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Adult Cognitive Development: Dynamics in the Developmental Web

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Kurt Fischer, Zheng Yan and Jeffrey Stewart

Adulthood normally spans more than 60 years, starting from about age 20, and the cognitive changes during those years are vast. Accumulated evidence indicates that cognitive development in adulthood is rich, complex, and dynamic, perhaps even more so than in infancy and childhood, with many factors acting together in various contexts to produce systematic, dynamic variation. For instance, it can be observed that adults frequently show regression performances and move down to lower levels of cognitive skill and then construct higher levels, instead of always following a simple forward progression. This kind of backward transition phenomenon in adult cognitive processes shows an interesting and important cognitive advancement, one that may seem frustrating and counter-intuitive to many intelligent adults.

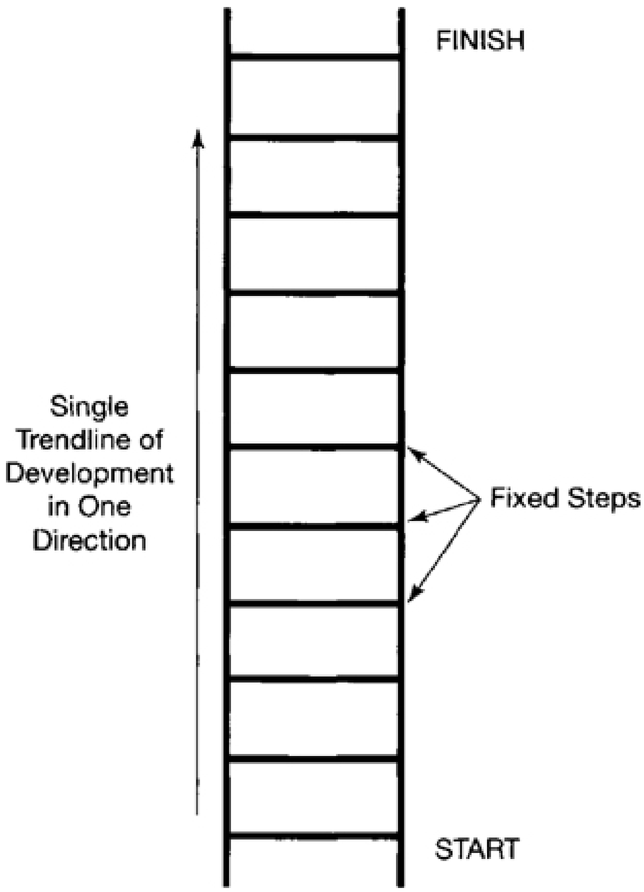
Backward transition is just the tip of the large iceberg of complex cognitive development in adulthood. In this chapter, we reframe adult cognitive development dynamically, resynthesizing research findings to reveal the complex dynamics behind the variability in adult cognitive development, and reexamine the limitations of traditional cognitive analyses (Fischer, 1980b; Fischer & Bidell, 1998; Valsiner, 1991; van Geert, 1994). A constructed web (like that built in nature by a spider) serves as the meta-metaphor for development, and from the web we elaborate three important types of dynamic patterns in adult cognitive development: dynamic ranges, dynamic strands and networks, and dynamic constructions. With these concepts, we begin to capture the richness and complexity of adult cognitive development and to offer a new story about what, how, and why adult cognitive development takes place over time.

Ladders and Webs: Meta-Metaphors of Adult Cognitive Development

The history of science shows that different meta-metaphors functioning as central mental models have had tremendous impact on scientific thinking (for example, viewing the earth as the center of the universe, seeing the spiral as the structure of DNA, considering the person as a digital computer). Likewise, different meta-metaphors drive fundamental views of adult cognitive development. We categorize two major types of meta-metaphors for adult development – ladders and webs – which engender different portraits of adult cognitive development.

Developmental ladders characterize development as a simple fixed progression, following monotonic change, with one step following another in a single direction. As shown in Figure 21.1, the developmental ladder-like trajectory has at least three features: (1) development simply follows a single straight line; (2) each step is fixed, following the previous step along the line; and (3) forward progression along the line is the sole form of development.

Figure 21.1 A developmental ladder



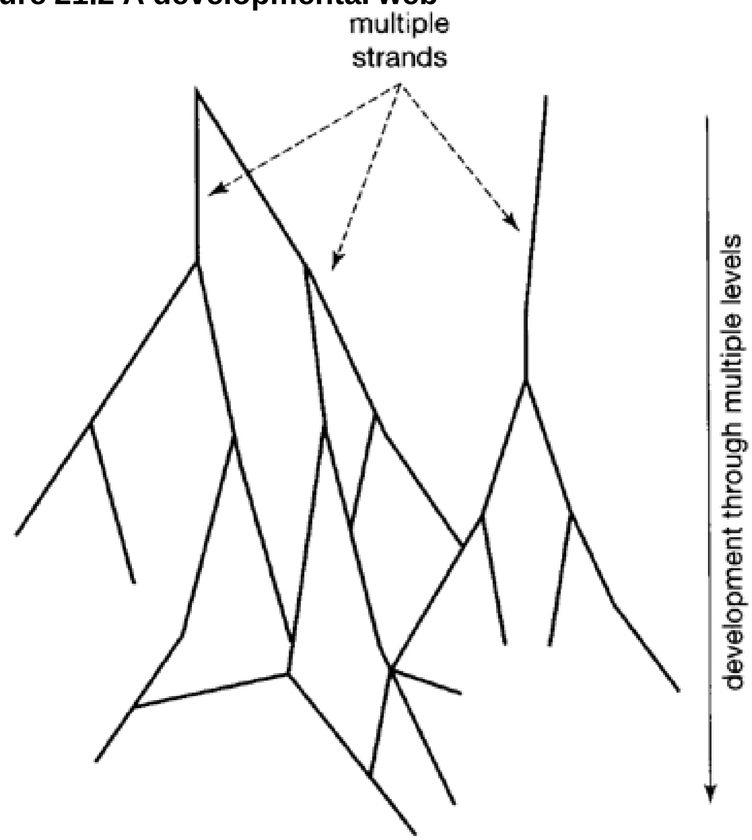
Piaget's (1983) cognitive developmental model, as it is usually understood, is one of the most common ladder-like models of human cognitive development (although Piaget himself had a more dynamic view, as in Piaget, 1975). According to this model, thinking progresses through a series of stages and then stops at the level of formal operations during adolescence. Many scholars have built upon this Piagetian framework by extending the model vertically or horizontally in adulthood, adding more stages or more unevenness across domains (Alexander et al., 1990; Baltes, 1987; Basseches, 1984; Berg, 2000; Commons et al., 1998; Dawson, 1999; Erikson, 1968; Gardner, 1983; Gruber, 1981; Kegan, 1982; King & Kitchener, 1994; Kohlberg, 1969; 1984; Loevinger, 1976; Sinnott, 1998). These models either have substantially expanded Piaget's model along the vertical dimension by adding higher cognitive stages such as post-formal operations and advanced reflective thinking, or have extended Piagets model along the horizontal dimension by including more cognitive domains such as moral reasoning and self-understanding.

Other models that are grounded primarily in psychometric research, such as standardized ability testing, often have acknowledged phenomena similar to Piagetian stages, but have emphasized certain upward and downward general developmental trends associated with age on standardized tests of abilities (Baltes, 1987; Birren, 1964; 1970; Craik, 1977; Craik & Salthouse, 1991; Horn, 1982; Horn & Cattell, 1967; Salthouse, 1984; 1992; Sternberg, 1985). Some abilities, such as crystallized intelligence, increase well into old age, while others, such as fluid intelligence, begin to decrease by early or middle adulthood.

These various developmental models have substantially added to knowledge of cognitive developmental changes and variations in adults, but all of them, to differing degrees, share an underlying ladder-like meta-metaphor. They treat adult cognitive development, like child cognitive development, as a static progressive process unfolding along a series of fixed ladder steps, either through stages or through linear ability scales. In short, this meta-metaphor does simplify complex developmental phenomena and sketch general developmental trends, but at the expense of neglecting, downplaying, and even misrepresenting the variability and richness of adult cognitive development.

In contrast, *developmental webs* portray adult cognitive development as a complex process of dynamic construction within multiple ranges in multiple directions. As illustrated in Figure 21.2, the developmental web has at least three important features: (1) development occurs in a complex multilevel range; (2) developmental pathways undergo dynamic transformation through multiple strands or network links; and (3) multidirectional construction is the form of development.

Figure 21.2 A developmental web



Dynamic skill theory (Fischer & Bidell, 1998) analyzes development as involving a constructed web that captures much of the rich variability in human behavior. Central to the variability, it turns out, is the fact that activities take place in specific contexts. People do not act in a void. Growing adaptively in a dynamic world with various social, emotional, technological, and physical challenges means that behavior must fit the immediacy of the situation. For a description of development that aims at both rigor and honesty, these contexts cannot be ignored. A web captures the interconnected complexity of skills in diverse contexts, as shown in Figure 21.2. Each web contains distinct strands for different contexts and activities, sometimes converging through coordination, sometimes diverging through separation or differentiation, always built through specific sensorimotor and mental activities. Emotional states also shape strands, such as the separation of positive and negative activities (good and bad, nice and mean, approach and avoidance). The web metaphor stresses that many components contribute to any activity, producing diverse shapes of development. A person acts interactively, engaged with his or her many environments, and the action process is dynamic and nonlinear because the outcome of an action involves more than adding together the behavior of the individual and the environmental components that contribute to it. Specifically, each person constructs a unique web, while at the same time ordering principles help generalization across individual webs.

The web also incorporates skill variation within each strand. Each strand is structured by a composite of available levels – the developmental range – with reference to the experiences and contextual supports that contribute to its construction. For any single domain of action (single strand), a person's competence is not fixed at a particular point on the strand but can vary along a portion of the strand. Practice and familiarity with a domain, contextual support for complex activity, and joint participation with others all affect the level of a person's activities along a strand. Each single strand shows the developmental range in skill and knowledge of the individual for that particular task and domain given varying amounts of experience and contextual support. Later in the chapter we will elaborate how this variability can be integrated into the web metaphor.

Conceptually, the developmental web differs from a developmental ladder in at least six important ways:

1 The web places variation in activity at center stage, whereas the ladder downplays variation, relegating it to marginality as error or individual differences.
2 The web is based on individual cognitive performance, whereas the ladder is primarily based on average group performance.
3 The web includes multiple cognitive levels in each person, whereas the ladder assumes a single level at a time.
4 The web distinguishes multiple tasks and domains, whereas the ladder treats diverse tasks and domains in terms of a single line.
5 The web has inherently complex interconnections within it, whereas the ladder does not include networking among elements.
6 The web shows multiple directions of construction, such as forward consolidation and backward transition, whereas the ladder assumes a single direction of forward progression.

Rethinking adult cognitive development requires establishing new meta-metaphors to replace old meta-metaphors. Developmental webs can capture more of the richness and complexity of adult cognitive development than ladders. As a powerful meta-metaphor, the web can facilitate better understanding of what, how, and why adults' cognition changes in complex situations over the extremely long period of life after childhood.

Dynamic Ranges in the Web

Research shows that the complexity levels of adult cognition continue to change in two important ways. First, for the same cognitive task, an adult often shows multiple levels of cognition under different circumstances. Because of the wide range of levels of which adults are capable, cognitive performance in adults varies much more widely than in children. Adults can think more flexibly, dynamically, and contextually than children, while like children they also continue to make errors, even ridiculous mistakes, and to act in simple, primitive ways. Second, the upper limit of cognitive functioning continues to increase beyond what Piaget called formal operations (Inhelder & Piaget, 1958; Piaget, 1975; 1983). Thus, adults can solve much more abstract and complicated cognitive tasks than children, even while they also can use low-level skills similar to those of children. The lengths of some strands in the web continue to expand into development, representing a continuing increase in adults' optimal cognitive skills and a wide range of variation in the level of skills that adults can use in a domain.

