 6, and 10 years, the period of oscillation shifts dramatically, and the relations of patterns of oscillation across brain regions shift from in-phase to out-of-phase, or vice versa. These patterns provide powerful clues for analyzing development of brain-behavior relations.

The cycles of coherence suggest not only a series of discontinuities but a growth cycle in connectivity among cortical regions for each level (Fischer & Rose, 1994; Immordino-Yang & Fischer, in press; Thatcher, 1994). Surges and drops in connectivity as measured by EEG coherence cycle through brain regions in repetitive patterns. The leading edge of growth moves in a systematic pattern around the cortex, showing one full cycle for each level, as diagramed in Figure 7.33. The connections are typically led by the frontal cortex, beginning with long-distance connections between frontal and occipital regions for both hemispheres. Then growth moves systematically around the cortex, extending through the right hemisphere and then through the left. For the right hemisphere, growth begins with long-distance, global connections and then contracts toward more local ones. In the left hemisphere, growth begins with more local connections and expands toward more distant ones. Growth moves systematically through cortical areas until it encompasses networks everywhere in the cortex. The cycle thus explains how independent networks manifest concurrent growth spurts in a general age period.

There is much exciting research to be done to test out these models of brain-behavior development and their implications for relations between brain change and behavioral development. It is important to remember, however, that they are dynamic systems, which means that they will not follow uniform shapes for growth. They will show variations from the simplified growth functions in Figure 7.15 and various figures in this chapter. They will also show important variations across individuals, tasks, states, and contexts, as predicted by the growth processes in the dynamic model.

CONCLUSION: DYNAMICS OF STABILITY AND VARIABILITY IN DEVELOPMENT

The proper focus for understanding human action, thought, and feeling is the organization of human activities and their many variable shapes. Activities form coherent patterns—dynamically varying structures that people actively construct at every moment, using not only their brains but also their bodies; the objects and people around them; and the roles, norms, and values of their culture. Dynamic structuralism analyzes human activities in all their complexity, combining concepts...
Figure 7.33 A cycle of growth of cortical connections for each level of skill development. Note: Jagged-line connections mark the leading edge of growth of coherence. Growth continues for each connection at other times as well. Connections between the middle and back of the left hemisphere are more prevalent than similar connections for the right hemisphere, and the temporal-central connection for the left hemisphere is shown as an example of that difference. Sources: From “Dynamic Growth Cycles of Brain and Cognitive Development” (pp. 263–279), by K. W. Fischer and S. P. Rose, in Developmental Neuroimaging: Mapping the Development of Brain and Behavior, R. Thatcher, G. R. Lyon, J. Rumsey, & N. Krasnegor (Eds.), 1996, New York: Academic Press; and “Cyclic Cortical Reorganization: Origins of Human Cognitive Development” (pp. 232–266), by R. W. Thatcher, in Human Behavior and the Developing Brain, G. Dawson & K. W. Fischer (Eds.), 1994, New York: Guilford Press.

and tools from nonlinear dynamics, biology, and cognitive science.

Explanation starts with people in medias res, and the structures of action, thought, and feeling are analyzed in the activities themselves, not in static logic, innate ideas, or internalized experiences. When a person acts, he or she functions on multiple developmental levels simultaneously, not just on a single level. As a person grows, his or her activities develop in many different shapes, not according to one or two basic patterns, as in linear change. Although the complexity of activities is great and their variability ranges widely, researchers can use powerful tools from dynamic systems and skill analysis to investigate the structures or organizations (patterns of components) and find the order in the variation.

The classic frameworks for analyzing structures have not acknowledged either the dynamics or the self-organizing properties of human action, feeling, and thought. They have relied on a static conception of structure as form, seeking simple “main effects” and “stabilities” instead of appreciating the power of analyzing variation. This static conception has reduced structures to one-dimensional forms with most of their components missing. It has reified psychological structures by treating them as logic, innate ideas, or sociocultural systems instead of placing them directly in the activities themselves. In its current guise, it forms the modern synthesis, in which nativist and empiricist positions are no longer in opposition but instead form a common framework based on Cartesian epistemology, reducing people to separate parts and analyzing them statically in separated nature and nurture.

Doing research within the dynamic structural framework leads to a different place. Analyzing the variability of human activities turns out to help illuminate the order within the variation; that is, designing research to analyze dynamics leads to new insights about the stabilities inside the variability. When development is analyzed as a constructive web instead of a linear ladder, clearly distinct pathways become evident for different people. For example, poor readers are not simply low on the ladder for development of reading, but they are developing their reading skills along more branched, less integrated pathways than normal readers. Abused children are not simply immature on the ladder for emotional stability and social reciprocity, but they have created distinct branched (often dissociated) pathways to cope with their abuse.

When multiple levels of skill are analyzed in each person, the debate about the existence of stages disappears. There is a common complexity scale for development and learning across domains, marked by discontinuous jumps at regular points in the scale, but it functions dynamically, not as a fixed ladder. Under optimal, highly supported conditions, people show jumps in performance
that act much like stages; but under ordinary, low-support conditions, the same people show no systematic stages, often progressing in smooth, monotonic growth. The complex shapes of growth curves under these various conditions provide important tools for analyzing relations among different components of human activity because the shapes can serve as clues for discovering such relations. Analysis of these shapes suggests relations between development of brain electrical activity and behavior, leading to new models of cycles of growth that relate brain activity to levels of skill development.

Recognition that individuals function at multiple simultaneous levels also allows the detection of strong microdevelopmental progressions reflecting people’s construction of new skills and knowledge. It illuminates previously unrecognized mechanisms of transition such as co-occurrence of alternative strategies for approaching a task, repeated reconstruction of a skill to make it generalized, and construction of empty algebra-like shells to guide one’s learning and facilitate building more complex skills. The common complexity scale in combination with growth models facilitates relating the short-term processes of microdevelopment to the long-term patterns of macrodevelopment.

When the collaborative nature of most activities is recognized and analyzed (instead of isolating people and studying them as separate “individuals”), important aspects of development become clarified. Processes of construction of skills can be straightforwardly detected in many situations because people interact with each other about their common activities with a task or problem. Many patterns of emotional development become clear because so much emotion arises from people’s social relationships. Emotions such as shame and love are obviously social as well as biological, but even emotions such as fear, anger, sadness, and joy grow up in relationships and are defined by social scripts. Emotions act dynamically to shape or bias activity and development, and persistent, strong emotional experiences create distinctive developmental pathways such as richly textured shame concepts in China and elaborated negative self-in-relationship models in children who suffer abuse and trauma.

Scholars and researchers now have many new tools and concepts for analyzing the richness of human development, moving beyond Cartesian paradigms that reduce dynamic organization to static form and dichotomous analysis in nature versus nurture. Many examples are already in hand of how dynamic structural analysis helps illuminate phenomena that have been perplexing or that have gone undetected in prior paradigms. With the new dynamics, developmental scientists now have the possibility of capturing human nature in all its richness and variation instead of reducing people to one-dimensional stereotypes.

REFERENCES


References


Canadian Broadcasting Corporation. (1990). *To a safer place* [Television broadcast].


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394 Dynamic Development of Action and Thought

Studies in cognitive development (pp. 67–120). London: Oxford University Press.


Fogel, A., & Lyra, M. C. D. P. (1997). Dynamics of development in...
References 395


Dynamic Development of Action and Thought


Shaver, P. R., & Clark, C. L. (1996). Forms of adult romantic attachment and their cognitive and emotional underpinnings. In G. G.
Dynamic Development of Action and Thought


