CHAPTER 1

The Evolving Complexity Theory of Talent Development
An Overview of "One Long Argument"

> *We can allow satellites, planets, suns, universe, nay whole systems of universe, to be governed by laws, but the smallest insect, we wish to be created at once by special act.*
>
> Charles Darwin, *Notebooks*

Charles Darwin called his evolutionary theory "one long argument," mainly because the evolution of species is a process of evolving complexity that cannot be condensed into something like the mass–energy equivalence formula ($E = mc^2$). To be sure, parsimony is a virtue of science, and, as Einstein put it, a scientific theory should be made as simple as possible, but not simpler to the point of overlooking many essential elements or processes. However, compare Einstein's probing into basic workings of physics with Darwin's endeavor of deciphering the secret of genesis and metamorphosis of species, which is a different genre of science. In what he called "one long argument," several theoretical conjectures and suppositions about living beings or organisms had to be substantiated and linked together in a coherent fashion (Fischer & Yan, 2002). In other words, a long argument has a rhetorical structure like a conceptual edifice that has to be supported by a long chain of reasoning linking together many seemingly discrete pieces of evidence about different kinds of animals and plants (e.g., why some animals have tails or wings and others do not). The evolving complexity theory (ECT) of talent development, by its nature of dealing with phenomena of various *special acts of human striving*, to use Darwin's words (see the opening quote), points to developmental diversity and divergence through real-time organisms' adaptation to their environments, with cultural selection (cultural distinction, privileged access, and gatekeepers) and support (tools and resources; see Csikszentmihalyi and Robinson, 1986).

1.1 Reductive Attempts of Explaining (Away) Evolving Complexity: Pro-Nurture versus Pro-Nature

The pro-nurture, environmentalist argument. To push the evolution metaphor a little further, the emergence and evolution of talent must involve qualitative changes in developmental organization of the human organism as well as more refined attunement to a task and social environment. For human talents to evolve, be it in sports, music, chess, or other domains, one has to engage, model, construct, and act upon a particular task environment with significant amounts of scaffolding by others or by self. This assumption seems to be obvious – or is it? For example, Herbert Simon saw ants and humans as alike in navigating and building up complex models of the world they find themselves in.

> An ant [or a human], viewed as a behaving system, is quite simple. The apparent complexity of its behavior over time is largely a reflection of the complexity of the environment in which it finds itself. (Simon, 1996: p. 52)

By implication, ants and humans both develop their static cognitive schemas and dynamic mental models that mimic the complexity of the world. For example, with experience, ants would presumably build a cognitive map of a terrain on which ants perceptually and physically navigate to find food, just like humans, who, with experience and knowledge of how to overcome the hurdles of waters, developed a mental image of a bridge that would allow them to cross a river. However, such an environmentalist account of evolving complexity raises a serious problem: Does an ant really have a mental schema or model of the world in the first place?

It is safe to assume that "evolving complexity" for ants is fundamentally limited, presumably by their genetics (e.g., their muscle mass, brain size, and limited representational capability). In contrast, humans' evolving complexity, say, in bridge-building, entails not just a cognitive image of the overpass but the knowledge of material, spatial, physical, and functional constraints for such a device. There is a fundamentally creative aspect of bridge-building that is not present in the navigation behavior of ants or other animals with limited representational capabilities (let alone building a supercollider that fathoms the ever-smaller particles that make up the physical universe).

The most marvelous and puzzling part is that neither the mental model of a bridge nor that of a supercollider is coded or programmed in human genetics. Simon said little about how humans made such cognitive

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breakthroughs, which lies in the essence of talent development (TD). In other words, the *intersection of the biological, experiential, cognitive, and sociocultural aspects of human adaptation through fashioning extraordinary feats of overcoming seemingly insurmountable barriers and challenges is completely ignored by Simon's analogy between ants and humans*.