Multiple Levels of Adult Cognitive Development

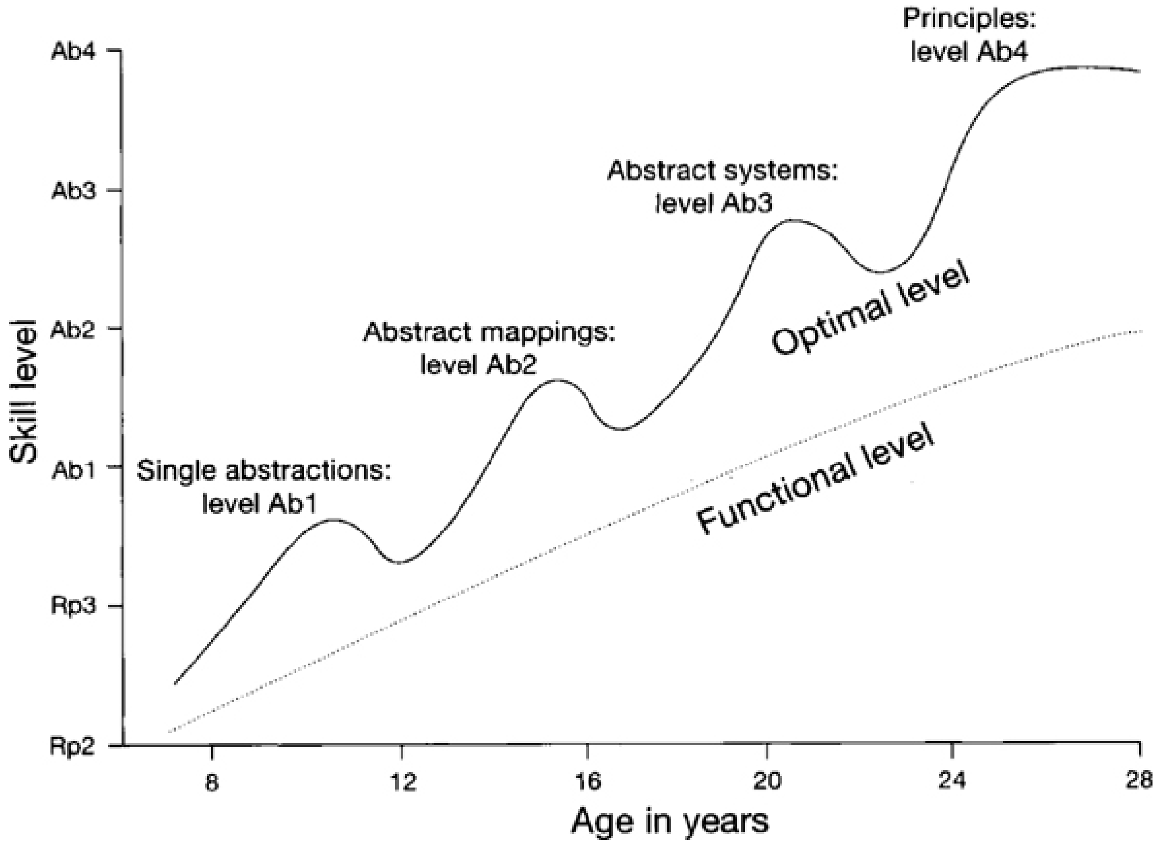
Along with the increase in overall complexity of adults' cognitive development, both developmental research and everyday observations indicate that adults show multiple levels of cognitive development, not performance at one fixed level. Even very wise adults use simple skills when the situation requires simple action, and from time to time they may make unwise decisions when dealing with complex tasks without sufficient contextual support to them. The dynamics of adults' multilevel performance vary with contextual support, prior experience, and joint action with other people.

Optimal and Functional Levels

A central concept in traditional developmental research is that of 'upper limit': people have an upper limit on a given skill beyond which they cannot go. This concept requires major revision, because even an adult's upper limit varies dynamically with contextual support. Developmental research differentiates two major types of upper limit on skill performance, varying with contextual support: optimal level and functional level. There is no single level of competence in any domain. Instead, in the absence of task intervention or scaffolding by others, individuals show great variation in skill levels in their everyday functioning (Fischer & Bidell, 1998; Fischer, Hand, & Russell, 1984; van Geert, 2002). Optimal levels are attained primarily in those infrequent circumstances when environmental conditions provide strong support for complex performance. Such conditions, including clearly defined tasks, familiar materials, practice, and memory priming of the gist of the activity, are not present in most situations. For this reason, every person shows a persistent gap between the functional level under typical (low-support) conditions and the optimal level afforded by high support.

Functional levels tend to be characterized by slow, gradual, and continuous growth over time, whereas optimal levels exhibit stage-like spurts and plateaus within an upward trend, like those in Figure 21.3. These two trend lines diverge, becoming more disparate with age, because they depend on different sets of growth processes. The functional level results from the steady construction of a skill in a particular domain over time, whereas the optimal level – the upper limit on functioning – is achieved through strong contextual support for a skill combined with organic growth processes that reorganize behavior and brain activity in recurring growth cycles. Furthermore, the gap between functional and optimal levels grows with age. Research has found a far larger increase with age in the optimal level for a given skill than in its functional level, and consequently the gap increases from early childhood through adulthood (Bullock & Ziegler, 1994; Fischer, Kenny, & Pipp, 1990; Kitchener et al., 1993; Watson & Fischer, 1980).

Figure 21.3 Development of optimal and functional levels in a domain

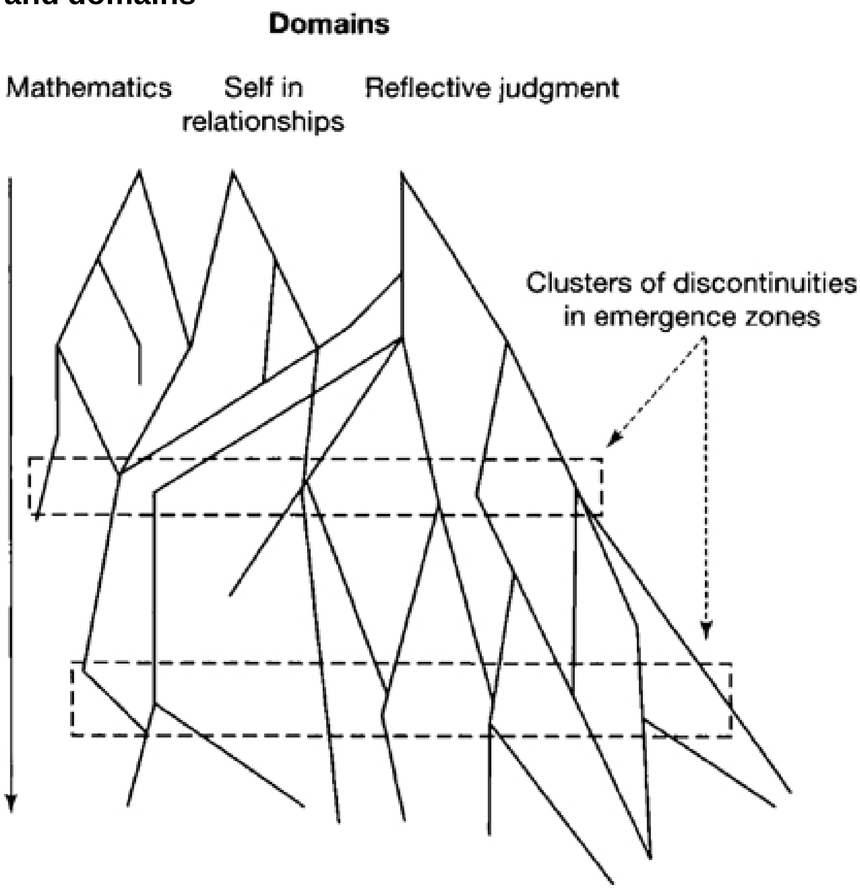


An example of optimal and functional levels in abstractions is the development of concepts of self in relationships. In a study of how Korean adolescents (grades 8 through 13, or adolescent through young adult) saw themselves in relationship with others, students participated in the Self-in-Relationships Interview, which included both an open-ended interview about their relationships (low support) and a high-support assessment (Fischer & Kennedy, 1997; Kennedy, 1994). Support was provided through their creation of a detailed diagram of the characteristics of specific relationships. In the high-support assessment, students (a) created descriptions of their characteristics with particular people; (b) placed the descriptions in one of three concentric circles from most to least important; and (c) grouped similar descriptions, drew connecting lines to indicate relations, and added a plus or minus to indicate emotional valence (good, bad, or ambivalent). Then the interviewer asked them a series of questions to elicit explanations of their diagram at different developmental levels. In the low-support assessment students produced only a slight increase over the six years and did not achieve even the level of single abstractions. The same students in the high-support condition started at a higher level, single abstractions, and moved up to the level of abstract systems. In addition, their trajectory showed spurts for the emergence of abstract mappings and abstract systems, similar to those shown in Figure 21.3. Much more sophisticated cognitive skills were called forth with support, while an absence of support led to low-level skills.

Note that optimal level produces a series of spurts in growth followed by plateaus or small drops – a dynamic pattern of change that is common in development (Fischer & Bidell, 1998; Fischer, Kenny, & Pipp, 1990); Thatcher, 1994; van der Maas & Molenaar, 1992). The fact that the functional level shows no such systematic variability underscores the potential for missing the telling dynamics of development by examining performance in only one condition and assuming that it represents the basic nature of cognitive development. Growth patterns differ under different conditions, even for the 'same' skill in the same person, and the dynamics of this variability are fundamental in adult cognitive development.

How do the spurts in optimal level relate to the web of development? Various strands/domains in a web show a cluster of spurts within a concurrent zone, as illustrated in Figure 21.4. Put another way, in the developmental web, the optimal level emerges when clusters of discontinuities appear across many strands in the same time period. This skill phenomenon has a neurophysiological correlate, in that cortical substrates for the increase in ability show developmental changes that mirror the behavioral ones (Fischer & Rose, 1994; Thatcher, 1994). That is, patterns of cortical activity show spurts that are approximately concurrent with the spurts in optimal skill level.

Figure 21.4 Clusters of discontinuities for two optimal levels across strands and domains



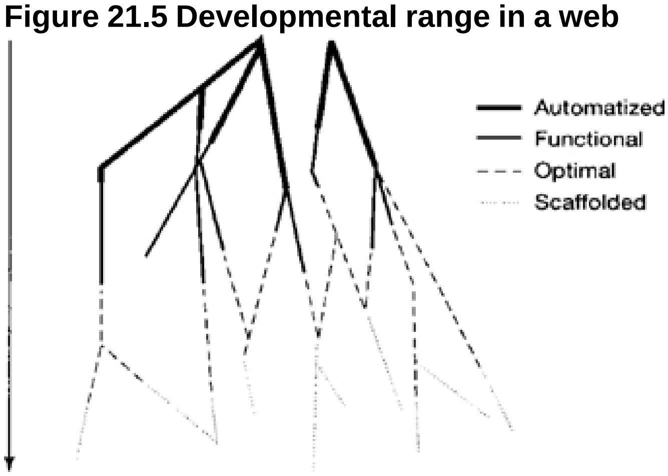
Automatization and Co-Participation

Optimal and functional levels are only two of the many skill levels that adults routinely use. For example, when people act automatically (without thinking or consciously choosing), they typically act at a low level, as when someone steps on the brake automatically when a child runs in front of the car. Researchers have not directly assessed the developmental level of such automatic actions, but they exist in every domain, and usually they are relatively simple and primitive.

On the other hand, people frequently act together with other people, cooperating to accomplish a task together – telling a family story, putting together a jigsaw puzzle, playing poker, or building a house. One person scaffolds the actions of another, sometimes in expert and novice roles as with teacher and student (Wood, Bruner, & Ross, 1976) and sometimes as more equal collaborators (Granott, 1993b; Valsiner, 1996). In actuality, many situations that psychologists often treat as individual are naturally social. Many children prefer to play video games with their friends, either directly sharing them or talking about them on the phone. Many scholars write papers with the help of other people, even when only one author is listed. In co-participation in general, people co-construct complex skills that often go beyond their individual capacity, as Vygotsky (1978) emphasized with his concept of the zone of proximal development, and Wood, Bruner, and Ross (1976) elaborated with the concept of scaffolding. Indeed, the importance of such social construction has been recognized for the entire history of modern psychology and child development, but it continues to be neglected in most research and theory (Valsiner & van der Veer, 1988), which is especially puzzling in elaborations of explicit theories of social construction such as Erikson's (1963). Co-constructive processes are at least as important in adults as they are in children.

In addition, people move up and down in the level of their performance, adapting to the situation, goal, task, emotional state, and their co-participants. Realtime analysis of ongoing activity shows how level varies dynamically with these factors, even more in adults than in children (Bullock & Ziegler, 1994; Fischer & Granott, 1995; Granott, 1993a; 2002; Kuhn et al., 1995; Roberts, 1981; Siegler, 2002; Vaillant, 1977). As a strand in a person's web grows longer, he or she has a wider range of skills to use across portions of the strand. Figure 21.5 shows how the four levels that we have described are evident in the web. Automatized skills, marked by thick solid lines, mostly occur early in each strand. Functional skills, performed thoughtfully but without support, are marked by thin solid lines. Optimal skills, which usually depend on contextual support, occupy later portions of the strand and are marked by dashed lines. Scaffolded skills, in which people jointly perform a complex activity, are most complex and are marked by dotted lines.

Figure 21.5 Developmental range in a web



Levels of Optimal Cognitive Development

Adult development must be understood in terms of the whole scope of development from infancy, both because later skills are built on earlier ones and because adults routinely use skill levels that first emerge in infancy and childhood (especially when they move down in a strand of the web to use automatized skills, or make backward transitions to build new skills). Dynamic skill theory describes the context-based constructive process of building from reflexes to actions, from actions to representations, and from representations to abstractions (Fischer, 1980b; Fischer & Bidell, 1998). Cognitive activity undergoes massive restructuring during the years of infancy and childhood, gradually building toward concrete skills and conceptual categories. In adolescence and early adulthood, people restructure their activities again, moving from representations to abstractions. Much of the rest of adulthood involves consolidation, elaboration, integration, synthesis, and extension of these abstract skills.

The skill hierarchy not only describes cognitive development, but provides a ruler for assessing and studying dynamic variations in adult activities. This ruler allows comparison of levels across conditions and tasks, such as optimal, functional, and scaffolded levels (Figures 21.2 and 21.3), and it makes possible analysis of the dynamics of real-time learning and problem-solving, as in backwards transitions and forward consolidation. Dynamic analysis of skill requires such a scale to assess variability and to model it. Cognitive development research has been hampered by the absence of such scales for coding activity across tasks, domains, and trials, except in the arena of motor activity, where Cartesian coordinates provide ready-made scales for dynamic analysis (Rose & Fischer, 1998; Thelen & Smith, 1994; van Geert, 1994).

Hierarchy of Adult Skill Levels

From birth to 30 years of age, an individual develops skills through four sequential *tiers* in a nested hierarchy. Early *reflexes* become coordinated into *actions*, actions are coordinated into *representations*, and representations into *abstractions*. Each of these qualitatively different behavioral repertoires cycles through a similar pattern of coordinations – the four *levels* of each tier. Movement is from an initial *single* expression of an ability (the first level of a given tier), to a *mapping* of two elements (the second level of a tier), to a *system* that relates multiple elements (the third level), and finally to a *system of systems* (the final level). Each level arises from the gradual combination of two or more skills from the prior level in a process of coordination and differentiation. Taken together, the four tiers produce a scale of 13 levels that increase in complexity and integration – a 13-point interval scale for assessing the dynamics of development and variation. Reorganizations of neural networks seem to help catalyze development of a wide range of skills at each new level (Fischer & Rose, 1994; 1996).

The levels that characterize the final tier move through single abstractions, abstract mappings, abstract systems, and abstract systems of systems, or principles. We will describe this development of increased complexity of abstract thinking from middle childhood through adulthood, as shown in the left-hand part of Table 21.1, and we will explicate the levels through discussions of reflective judgment, moral judgment, identity development, and Darwin's construction of the theory of evolution.

Table 21.1 Levels of development of representational and abstract skills

Level	Tier		Age[1]
	Representations	Abstractions	
Rp1 single representations	$[Q]$		18 – 24 months
Rp2 representational mappings	$[Q\text{——}R]$		3.5 – 4.5 years
Rp3: representational systems	$[Q^{U}_{V} \longleftrightarrow R^{U}_{V}]$		6–7 years
Rp4/Ab1: systems of representational systems, which are single abstractions	$\begin{bmatrix} Q^{U}_{V} \longleftrightarrow R^{U}_{V} \\ \Updownarrow \\ S^{W}_{X} \longleftrightarrow T^{W}_{X} \end{bmatrix}$	$\equiv [\mathbb{Y}]$	10–12 years
Ab2: abstract mappings		$[\mathbb{Y}\text{——}\mathbb{Z}]$	14–16 years
Ab3: abstract systems		$[\mathbb{Y}^{\mathrm{C}}_{\mathrm{D}} \longleftrightarrow \mathbb{Z}^{\mathrm{C}}_{\mathrm{D}}]$	19–20 years
Ab4: systems of abstract systems, which are principles		$\begin{bmatrix} \mathbb{Y}^{\mathrm{C}}_{\mathrm{D}} \longleftrightarrow \mathbb{Z}^{\mathrm{C}}_{\mathrm{D}} \\ \Updownarrow \\ \mathbb{A}^{\mathrm{E}}_{\mathrm{F}} \longleftrightarrow \mathbb{B}^{\mathrm{E}}_{\mathrm{F}} \end{bmatrix}$	24–25 years

Note: Italic letters designate representational sets, and outline letters abstract sets. Subscripts and superscripts designate differentiated subsets. Long straight lines and arrows designate a relation between sets or systems. Brackets mark a single skill. Note also that structures from lower tiers continue at higher levels (representations in abstract skills, etc.), but the formulas are omitted because they become so complex.

[1] Ages are modal for the emergence of optimal levels based on research with middle-class American and European children. They may differ across cultures or social groups.

The optimal level of representational systems (Rp3) usually emerges around the age of 6 years in middle-class children with high contextual support, and is elaborated and consolidated over the next 3 or 4 years. (The earlier representational levels are shown for completeness and because they appear in adult problem-solving, discussed below.) This level is the core of much adult functioning, because for many activities people need only concrete actions and representations, not sophisticated abstract thinking. With a skill at this level, a person can coordinate two or three different aspects of several representations. For instance, a child Kara and her mother Jane can play teacher and student, where the child/teacher interacts simultaneously and reciprocally with the mother/student:

$$\overset{\textit{Play}}{\begin{bmatrix} \textit{STUDENT} & & \textit{TEACHER} \\ \textit{JANE} & \longleftrightarrow & \textit{KARA} \\ \textit{MOTHER} & & \textit{CHILD} \end{bmatrix}} \qquad (1)$$

Children especially enjoy reversing conventional roles to assume more powerful and independent adult roles in play; and adults frequently cooperate in this pretense. The mother and the child both act with a similar representational system, as shown in formula 1, but the mother's skill may include an additional component for scaffolding her child's skill. The category relations usually remain fully concrete, even when the story becomes complex.

The optimal level of single abstractions (Rp4/Ab1) emerges at about age 10, when youngsters begin to understand abstract concepts commonly used by adults. At this first level of abstract thinking, the ability to relate different explicit instances of representations to an intangible concept becomes commonplace. For a 12–year-old girl, traveling with friends to a parade, buying her own lunch, and choosing her own new clothes can all be related in the concept of independence. The representational systems for the parade, the lunch, and the clothes, which each have a structure similar to that in formula 1, are richly coordinated in a new skill, which is an achievement of representational complexity (Rp4). A diagram for the coordination of two systems to form an abstraction is shown in Table 21.1. The coordination of parade, lunch, and clothes systems gives them the power to broadly unify the three contents into a single abstract concept, independent:

$$\begin{bmatrix} \text{SELF} \\ \text{INDEPENDENT} \end{bmatrix} \qquad (2)$$

At this initial level, abstractions are somewhat fuzzy because they are single: without comparison, abstractions cannot be easily differentiated from each other. The 12–year-old may use the same three examples for both independence (formula 2) and individualist:

$$\begin{bmatrix} \text{SELF} \\ \text{INDIVIDUALIST} \end{bmatrix} \qquad (3)$$

When asked how the two differ, she muddies them together, not clearly articulating a difference: ‘They're the same thing. Both of them involve being free.’ Imagine how complex and confusing it is when a third concept such as liberty is added to the pot! The same kinds of confusion create difficulties in coordinating one's own identity with another person's, often leading to a kind of merging or globbing of identities with a close friend or partner (Erikson, 1968). Adults as well as adolescents show this globbing together of distinct abstractions, and it takes many different forms (Fischer, Hand, & Russell, 1984). At least adults are capable of building higher-level skills to compare and differentiate related abstractions.

The optimal level of abstract mappings (Ab2) appears when adolescents are first able to coordinate two or more abstractions, beginning at about age 15. Much sophisticated adult activity involves this level of simple relations of abstractions (Colby et al., 1983; Commons et al., 1998; Cook-Greuter, 1999; Dawson, 1999; King & Kitchener, 1994). Being able to use one abstraction in comparison with another is a great help in making thinking more precise. Independence and individualism are related but distinct, with independence involving the freedom to do things on one's own, and individualism involving a commitment to freely choosing who one wants to be:

$$\begin{bmatrix} \text{SELF} & \text{———} & \text{SELF} \\ \text{INDEPENDENT} & & \text{INDIVIDUALIST} \end{bmatrix} \qquad (4)$$

In tandem with the increase in cognitive clarity at this level is a jump in social facility because of the capacity to coordinate and differentiate one's own abstractions with someone else's. In identity, a person can coordinate an abstraction about themselves with one about a close friend or partner, allowing for a new kind of intimate relationship, such as how my independence is similar to and different from my friend's, especially in our close relationship:

$$\begin{bmatrix} \text{SELF}_{\text{INDEPENDENT}} \text{ ——— } \text{FRIEND}_{\text{INDEPENDENT}} \end{bmatrix} \qquad (5)$$

(Erikson, 1968; Fischer & Ayoub, 1996; Kegan, 1982; Loevinger, 1976; Noam et al., 1990).

At around the age of 19 or 20, the optimal level of abstract systems (Ab3) emerges, as individuals coordinate multiple abstractions and begin to understand the subtleties and nuances in abstract relations in many domains, including understanding of self and others. For instance, the young adult can compare and relate the subtleties of abstractions like conformity and independence. At the prior level, relating different forms of conformity and independence in different situations is difficult, but with abstract systems it is easier to see: for example, that both at school and with friends I show mixtures of both conformity and independence. Similarly with identity coordination, a mother and father can understand how their two identities differ with their son and daughter, and a person can more readily coordinate his or her own conformity and independence with a friend's or partner's:

$$\begin{bmatrix} \text{SELF}^{\text{CONFORMING}}_{\text{INDEPENDENT}} \longleftrightarrow \text{FRIEND}^{\text{CONFORMING}}_{\text{INDEPENDENT}} \end{bmatrix} \qquad (6)$$

The optimal level of abstract systems of systems (Ab4), or principles, is the final developmental level predicted by skill theory. Emerging under high-support conditions around the mid-20s, this highest cognitive level allows a person to coordinate several abstract systems together, as diagrammed in Table 21.1. How does my own personal identity relate to moral dilemmas that I have faced, or career choices I have made, or different intimate relationships I have had (Erikson, 1963; 1968)? By coordinating two or more abstract systems, a person can construct and use a general principle that goes across systems, such as the Golden Rule in morality and Reflective Judgment in knowledge dilemmas. We will describe in some detail how Darwin built his level Ab4 principle of evolution by natural selection:

$$\begin{bmatrix} \mathit{EVOLUTION}_{\mathit{SELECTION}} \end{bmatrix} \qquad (7)$$

Once constructed, such a principle can be extended to many different abstract systems, as we will illustrate later. People do not remain at this level for long periods, but only use it as needed, with environmental and social supports required to sustain it in the day-to-day activities of living.