It can be argued, then, that behaviors of ants or most animals (how they go about living their lives, even where they live) are largely preordained or fixed by their genetics. The same cannot be said of humans; even identical twins can live different lives and have different skillsets, say, one becoming an artist and the other an engineer. While an ant's destiny is predetermined, for better or for worse, humans face enormous uncertainties; they do not grow thick fur to fend off cold weather, and they do not have the night vision of felines for catching prey in the wild. However, humans develop a talent for making tools to survive and thrive, for invented language for puzzling out things with other people, and even for telling how others feel and think (i.e., the theory of mind), and for finding out patterns and regularities. Compared to ants and other animals, humans are "free," as it were, from "stimulus control," to decide on what to do and what to choose; they gain this freedom mainly by their cognitive representational capabilities, the ability to conjure up stories about the world and the self, to reflect on their experiences, and to chart their own paths that work for their long-term success.

Thus, the analogy between ants and humans breaks down when we consider *Homo sapiens* not merely attempting to survive and reproduce; they are also thriving by envisioning and seeking a prosperous future. This is so because humans are more capable of actively choosing and shaping their environments to maximize their gains, rather than being passively shaped by their genes or succumbing to the shaping power of their environments (Bandura, 1986; Bronfenbrenner & Ceci, 1994). *It is these properties of active adaptation and representational and creative capabilities (hence various "talents") that distinguish humans from ants or other animals*.

The pro-nature, genetic account. A simplification in favor of the nature argument on the opposite end of what Herbert Simon (1996) characterized is adopted by behavioral and molecular genetics researchers who believe that genetics works in a unidirectional, deterministic fashion. Galton's (1869) heritability of genius is perhaps the earliest rendition of that argument. He came up with the idea of human achievement as capped by some sort of the fixed capacity that is genetically predetermined. The modern version of such an argument can be found in Belski et al. (2016), who used a polygenic index, a set of genes derived from genome-wide

association studies (GWAS) as having a causal bearing on years of education. They further claimed that this causal relationship is likely mediated by intelligence, which is also associated with a set of genes. Such an approach represents a short-cut attempt to explain human development, not unlike Simon's environmentalist account. Similar to the environmentalist accounts that skip individual development altogether, the gap is too large and deep between genes and long-term developmental outcomes (see Horowitz, 2000; Lerner, 2004 for a critique), especially when genetics are linked to social success and excellence in a linear, deterministic way. The conjecture that a set of genes somehow produces developmental outcomes as complex as years of education represents what Dennett (1987) called *greedy reductionism* in terms of genetic causation, with tenuous evidence (e.g., the variance accounted for by the polygenic index) at best.

It is not that pro-nature or pro-nurture accounts are totally wrong; the real problem is that they do not really constitute valid explanations from a theoretical point of view; no insight into "how" (Anastasi, 1958) is achieved by radical reductionism. When a claim is made that nature prevails over nurture (Galton, 1869; Murray, 2003), or vice versa (Howe et al., 1998), not much is gained with respect to what developmental transformations the organism goes through that lead to various human accomplishments, and, for that matter, why there are divergent trajectories and pathways for individual development among people.

1.2 An Alternative, Nonreductionist Approach: ECT as "One Long Argument"

Instead of making theoretical shortcuts one way or another, an alternative approach is to use a nonreductionist method in dealing with dynamic changes and transformations of organization underlying a developmental phenomenon. Kenneth Libbrecht (2004), a physics professor at CalTech, provides an inspiration with his studies of the dynamic formation of snowflakes.

> Growth is the key ingredient for the generation of snow-crystal patterns . . . Even the tiniest protruding points will grow faster than their surroundings and thus protrude even more. Small corners grow into branches; random bumps on the branches grow into sidebranches. Complexity is born. (p. 25)

If the shaping of snowflakes reveals much of physics, mathematics, and chemistry, the evolution of living systems allows us to delve into the more complexly organized existence of the biological, psychological, sociocultural