These skill levels provide a complexity scale with which to assess the variability in people's activities and to look for patterns of stability and order. People do not act stably at one skill level, as in the ladder metaphor for development. Instead they range widely over many levels, sometimes changing almost instantaneously in adapting to different challenges. The range extends from low levels of action and representation (far below those shown in Table 21.1) to the highest level of abstraction (Brown & Reeve, 1987; Bullock & Ziegler, 1994; Fischer & Bidell, 1998; Fischer & Granott, 1995; Granott, 1993a; 1998; Kuhn et al., 1995; van Geert, 2002). Much of what we describe in this chapter is the rules for order in this pervasive variation in adult cognitive development.

Development beyond Abstractions?

Is there any evidence from these studies that might point to the development of levels and tiers beyond the level of principles (Ab4) – perhaps relating principles to each other or changing skill capacities in some other way? Sound and sufficient empirical evidence is required to answer this question, and we know of little that has been decisive beyond the level of principles for newly emerging optimal levels. Perhaps adults have enough to do simply generalizing and consolidating the abstractions required of them. However, some interesting work by Francine Benes (1984) on myelination of neurons in the brain suggests a possible major reorganization at mid-life. Myelin is the insulation around neural axons that greatly improves the speed and efficiency of neural transmission. After years of only slow change in myelin, adults in their 40s and 50s show myelin growth spurts for neurons connecting the prefrontal cortex to the limbic system. One speculation is that this change creates more refined control of emotional impulses, perhaps in relation with the mastery of the highest levels of abstraction that many adults achieve by these ages. With the capacity to sustain complex abstract and principled thinking without contextual support (at least in areas of expertise) comes a greater opportunity to bring wisdom to bear on emotional equilibrium and self-control. Perhaps this change is relevant to Erikson's (1963) suggestion that wisdom is the central issue in his final stage of identity development.

Development of Reflective Judgment and Moral Judgment

The foundations of knowledge are a fundamental issue in cognitive science and philosophy, and John Dewey (1910) described a model for the development of understanding the bases of knowledge. The goal of education is what he called *reflective judgment*, the ‘active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends’ (1910, p. 6). Key elements include the use of evidence and reasoning, the frameworks for knowledge and belief, and justifications for conclusions. Developing reflective thinking is one of the important tasks and intellectual challenges in adult cognitive growth.

The foundations of moral reasoning are even more important than reflective judgment in human society, especially for socially responsible adults. Moral evaluation and judgment are one of the intellectual challenges that adults face in a world with multiple, often conflicting moral standards and decisions. Good moral reasoning not only requires abstract thinking, but also complex value judgments and emotions. The influential work of Lawrence Kohlberg (1969; 1984) on moral reasoning reveals how people move in their thinking from an authoritarian notion of morality through a gradual relativizing of their judgments, and then to an established value system (a process generally analogous to that for reflective judgment). Indeed, the research on reflective judgment was based directly on the research and methods that Kohlberg devised for moral judgment.

A rich research program led by Kitchener and King has investigated the development of reflective judgment in adults, as well as adolescents, including tests of optimal and functional levels (King & Kitchener, 1994; Kitchener et al., 1993), whereas the research on moral judgment has not assessed these two distinct levels. Kitchener and King start by asking people about difficult dilemmas and how they know something is either true or false for such a dilemma. One of their standard dilemmas concerns chemical additives: are they good things because when added to food, they prevent some illnesses; or are they bad because they may cause cancer? Depending on the response to this dilemma, people can vary over seven stages of understanding, with the optimal stages emerging from, roughly, 2 years of age up to 25 years and beyond (Fischer & Pruyne, 2002). The stages map exactly onto the skill levels outlined in Table 21.1 (Kitchener et al., 1993).

At the first stage, responses reflect only an absolute kind of thinking: a fact or conclusion is either right or wrong. In moral judgment, the first several stages reflect a similar concrete approach to morality: an action is simply good or bad. By stage 4 of reflective judgment (the middle stage) people have moved to a relative type of thinking: the truth of a statement varies with the perspective. Whether something is true 'depends on your bias'. This stage involves the construction of single abstractions (Ab1) for relative knowledge, and, as is typical for this level in general, people have difficulty moving beyond the confusion of single, uncoordinated abstractions. A person knows simply that knowledge is a variable thing, and even though an attempt is made to justify a decision about chemical additives, the justification is neither coordinated conceptually with the decision nor differentiated from it.

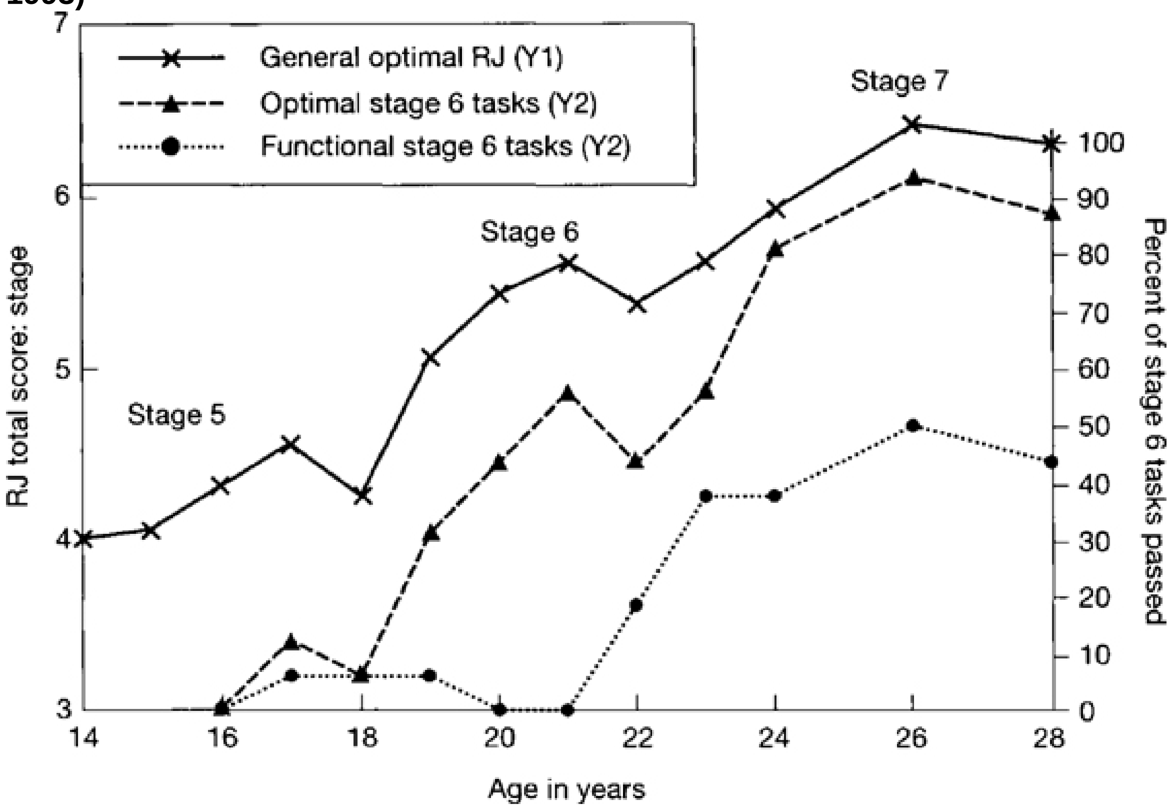
The nature of relativism in moral judgment remains a question in the research. It is unclear whether there is a distinct stage of relativism. Two candidates are stage 3, where moral judgment is based on one's social group norms, or an additional stage between 4 and 5, where the relativity of moral judgment to society and culture is recognized (Dawson, 2002; Fischer, Hand, & Russell, 1984).

In stage 5 of reflective judgment (the level of abstract mappings, Ab2) people begin to compare arguments, evidence, and viewpoints, recognizing that some arguments and conclusions are better than others. Arguments and justifications are linked to a certain context or viewpoint, and there is certain logic relating to the conclusions, but still people take a mostly relativistic stance. At stages 6 and 7, Dewey's goal of reflective judgment comes into play: the truth of the proposition depends on the specific arguments made and the supporting evidence for the arguments. With sufficient evidence and argument, a conclusion can be firmly reached that goes beyond a relativistic dependence of viewpoint. Stage 6 arguments (abstract systems, Ab3) recognize that knowledge is not always certain but that strong, justified conclusions can be made with sufficient evidence. Stage 7 arguments (principles, Ab4) move to fully reflective judgment, including formulation of a principle that strong, justified conclusions rest on their evidence, and that different kinds of evidence depend on the situation and viewpoint from which they were collected.

In moral judgment, Kohlberg's stages 5 and 6 constitute what he called *principled moral reasoning*, analogous to the principle of reflective judgment. General principles are held to apply across cultures, along with local variations, and are used to guide judgments of lawful and moral activities. Empirical evidence supports the existence of a social-contract principle, which Kohlberg characterized as stage 5, in which people argue that values established by norms in order to promote social harmony for the good of everyone are subject to modification according to the will of the people. The universal ethical principles that Kohlberg hypothesized for stage 6, such as the Golden Rule (do unto others as you would have them do unto you), remain controversial because research to date has found few people who consistently function with such principles (Colby et al., 1983). We propose that research on dynamic variation in moral judgment, such as optimal and functional levels, will resolve this dispute.

One study of reflective judgment suggests a kind of order in the variation behind the emergence of optimal levels. When a level or stage first emerges, people do not quickly generalize the new skill across all tasks but work slowly and painstakingly to create the general skill. For instance, when the level of abstract systems first emerged in the students in this study at about age 20, they produced only about 50% of their arguments at stage 6 (Figure 21.6). Not until the next level emerged at about age 25 did they produce nearly 100% of their arguments at stage 6. In general, each optimal level produces a spurt in performance, as shown in the line for the general reflective judgment score in Figure 21.6. But that level does not become powerfully generalized until some years later, with the emergence of the next level (or even a further level beyond the next). For the functional level, the process is much longer yet, reaching 50% only in the late 20s. In general, functional consolidation of optimal skills requires many years of adult development.

Figure 21.6 Development of reflective judgment (data from Kitchener et al., 1993)



An important finding about both reflective judgment and moral judgment is that higher education plays a central role in their development and consolidation. All the people in the study in Figure 21.6 were students, either graduate students, college students, or college-bound high school students. Research shows strongly that education plays a more important role than age alone in producing movement to sophisticated judgments about moral issues and the nature of knowledge (Colby et al., 1983; Dawson, 2002; King & Kitchener, 1994; Rest et al., 1999). The emergence of a new optimal level is not enough to produce the stable development of a sophisticated skill. A stimulating environment must catalyze the development of the highest stages of moral and reflective judgment, and it may be essential for other domains of adult development as well.

Dynamic Strands and Networks in the Web

Adults develop not only deeply but also broadly. To deal with complex natural, social, and spiritual worlds, adults apply, extend, and expand their sophisticated cognitive skills in a wide variety of distinctive tasks and domains that they encounter in both academic settings and their everyday lives, including job, profession, health, family relationships, child rearing, home purchase and maintenance, self-understanding, emotion regulation, moral reasoning, religion, and politics (Baltes & Staudinger, 1993; Erikson, 1978; Fischer, Hand, & Russell, 1984; Gardner, 1983; Kegan, 1994; Neugarten, 1968; Sternberg, 1990). In all phases of adulthood, people need to update their skill repertoire in multiple domains constantly in order to adapt themselves to change. Adults must develop multiple specialized cognitive skills, such as critical reading, academic writing, moral judgment, household management, business practices, emotional intelligence, and religious practices, to meet challenges they face. The dynamics and complexity of strands in the web provide a model of the richness and complexity of this breadth in adult cognitive development.

The complex interconnections among skill components and domains in a web remind us of a neural network, especially of the many dendrites that can proliferate from a single neuron within a network. With complex networking among multiple skills in multiple domains, adults manifest phenomena that occur not at all or in much reduced form in children, such as complex multiple identities, interdisciplinary expertise, creativity, and wisdom. Moreover, dynamic networks of strands constantly change over time and context, and produce emergent and complicated cognitive processes and products. Examples of how adults develop in multiple domains include strands of identity in adulthood, Darwin's construction of the theory of evolution, and the pluses and minuses of cognitive aging.

Strands of Adult Identity Understanding

Observing, analyzing, and understanding oneself is one of the most difficult lifelong intellectual challenges that each adult has to face. Erik Erikson (1963; 1968), in his classic work on identity development over the life course, had the insight that identity always develops in *relationship* with other people, especially in family, friendship, and work. Erikson described a developmentally ordered sequence of crises that reaches its pivotal point at the end of childhood with the emergence of identity in adolescence. Identity is a person's sense of who she or he is and wants to be, a self-constructed organization of emotions, beliefs, values, goals, and individual history. It is not fully achieved and finished in adolescence or early adulthood but continues to be woven across multiple life strands gradually as we grow older.

From the first formation of identity as the climax of childhood, adults extend and coordinate their own identities with other people's identities across contexts and time periods, progressing through three further stages, according to Erikson. This concept of identity has permeated modern society, so that it is almost a truism today, although everyday use of the concept is often superficial. Most of the empirical work on identity development has unfortunately not focused on the full scope of identity development during adulthood but has instead considered primarily microdevelopment (substages) within the emergence of identity in adolescence and early adulthood (for example, Marcia, 1980; 1994; Matteson, 1977; Phinney, 1989; Turkle, 1995). This research also neglects the importance of social coordination of one's own identity with other people's. As a result, considerable confusion has reigned about the degree to which the crises in fact form stages, although this research has not actually tested the stages themselves. Fortunately a few studies have gone beyond the stage of emergence of identity (versus role diffusion) to examine the full set of stages Erikson described, especially through case analyses and clinical material (Erikson, 1969; 1978; Gilligan, 1982; Loevinger, 1976; Neugarten, 1968; Noam et al., 1990; Vaillant, 1977).

We propose an important differentiation of the identity framework through cognitive analysis of the skills involved in identity formation and coordination with others. Articulating identity development through this skill analysis illuminates the ways that multiple strands of identity develop systematically in a person's web and how people construct identity skills hierarchically in a way that correlates with Erikson's stage crises. The stages are shaped by basic human tasks and issues that people share across cultures, such as learning skills for home and work, choosing a romantic partner, making a living, raising children, and growing old. Individual circumstances differ widely across cultures and families, yet the general pattern of crises (tasks and issues) remains similar. In addition, later crises build up more complex demands in life situations and the need for integration of strands of one's life web – an important cognitive challenge (Kegan, 1994).

Each of the identity stages beyond the first requires co-construction of one's own abstract identity with those of other people, and in each case this challenging task requires a minimum skill level. Table 21.2 lists Erikson's stages, beginning with identity, and shows how each one depends on a skill structure at a particular level to afford the coordination that the stage requires. The earlier levels before the emergence of identity are also shown, because they lay the groundwork for identity through the formation of concrete identifications that characterize oneself (*ME*) in relation to important others (*YOU*). These identifications are coordinated with a minimum of single abstractions to create the beginnings of identity in early adolescence. The skill formulas in Table 21.2 are listed with general components (letters for variables to be filled in) to make the point that a similar skill structure develops across strands/domains in the web. For application to real people, note that the general variables need to be specified with concrete content. There are no instantly general and generalizable skills.

Table 21.2 Development of identification and identity: relation to Erikson's stages and generalized skill diagrams

Erikson's stages of identity: first emergence	Skill level	Representational tier: identification	Abstract tier: identification
↑	Rp1	$[ME_A > YOU_B]$	
Concrete identifications	Rp2	$[ME_A — YOU_B]$	
↓	Rp3	$[ME^C_A \longleftrightarrow YOU^D_B]$	
Stage 5: identity versus role diffusion	Rp4 Ab1	$\begin{bmatrix} ME^C_A \longleftrightarrow YOU\ 1^D_B \\ \Updownarrow \\ ME^G_E \longleftrightarrow YOU\ 2^H_F \end{bmatrix}$	$\equiv [SELF_W]$ or $[OTHER_V]$
Stage 6: intimacy versus isolation	Ab2		$[SELF_W — OTHER_V]$
Stage 7: generativity versus stagnation	Ab3		$[SELF^Y_W \longleftrightarrow OTHER^X_V]$
Stage 8: ego integrity versus despair	Ab4		$\begin{bmatrix} SELF^Y_W \longleftrightarrow OTHER^X_V \\ \Updownarrow \\ SELF^T_Z \longleftrightarrow OTHER^S_U \end{bmatrix}$

Note: People develop specific skills, not global ones. These formulas must be filled in with specific content to capture a real skill.

A to *H* are concrete personal characteristics. S to Z are abstract identity characteristics.

The creation of multiple concrete identifications during childhood sets the stage for the emergence of identity at the end of childhood and the beginning of adolescence. For example, Kara played a teacher game with her mother Jane, as described in formula 1. With just a minor change in that representational skill (level Rp3), she identifies with Jane as both a teacher and a mother:

$$\begin{bmatrix} & \textit{Identification} & \\ TEACHER & & TEACHER \\ JANE & \longleftrightarrow & KARA \\ MOTHER & & MOTHER \end{bmatrix} \qquad (8)$$

She tries to act like a teacher and mother herself, not only in play but in real-life choices that she makes, such as helping another child with homework similar to the way that she sees Jane teach students and care for a younger sibling and similar to the way Jane takes care of Kara's brother. With many such concrete identifications, a child builds material for the creation of an abstract identity.

The stage of identity versus role diffusion involves abstract answers (not just one) to the question, 'Who am I?' A young person brings together at least two concrete representational systems like formula 8. Coordinating that identification with her identification with her father as physician and parent,

$$\begin{bmatrix} \mathit{PHYSICIAN} & & \mathit{PHYSICIAN} \\ \mathit{WALTER} & \xleftrightarrow{\mathit{Identification}} & \mathit{KARA} \\ \mathit{FATHER} & & \mathit{PARENT} \end{bmatrix} \qquad (9)$$

as shown for level Ab1 in Table 21.2, she creates an identity of herself as caregiver:

$$\begin{bmatrix} \text{SELF} \\ \text{CAREGIVER} \end{bmatrix} \qquad (10)$$

At the same time she builds up many other specific identities, such as self as independent (formula 2), and she constructs her own conceptions of other people's identities in a similar way, such as that her best friend Isabelle is independent:

$$\begin{bmatrix} \text{FRIEND} \\ \text{INDEPENDENT} \end{bmatrix} \qquad (11)$$

Much of the confusion of early identity formation comes from the multiplicity of strands of identity formation and the difficulty in relating different abstract identity characteristics to each other at this optimal level. To do comparisons of two personal characteristics of her own identity with that of Isabelle, Kara must drop down to concrete characteristics, using a representational system. The coordination of her own abstract identity with that of her friend's thus remains out of reach.

Erikson's next stage of intimacy versus isolation involves the coordination of one's own identity with that of a friend or partner, and the cognitive minimum is abstract mappings, as shown in Table 21.2. When Kara focuses on her own independent tendencies, then she can easily coordinate her own identity with that of Isabelle as she sees it, in a repeat of formula 5:

$$\begin{bmatrix} \text{SELF} & \text{———} & \text{FRIEND} \\ \text{INDEPENDENT} & & \text{INDEPENDENT} \end{bmatrix} \qquad (5)$$

A challenge of intimacy is to have her own abstractions about Isabelle matching well enough with Isabelle's actions and abstractions to sustain a close relationship. Contradictions also come easily at this optimal level, because people have difficulties dealing with multiple abstractions about self and other. When Kara focuses on her own caregiving, for example, there may be a conflict with Isabelle's independence. Within herself too, her own care-giving can seem to contradict her independence – an example of the sense of contradiction and conflict that many adolescents and adults experience (Fischer & Kennedy, 1997; Harter & Monsour, 1992).

Issues of intimacy, like the issues of every one of Erikson's stages, exist throughout life, long before the years of early adulthood and long after them. The reasons that they belong especially to early adulthood are primarily two: (1) people commonly seek intimacy at this age, especially sexual intimacy and long-term partnership; and (2) at this age, cognitive capacities make it possible to truly coordinate abstract identities in intimate relationships. In many cultures and life situations, young adults face the challenge of deepened relationships, involving either sex or work, where the coordination of identities is paramount. Intimate relationships require holding a sense of self, but also an openness toward the uniqueness and depth of another; they require learning the major components of another identity, with the two people becoming a dynamic unit, especially for the ideal intimate partnership that Erikson describes, in which both partners grow together toward fulfillment in a stable relationship.

Intimacy of identities can be much easier with higher levels, because then one skill can readily incorporate more than one or two abstract characteristics of self and other. Marriage partners with children, for example, can share the identities of caregiving and independence, working together to support each other as parents and as independent persons with their own separate needs in an abstract system (Ab3):

$$\left[\begin{array}{lcl} \text{CO-PARENT} & & \text{CO-PARENT} \\ \text{SELF} & \longleftrightarrow & \text{SPOUSE} \\ \text{INDEPENDENT} & & \text{INDEPENDENT} \end{array}\right] \quad (12)$$

Just as identity only begins to develop with the level of single abstractions (Ab1), intimacy only begins with the level of abstract mappings (Ab2). That is why Table 21.2 refers to the first emergence of Erikson's stages at a specific developmental level.

For the last two stages Erikson depicts even more complex life tasks. The stage of generativity versus stagnation requires meeting the challenges of productivity and creativity, in contrast to feelings of lack of purpose, direction, or self-worth. The most obvious generativity is having children, but generativity involves much more than procreation. This process emerges with abstract systems, because with them one can coordinate multiple abstract identities in self and others, as in the example of parenting and independence. However, the challenges of generativity are enormous: people must coordinate their identities with those of not only their partners, co-workers, or friends, but also children, aging parents, and other people. The abstract thinking at this stage has to accommodate a rich web of interdependence, relating a strong sense of personal identity and its changes over time with the identities of others, both younger and older, whom one seeks to guide in ways commensurate with their own needs for identity and change.

Bernice Neugarten emphasized how cognitive development contributed to the process of generativity in a group of successful middle-aged people: ‘We have been impressed with the central importance of what might be called the executive processes of personality in middle age [including] the stocktaking, the heightened introspection, and above all, the structuring and restructuring of experience – that is, the conscious processing of new information in the light of what one has already learned’ (1968, p. 98). As one woman from the study stated, ‘It is as if there were two mirrors before me, each held at a partial angle. I see part of myself in my mother who is growing older, and part of her in me. In the other mirror, I see part of myself in my daughter.’ Kara's mother Jane in such a situation considers her focus on parenting in relationship to her mother and daughter, as well as the independence that she sees in different forms in all three of them. That kind of comparison, going beyond the concrete particulars of one set of actions to general identity analysis, involves a highly complex abstract system:

$$\left[\begin{array}{lclcl} \text{CAREGIVER} & & \text{PARENT} & & \text{PARENT} \\ \text{DAUGHTER} & \leftrightarrow & \text{SELF} & \longleftrightarrow & \text{MOTHER} \\ \text{INDEPENDENT} & & \text{INDEPENDENT} & & \text{INDEPENDENT} \end{array}\right] \quad (13)$$

Erikson's final stage involves ego integrity versus despair, with the challenge of putting the great expanse of one's life into a meaningful synthesis, and with the potential achievement of what may properly be called *wisdom*. Understanding that one is many identities, in interdependence with many other people, as well as with the social and cultural roles required for the meaningful participation in a historical time and place – all these strands coalesce into what Erikson calls *integrity* as one approaches the end of life. Failure to accomplish this synthesis may bring depression and despair at midline or in old age. Achievement of such a grand synthesis requires not only the highest level of abstract thinking, systems of abstract systems (Ab4) and the broad integrative principles about one's life that they can create, but also years of experience relating one's own identity to those of intimate partners, friends, co-workers, children, as well as cultural groups and historical epochs. This is truly a grand cognitive achievement!

Networks in Darwin's Development of the Theory of Evolution

We have described identity development globally, outlining a process that most people develop through, taking many different pathways with common themes (issues, crises). Now we switch to a different perspective: analysis of a case of one person's construction of a multistrand, networked web. The case of Charles Darwin's construction of the theory of evolution portrays the dynamics of strands and networks in the web. Dynamic analysis is at its richest in analyzing individual growth in detail (van Geert, 1994), and Darwin unintentionally provided a great source of data for analyzing how he created the theory of evolution by natural selection. Darwin kept a series of notes between 1832 and 1839 in which he recorded his observations and ideas as they developed into his theory of evolution by natural selection.

The way Darwin constructed his revolutionary understanding is tantamount to a case study of building complex knowledge networks in adult cognitive development. At the age of 22, in December of 1831, Darwin set out on a five-year voyage around the world on the ship *HMS Beagle*, during which he recorded observations and thoughts about the natural phenomena he encountered. Toward the end of this time, between 1837 and 1839, he kept a series of specific notebooks on his thinking about 'the transmutation of species'. In 1839 at the age of 30, he had constructed what became his general theory, although he would not dare release it to the world at large for another 20 years, when he finally published *The origin of species* in 1859. Because of his notes and notebooks we can peer over his shoulder to see the steps he took in building the theory and creating the principle of evolution by natural selection (level Ab4). Table 21.3 outlines some of the major steps in Darwin's web, showing several separate strands (distinct skills for different domains) at each level. Detailed exposition can be found in several other sources, especially Gruber (1973) and Fischer and Yan (2002).

Table 21.3 Development of Darwin's theory of evolution (1831–1839): a general overview

Level	Skill	Major events	Dates
Ab1: single abstractions	[WORLD ORGANIC] or [WORLD PHYSICAL]	From adolescence: musings about creation and species; separation of organic and physical worlds	Before 1831
Ab2: abstract mappings	[WORLD —deviant— WORLD PHYSICAL ORGANIC]	Physical world eliminates deviant organisms	
	[WORLD —breed— WORLD HUMAN ORGANIC]	People selectively breed animals and plants for desired characteristics	
		Voyage of *Beagle*: mastering Lyell's *Principles of geology* and collecting observations	1831–1836
	[WORLD —reef— WORLD ORGANIC PHYSICAL]	Beginning of coral reef theory: corals vary with changes in physical world	
Ab3: abstract systems	[ORGANIC X reef PHYSICAL X WORLD ⟷ WORLD ORGANIC Y PHYSICAL Y]	Final coral-reef theory: coral reefs grow as corals adapt to changing ocean depths by growing upward to reach light	1835–1837
	[ORGANIC X match PHYSICAL X WORLD ⟷ WORLD ORGANIC Y PHYSICAL Y]	Variations in Galapagos species match species characteristics with physical niche	
	[ORGANIC R1 time ORGANIC R2 WORLD ⟷ WORLD ORGANIC T1 ORGANIC T2]	Many species show systematic change over long time periods	
		Struggling with idea of multiple creations	
Ab4: systems of abstract systems, which are principles	[monad creation ORGANIC X1 PHYSICAL X1 WORLD ⟷ WORLD ORGANIC Y1 PHYSICAL Y1 tree of ⇕ change ORGANIC X2 PHYSICAL X2 WORLD ⟷ WORLD ORGANIC Y2 PHYSICAL Y2]	Inadequate process of evolution: monad theory, branching tree	1837
		Hybridization (instead of natural selection)	
	[evolution ORGANIC X1 PHYSICAL X1 WORLD ⟷ WORLD ORGANIC Y1 PHYSICAL Y1 natural ⇕ selection ORGANIC X2 PHYSICAL X2 WORLD ⟷ WORLD ORGANIC Y2 PHYSICAL Y2	Emergence of theory of evolution by natural selection (heredity, variation, natural selection)	1838–1839

Note: Skill structures in this table emphasize relations between physical and organic worlds in the various phases of Darwin's work. Fischer and Yan (2002) describe the actual skills, specifying the components from physical and organic worlds that Darwin actually coordinated.

Sources: Table adapted from Fischer & Yan (2002). Sources for historical information: Barrett (1974), Darwin (1859), Keegan (1989), and especially Gruber (1981).

Before his voyage on the *Beagle*, Darwin held a view of the world informed by conventional religious belief, like other scientists at that time. God had created two separate worlds, the Physical World of substances and the Organic World of plants, animals, and people. The fact that these worlds hardly interacted was accepted as God's law. In terms of skill level, the concept for each of these two worlds required only a single abstraction for each world, with little need for a higher level because of the lack of interaction between the two. It was Charles Lyell's *Principles of geology*, which Darwin avidly read on his voyage, that opened up for him the question of interaction. Inspired by Lyell's description of gradual change in the physical world, Darwin was at great pains to record the supporting evidence he found.

Darwin began to realize that the physical changes he saw might relate to the common observation that creatures ill-suited to their environment by some defect tended to die, such as birds with defective wings or fish with defective gills. This phenomenon suggested how the physical world can influence the organic world by getting rid of ill-adapted organisms. Darwin's knowledge of the practices of selective breeding of animals also contributed to the development of his insight about the action of physical forces on the viability and adaptation of organisms. His thinking moved beyond single abstractions to construct abstract mappings – lawful interactions between the worlds of the physical and the organic, as illustrated for level Ab2 in Table 21.3.

Darwin's notes portray his years of following this insight in organizing the countless observations he had gathered on his voyage. One especially important example is his work on the various species of Galapagos finches: he discovered that the different species' feeding habits were closely related to the shapes of their beaks (a level Ab3 system insight). He realized that the form of the beak matched the way the particular finch obtained its most common kind of food. This adaptive match pointed to the finely honed adaptation of the organism to its environment. In another strand/domain, Darwin used his knowledge of fossils to analyze how species had changed (evolved) over long time periods – how characteristics of current species could be related to characteristics of earlier species through concepts of change overtime. In this way, he built systems of abstractions in several independent strands, which he soon wove together to create the theory of evolution by natural selection.

In attempting to build his understanding into a comprehensive explanatory network, Darwin tried out a number of concepts before discarding them as inadequate. Darwin's reading of an essay by Thomas Malthus, concerning how populations can reproduce at much higher rates than their environments can support, played a central role in his formulation of the final theory. Based on his notebooks, it seems that Darwin hit upon his eventual theory several times, but he was not able to generalize it fully until he had reconstructed it repeatedly. This is a common occurrence in the construction of new knowledge, perhaps even more so for complex knowledge networks. Darwin not only had to coordinate a number of complex relationships (coral reefs, finches' beaks, species change over eons), but also had to generalize these coordinations into a principle – evolution by natural selection. Repeated construction is often essential to new understanding: indeed it constitutes generalization, with components being worked into the new fabric of a general skill, such as Darwin's evolutionary principle. In sum, Darwin's construction of the final form of his famous theory illustrates an extremely complex process of organization and reorganization of connections across multiple domains in order to build the coherent, innovative, and powerful knowledge network of evolutionary theory.

Older Adults' Cognitive Ageing

Most adults do not create a new principle that revolutionizes human thinking, but most do deal with the challenges of cognitive and physical ageing, including the growth of wisdom, at least for some domains, and the loss of some speed and facility, especially late in life. When conceptualized in terms of dynamic developmental webs, ageing involves growth combined with decline, wisdom along with slowing down.

The cultural stereotype, at least in many Western countries, is that cognitive ageing means cognitive decline and intellectual deterioration: ‘The older, the dumber.’ Other common false beliefs are that people become less happy and more lonely with age. Happily, research data paint a more optimistic portrait. Most adults experience more positive emotions and more numerous social connections as they grow older, with early adulthood being one of the loneliest and least happy life periods, on average (Carstensen, 1993; 2000). Likewise for cognition: research does not support the proposition of an overall decline in intelligence during adulthood in concert with the general physical ageing process (Wechsler, 1972). Horn and Cattell's (1967) classic research shows the interweaving of gain and loss with cognitive aging. Many kinds of intellectual skills increase slowly but consistently with age, even in research limited to standardized psychometric tests. These reflect what is called *crystallized intelligence*, composed of skills that benefit from accumulated experience, such as vocabulary and general knowledge. On the other hand, many skills also decline with age, especially from middle adulthood, and these reflect what is called *fluid intelligence*, composed of skills that depend on novel activities and information. Most of the activities that adults need to do involve accumulated knowledge and crystallized intelligence, and they get better with age. For example, Schaie's (1996) longitudinal data indicate that inductive reasoning rises slightly through middle adulthood, with a gradual decline beginning only in late adulthood. On the other hand, there are clear, small declines in speed and physical strength beginning in middle age (Horn, 1982; Salthouse, Hambrick, & McGuthry, 1998). Illness is also an important factor, producing powerful declines in skill at any age and becoming more likely in old age.

Cognitive ageing is clearly multidimensional and multidirectional (Baltes, 1987; Baltes & Baltes, 1990; Berg, 2000; Birren, 1970; Craik & Salthouse, 1991; Schaie, 1983; Sternberg, 1985). Research that seems to show one simple factor underlying ageing (or development) is based on assumptions and statistical techniques that force complex webs into single, monolithic dimensions and preclude consideration of the textured richness of developmental webs (e.g. Gottlieb, Wahlsten, & Lickliter, 1998).

The standardized tests used in most ageing research do not assess the complex skills that develop at the highest levels of abstraction, or the integration of emotional and cognitive strands that ground wisdom. Even the reduction in speed with age sometimes comes from the increased sophistication of adult cognitive skills and their thinking processes: more complex webs and networks take longer to process information (Atkinson & Shiffrin, 1968; Fischer & Rose, 1994; Gruber, 1973; Schacter, 1999). What might be called *cognitive pragmatics*, or the culture-based software of mind and body, actually improve with age, as evidenced by numerous studies of adult development (Baltes & Baltes, 1990; Colby et al., 1983; Dawson, 2002; Erikson, 1969; 1978; Levinson, 1978; Loevinger, 1976; Neugarten, 1968; Noam et al., 1990; Vaillant, 1977; 1986). One of the most telling findings is the age at which productivity reaches its maximum in creative people working in highly complex fields, such as historians and novelists (Dennis, 1958; Simonton, 1991; 2000). People in these fields become most productive and creative in their 40s, 50s, and even 60s. In contrast, people in less complexly textured fields, such as mathematicians and poets, often peak in their 20s and 30s.

How can the complex interconnections among these features in cognitive ageing be analyzed and understood? Obviously, they are not totally separate features moving in different directions. With multiple elements interacting with each other over time, a dynamic process of self-organization occurs in which adults actively organize their limited mental resources into dynamic skill networks to adapt to their complex life needs. While some components, such as speed of activity and speed of processing information, reduce the richness of the network past middle age, other components, such as synthetic thinking and interpersonal wisdom, can increase the richness. Through this process, both ageing and aged adults build dynamic cognitive networks to meet various complex life challenges. Two examples from research involve the specific motor skill of typing and the broad cognitive-emotional skill of wisdom.

For the motor skill of typing, older adults organize their skills differently, anticipating a wider span of letters and compensating for lower perceptual-motor speed in simple tasks such as reaction time and tapping (Salthouse, 1984). In a sample of 19- to 72-year-olds, older adults maintained typing speed by more precisely controlling the sequencing of keystrokes across larger spans of characters than did younger typists. For many skills besides typing, dynamic interconnection and compensation play a similar critical role in changes during adulthood. Dynamic compensation and adjustment within complex cognitive networks are widely observed in domains of memory (Barrett & Watkins, 1986, p. 129), chess playing (Charness, 1981), social interaction (Carstensen, 1993), emotional understanding (Labouvie-Vief, De-Voe, & Bulka, 1998), and job change (Sternberg, 1990).

Wisdom is very different from typing, yet it too involves building complex cognitive networks to adapt to needs in life. Wisdom requires integration of multiple types of knowledge and skill about practical and ethical issues in human life (Baltes & Staudinger, 1993; Dawson, 1999; Erikson, 1963; Sternberg, 1990). It requires an implicit, complex, effective knowledge network combining multiple domains over long time periods and extensive experience, and it seems to require special coordination of emotional and cognitive processes. Wisdom seems to compensate for physical slowing in middle and old age, enabling many adults to perform synthetic thinking about self and others in the complex world, often making people especially effective as, for example, political leaders, judges, moral leaders, and scholars.

In summary, adults can develop deeply and broadly in their skills – building complex identities with their family, friends, and colleagues, creating new ideas, practices, or products that shape their society, and building wise ways that go beyond self-interest and immediate response. All these outcomes depend on development of networks connecting multiple strands in the web of skill and emotion.

Dynamic Backward and Forward Constructions in the Web

Besides multiple levels, strands, and connections, development in adults also moves in multiple directions for cognitive construction. The complete picture includes not only complex variations in the strands and networks but also dynamic construction processes within the web. Dynamically, adult cognitive development moves forward, backward, and in various other directions. It forms a dynamic web, and even each separate strand is dynamic (and fractal), not a linear ladder (Fischer & Granott, 1995). Traditionally development is defined as forward progression, but cognitive development moves backward as well as forward. ‘Progress’ results from a combination of backward and forward movement, with much backward movement preparing the way to move forward through the construction of new adaptive skills. Through thus constructing skills in multiple directions, adults can handle complex tasks effectively and flexibly and advance their competence. Adults' backward directions of cognitive construction are sometimes treated as an indicator of failure and malfunction, especially in old age, but instead, flexible use of simpler and more complex skills reflects maturity and wisdom. Two developmental phenomena show some of the order in the multidirectionality of adult development: backward transition and forward consolidation.

Backward Transition

One important principle of dynamic construction is backward transition, a movement of activity from higher-level skills down to lower-level ones followed by gradual movement in fits and starts back up to higher-level, new skills (Duncker, 1945; Fischer, 1980b; Fischer & Granott, 1995; Granott, 1993a; 1998; 2002). Backward transition or regression seems to be a universal strategy that people use when they are trying to construct new skills, as reflected in explicit problem-solving strategies such as ‘breaking a problem down into its simplest units’ and ‘starting again from the beginning’. When people encounter a task that they do not have the skills to perform, they fall down to low-level activity – even sensorimotor actions similar to those of an infant – so that they can figure out the task and gradually build toward high-level skills. Recent microdevelopmental research indicates that backward transitions are pervasive in adulthood and play such an important role that supposedly inadequate, lower levels of performance need to be reexamined and reevaluated. Backward transition leads adults to perform flexibly and to devise ways of solving complex tasks that are initially beyond them.

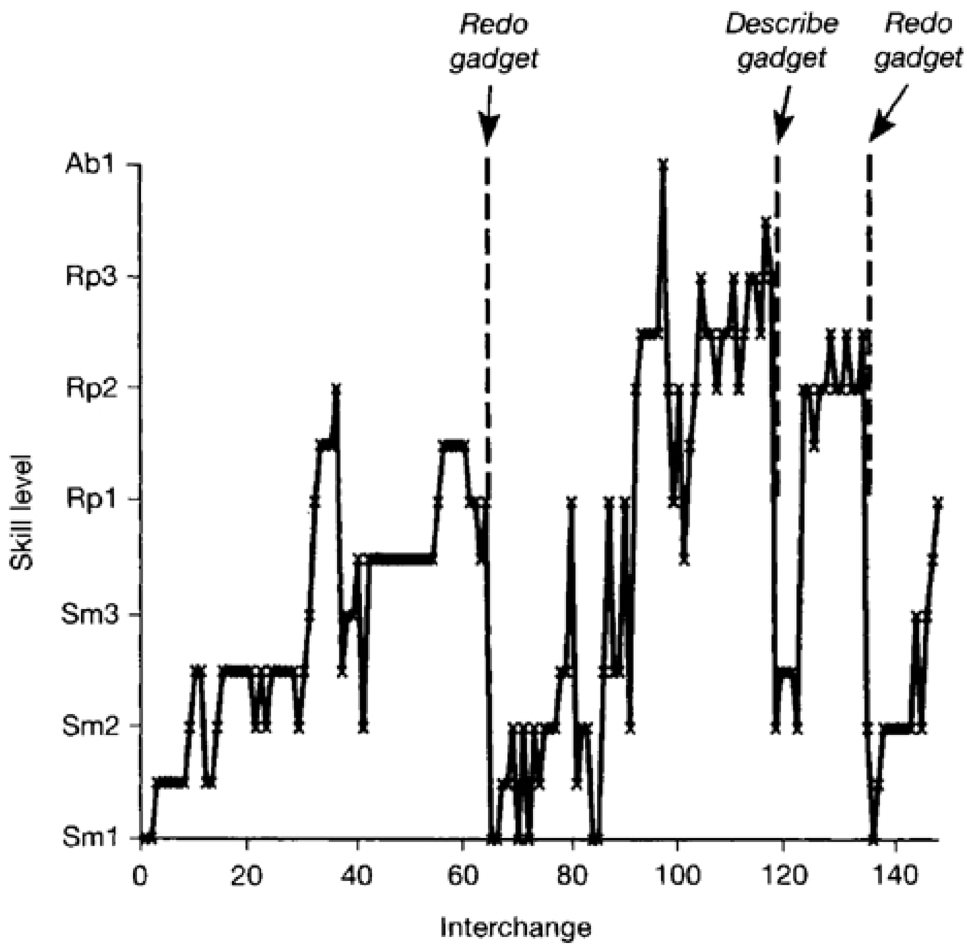
Nira Granott (1993a; 2002) devised a methodology that allows a focus on both realtime skill construction and the generalization and consolidation that accompany it. She had teams of adults interact with a small Lego robot called a wuggle. The wuggle, which was about the size of a toy truck, was programmed to respond to changes in light/shadow, sound, and touch by altering its movements. The dyads were given the task of figuring out what the wuggle did, while video cameras recorded interactions and discussions. Granott (1993b) reasoned that because most human cognition takes place in the social arena, observing dyads will provide useful insight into spontaneous learning and problem-solving and the social interaction will make overt many learning processes. Participants began in a small group in a room containing several wuggles that moved or sat among common objects such as tables and boxes, and they formed dyads spontaneously during the observation session.

In analyzing videotapes of this session, Granott and her coders easily reached agreement on what constituted an *interchange*, a single dyadic interaction with the wuggle, and each interchange was scored for complexity using the skill scale. For instance, when a dyad understood that making a loud noise led the wuggle to change direction, the level was coded as an *action mapping* – that is, the second level of the action tier (Sm2), connecting making or hearing a sound with seeing a change in movement.

In a typical initial encounter, the subjects were at first confused, then more engaged as their experimentation brought responses from the wuggle. Granott (1993; 2002) used the dyad of Ann and Donald to illustrate this process. Encountering a wuggle for the first time, they had to learn how it changed its movement in response to a sound. In 148 interchanges over 27 minutes, they started with mere observation of the wuggle's movement (the lowest level of single actions, Sm1) and gradually built up through higher levels as they tried to understand the wuggle. The sequence from action to representation unfolded as follows. Seeing the wuggle move is a single action, and hearing a sound is another single action (level Sm1). A mapping of actions (level Sm2) is noticing that hearing a loud sound goes with seeing the wuggle change movement. A system of actions (level Sm 3) is combining several movements and sound situations. A single representation – the wuggle reacts to sound – emerges from coordinating several action systems (level Sm4/Rp1). And so forth: microdevelopment continues with relating and differentiating representations of the wuggle and sound.

Among the dyads, however, such construction of a representation did not proceed directly through the levels in a ladder-like manner. As shown in Figure 21.7, progress toward a skill for understanding the wuggle went in fits and starts – a series of backwards transitions and reconstructions, not one consistent upward construction. Initially Ann and Donald fell down to a level far below their capacity, producing several level 1 actions and then building up a more complex skill over several minutes. They interacted with the wuggle and made sounds and other actions to explore it, in a faltering way gradually building their first representation that the wuggle reacts to sound (level 4). But then at interchange 65 something interesting happened: a wire had fallen out of the wuggle, and when they placed it back (in a different hole, by mistake), the wuggle acted differently. In the face of this task change their fragile skill collapsed, dropping back immediately to a level 1 action. Over the next several minutes they once more rebuilt more complex skills, gradually returning to a representation that the wuggle reacts to sound (level 4) and then going further to higher levels still, relating several representations to each other.

Figure 21.7 Backward transition and microdevelopment in understanding a wuggle: Ann and Donald (Granott, 1993a; 2002)

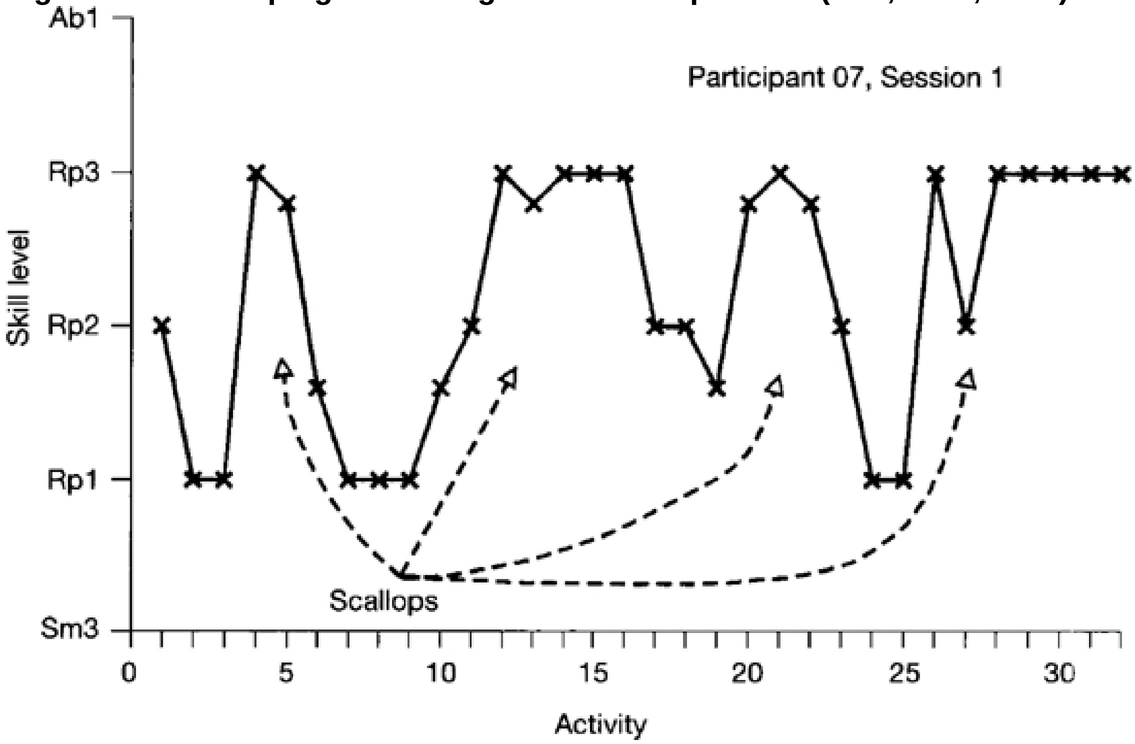


This process of backward transition and reconstruction happened two more times in the 27 minutes of problem-solving. At interchange 118 Ann and Donald encountered another variation in the task: they set out to summarize what they knew, and again the change in task led to a drop in their skill – this time level 2 mappings of actions followed by again rebuilding skills to reach representations (levels 4 and 5). Then at interchange 134 Ann and Donald changed the wiring of the wuggle again, and they showed backward transition to low-level actions followed by reconstruction of complex actions and representations.

The repeated fall and rise of skill levels in the construction and generalization of new knowledge is a common feature of microdevelopment. Adult learners also showed this scallop-shaped growth in Yan's (1998; 2000) recent study of learning to use a computer program to do simple statistical operations. Participants were graduate students who varied widely in their expertise, both with computers and with statistical operations. Each student worked at a computer, with a teacher at her or his side to answer questions and to intervene when help was needed. Students with intermediate background experience showed clear scalloping in their learning graphs – a low level of skill followed by a gradual increase and then an abrupt drop when a new task element was introduced, as illustrated in Figure 21.8. For students with little background, skill level showed wide fluctuation initially, and scalloping gradually appeared as they became more familiar with the tasks, concepts, and computer operations. Students with a high degree of knowledge (experts), on the other hand, showed little scalloping, staying generally at the upper limit of skill required by the task, with occasional transient drops.

Another important finding of these studies is that adults function at a level appropriate for the task at hand, which may be far below their upper limit (either optimal or functional level). In Figure 21.8, for example, a highly intelligent adult graduate student performed with skills that at maximum were only representational systems (Rp3). This optimal level first emerges at 6 or 7 years of age, and the adult student was capable of much more sophisticated activity, including high levels of abstraction, which she regularly demonstrated in other class activities. The reason for the low level that she and all other students demonstrated in this study is that the task required only this level – nothing more!

Figure 21.8 Scalloping in learning a statistics operation (Yan, 1998; 2000)



Yan further asked how interaction with the teacher affected learning. He found that the upward arc of the scallop often followed the teacher's response to a relevant question, especially for the intermediate-level students: the scaffolding provided by the teacher's response allowed the student to build up understanding of the task. The support offered by the instructor through clues and priming facilitated the temporary rises in skill level evident in scalloping.

Just as a teacher can provide a scaffold to support a student's construction of understanding, people can support their own skill construction through a recently discovered mechanism called *bridging* (Fischer & Bidell, 1998; Granott, 1993a; Granott & Parziale, 2002; Parziale, 1997). A bridging shell allows people to bootstrap themselves to new knowledge by creating a temporary target or open-ended shell for what is as yet unconstructed. The shell is a framework (an attractor in dynamic systems terms) for guiding a current level of performance through the search space to the next higher level – like an algebraic skill formula with unknown variables that a person uses to guide discovery during problem-solving. In the wuggle task, dyads continually created shells that helped bridge their exploration of the wuggle to higher levels. For example, the dyad Kevin and Marvin noted that their wuggle showed a ‘reaction’ to something that they did, but they could not articulate either the cause of the reaction (unknown variable X_a) or the nature of the wuggle's change in activity (unknown variable Y_b) (Granott, Fischer, & Parziale, 2002). They used a sketchy mapping skill as a shell to bridge their construction of an understanding of these two factors:

$$[(\mathbf{X_a}) \xrightarrow{\text{Reaction}} (\mathbf{Y_b})] \qquad (14)$$

Exploration of the wuggle guided by this shell led them to a series of more explicit skills based on the shell, starting with the realization: ‘When it comes over here and as soon as it gets underneath part of the shadow there, it starts changing its behavior.’ This statement of a causal relationship began to fill in the shell:

$$\begin{bmatrix} \textbf{SHADOW} & \text{——} & \textbf{IT (WUGGLE)} \\ \textbf{(ON WUGGLE)} & & \textbf{CHANGE(S)} \\ & & \textbf{BEHAVIOR} \end{bmatrix} \qquad (15)$$

As with all new knowledge, the new skill remains a temporary one until it can be reconstructed several times with sufficient variation so that it stabilizes. In a similar manner, adults use bridging frequently to guide their own learning. This process of bridging cries out for research to unpack how adults guide their own learning and development. (Note that bold font indicates sensorimotor skills, which are based in action. The levels prior to representations involve actions, which form the basis for representations.)

The examples with wuggles and computer programs demonstrate that knowledge is not simply a stable accomplishment. In both studies, people moved to high skill levels in a short time, but when they encountered a small change in the task, they instantly fell back to lower levels. General skills must be built through this repetitive process of doing and redoing a task to stabilize and generalize it. Whenever a task is changed, there is backward transition and reworking, gradually leading to a more stable representation (Bever, 1982; Duncker, 1945; Fischer, 1980a; 1980b; Fischer & Bidell, 1998; Granott, 1993a; 1998; Granott, Fischer, & Parziale, 2002; Werner, 1948). The point here is that people do not simply work up to a level of skill and then keep it available for all similar circumstances. For knowledge to become readily accessible across tasks and domains, it has to be reconstructed multiple times, probably with its flexibility determined in large part by the range of variations in the tasks when a person has to reconstruct it.

Knowledge disappears easily and has to be reconstructed. It is unstable. Relatively stable knowledge comes only with extensive generalizing reconstruction for familiar tasks and situations. (Knowledge can be stable in the community without being stable in the individual.) With so little research on the naturally dynamic variation in individual activities and knowledge in the real world, scientists and educators have too easily treated knowledge as stable, even fixed – thus perpetuating a myth of stable individual knowledge that permeates human language and culture (Lakoff & Johnson, 1980).

Forward Consolidation

The phenomenon of forward consolidation involves a different pattern of movement during adult development: The optimal performance that comes with high contextual support is gradually consolidated into functional performance without contextual support. Most cognitive-developmental research examines only conventional forward progression within the same contextual condition: from lower optimal performance to higher, or from lower functional performance to higher, or from lower performance on a standardized test to higher. When young adults face, for example, a difficult dilemma, such as whether chemical additives to food are helpful or harmful, or whether an unwed, poor, young woman who is pregnant should consider giving up the child for adoption, they will show a higher level of reasoning with optimal contextual support than without it. They cannot sustain the optimal level on their own, but they can remember it vaguely and build a bridging shell that eventually leads them to consolidation and mastery of the higher level skill without support. As shown in the developmental web in Figure 21.5, forward consolidation takes place along the strands so that the optimal portion will gradually be turned into the functional portion. This kind of forward consolidation is pervasive in adulthood and plays an important role in adults' cognitive development.

One demonstration of forward consolidation is the pattern of emergence of performance of skills at a given level. The skills that emerge at one optimal level predominate not when they emerge, but years later, often upon emergence of the next optimal level, or even the one after that (Fischer, Kenny, & Pipp, 1990; Kitchener et al., 1993). In other words, the consolidation of skills at a given level takes place with the emergence of the next level. In reflective judgment, skills for stage 6 first spurted at age 20, the usual age when the optimal level of abstract systems (Ab3) emerges. However, students at that age only produced about half of their arguments at stage 6, as shown in Figure 21.6. Not until five years later at age 25 did stage 6 performance jump to nearly 100%. (Age 25 was also when stage 7 performance jumped to 50% as the optimal level of principles, Ab4, emerged.)

The number of years that it takes adults to move from optimal level to consolidation of functional level varies greatly across domains and individuals. For reflective judgment, Table 21.4 describes the age range between emergence of an optimal level for a stage and the consolidation of that skill at functional level. These ages are based mostly on research with American students who have a college education or plan to attend college, and of course they vary for people from other cultural or educational groups. For example, stage 5 reasoning emerges in many students as early as 15 years of age under high support, but in low support (functional) situations, it is not seen until somewhere between 18 and 30 years of age. Similarly, stage 6 may appear at 20 years under optimal support, but it is not consolidated at functional level until 25 to 40 years. Note that the ages for functional level involve only adults who actually showed those stages in research. Many adults never reach the highest stages in any particular domain, as evidenced even in research with college-educated adults.

Table 21.4 Approximate ages for optimal and functional levels of reflective judgment

Stage of reflective judgment	Emergence of optimal level	Emergence of functional level[1]
Pre-reflective judgment		
Stage 3 (level Rp3)	6 to 7 years	Middle school and high school age 12 to 17 years

Quasi-reflective judgment		
Stage 4 (level Ab1)	10 to 12 years	Late high school, college, and above 16 to 23 years
		Never for many people and domains
Stage 5 (level Ab2)	14 to 16 years	Early graduate school 19 to 30 years or older
		Never for many people and domains
Reflective judgment		
Stage 6 (level Ab3)	19 to 21 years	Advanced graduate school 23 to 40 years or older
		Never for many people and domains
Stage 7 (level Ab4)	24 to 26 years	Advanced graduate school 30 to 45 or older.
		Never for many people and domains.

Note: this table includes only the last five of the seven stages, which are the ones that adults use most.

1 Ages for emergence of functional level vary widely, and so these estimates are coarse.

Sources: reviews and research by King and Kitchener (1994), Kitchener and Fischer (1990), Kitchener et al. (1993), as well as Basseches (1984), Colby et al. (1983), Cook -Greuter (1999), Dawson (2002), Fischer, Kenny, and Pipp (1990), Perry (1970), Rest et al. (1999), and Vaillant (1977).

It takes years for an individual adult to move from emergence of an optimal performance to consolidation of a functional performance. Darwin took several years of intense thinking with high self-scaffolding and long immersion to move from the theory of coral reefs to the principle of evolution by natural selection, even though the coral-reef theory was later seen as an instance of the principle (Fischer & Yan, 2002). The extension of that theory to hundreds of problems in biology went on for the rest of his life. Forward consolidation is both a challenging cognitive journey and a significant intellectual accomplishment, whether for an extraordinary thinker or an ordinary adult.

Why are there such gaps in the timing and performance of reflective judgment and other skills? Catastrophe theory (a kind of dynamics) helps to explain these nonlinear processes. When a number of influences act together, they can produce a nonlinear pattern with a complex shape that includes powerful discontinuities called *catastrophes* (van der Maas & Molenaar, 1992; Zeeman, 1976). Catastrophe theory describes how a developing pathway can bend back on itself over time as it progresses, giving a distinctive scalloped shape to the ascending pathway. This backward bending shows a remarkable parallel to the spikiness and gappiness in the development of optimal level in a given domain or in the confluence of integrating domains, as shown in Figures 21.3 and 21.6 (Fischer & Bidell, 1998; Rose & Fischer, 1998). In a sense, the cognitive capacities pressed into service under high-support conditions are unstable until the person has consolidated them through extensive experience and practice. The instability takes two forms: (1) development of optimal performance shows sudden jumps and drops; and (2) the level appears and disappears with variation in contextual support.

Backward transition and forward consolidation as well as other growth processes form foundations for the dynamic phenomena of adult development. These dynamic processes operate within the strands of the developmental web, and they create the wide range of levels of everyday skill. Skills range from large drops to basic levels in backward transition to high levels of new skill constructed on these basic actions. They range from low levels of automatized actions to functional levels of unaided actions and further up to optimal levels of supported actions. They even extend to the high reaches of collaborative action. The range of variation is especially broad and pervasive in adulthood, even more so than in childhood.

At least three reasons account for this broad variation. First, adults have a wider range of skills available because they are capable of going all the way from elementary sensorimotor actions to complex abstractions. Second, the high-level abstractions of which adults are capable are especially subject to the influences of culture and education, even more than the basic skills of childhood. Third, adults tend to specialize in particular domains, based on their life choices and situations – entering one job and not another, one avocation and not another, one family role and not another.

Conclusion: Richness and Complexity of Adult Development

Accumulated evidence indicates that Piaget's formal operations is not the end of human cognitive development. Instead, development over the 60 years of adulthood is an important part of the whole picture of human cognition. Adult cognitive development is rich and dynamic, like a complex web that is constantly changing with multiple levels, strands, networks, and directions. The wisdom and intelligence of an adult cannot be captured by one developmental level, one domain, one pathway, or one direction. During adulthood, intelligence commonly moves to become more sophisticated, flexible, synthetic, constructive, and socially oriented – more complex and dynamic. Cognitive development in adulthood takes a number of different shapes, and it occurs through a set of fine-grained mechanisms for building and adapting skills. Specific skills emerge at one level but require long periods of consolidation before they predominate in ordinary contexts. They emerge abruptly as new optimal levels for a given domain, but develop more slowly and gradually as functional levels of everyday action. An important mechanism for construction of new knowledge is backward recursion to lower levels of actions and representations followed by repeated rebuilding of a skill until it is consolidated and stabilized as available and generalizable. A major impetus to the work of constructing new approaches to the challenges of a rapidly changing world is through learning with others – colleagues, friends, mentors, parents, relatives, and even their children. Research in the future will need to unpack further the richness, complexity, and dynamics of adult cognitive development, building knowledge of the developmental webs and dynamic processes that we have begun to describe. By opening up the scope of research and theory to analysis of the dynamics of variability and change, we can better understand the true richness and complexity of each adult's adaptive construction of knowledge. This new knowledge of what, how, and why adult cognition changes can eventually help millions of adults to meet new challenges from their complex natural, social, and spiritual worlds more successfully and enjoyably.

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