nature. Living things have, over millions of years of evolution, developed complex nervous systems, consciousness, language, shared technology, and culture, which enable *Homo sapiens* to achieve a maximal fit through learning and development in an unprecedented manner (Dawkins, 1976/2006). An adequate theory of human functioning and development, including a theory of high human potential and accomplishments, needs to consider all those properties bestowed on an individual human living system through phylogeny (i.e., evolution of a species or group) and ontogeny (i.e., individual development) (Dai & Sternberg, 2004, 2021). The emergence and evolution of talent is similar to snow-crystal formation, except that it involves *a developing person, who is undergoing changes in themselves in multiple ways at multiple levels while interacting with the environment and exercising their agency and control* (Dai & Renzulli, 2008). Lewis (2000) viewed the developing person as an open, dynamic, and adaptive living system that shows the following tenets: (a) Producing novelty in its developmental organization, (b) becoming ever more complex, (c) undergoing phase transitions, and (d) being intrinsically robust to maintain its own continuity and extrinsically sensitive and adaptive to the environment. Dynamic system theory provides a foundation for conceptualizing talent development as following the same developmental principle of evolving complexity, hence the evolving complexity theory (ECT) of talent development and human excellence (Dai, 2017, 2020a, 2021).

To explain a wide range of talent development and human excellence, ECT has no choice but to make "one long argument." The argument has three components. The first component is bio-ecological settings where developing individuals work on the mode of surviving–thriving; the second component is the emergence of conscious self-awareness that enables individuals to choose what they do to shape their own life course under given life circumstances; and the third component is the emergence and evolution of culture (i.e., shared norms, tools, ways of conducting their life for a group of people) that ether facilitate or impede such a life endeavor. In short, ECT is trying to capture three elements at work: biology, culture, and personal agency. *Biology* provides drives and instruments. *Culture* helps shape their ways of self-expression and social organization by setting rules, norms, and values, and extends their capabilities with its tools and technology, all mediated by human language. And *personal agency* comes into play in two fundamental ways. First, *talent is always situated* as a joint function of what the person brings to a situation and what stimulation and opportunity of an environment affords the person to do, and what kind of resources and tools are available to sustain the person's learning and

development. Second, *talent is always augmented* when one becomes more capable of viewing oneself as a source of agency capable of charting one's own course of life and making the most of what one has or potentially can have to achieve life ambitions. The question, then, is how these three main functions are realized through human development. The developmental process that integrates these three elements is portrayed in Figure 1.1.

In Figure 1.1, the vertical dimension represents the person–environment transactional interface, which evolves from the local social-cultural history. The horizontal dimension represents a life-span temporal progression from birth toward maturity and later aging; it arises from human evolution and inherits a distinct genetic makeup. The diagonal dimension represents the increasingly differentiated and integrated competences and personhood (i.e., individuality) *contextually and temporally emergent* from the person-environment transactions. The arrow from contextual to temporal emergence indicates a developmental process of self-organization or appropriation that is not instant but has its own latency or even *décalage* (delay) (as per Piaget; see Scardamalia, 1977). The three dimensions intersect to form a basic

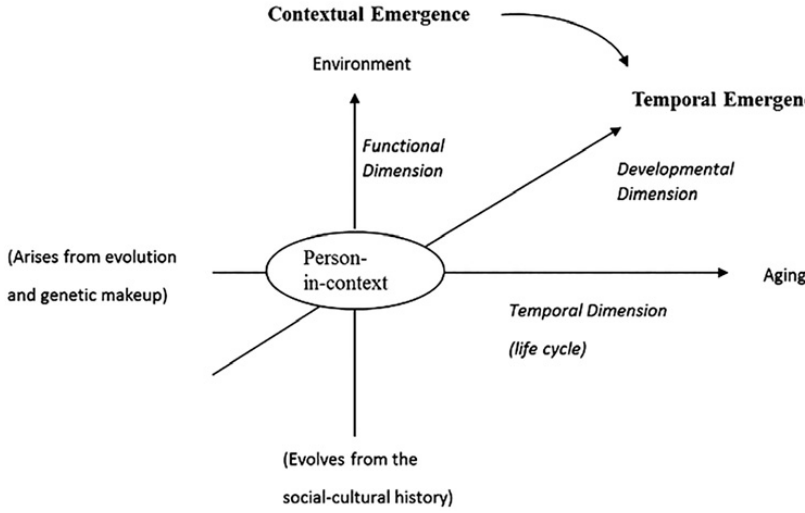

Figure 1.1 A schematic representation of a dynamic, relational developmental system. *Functional* (the vertical dimension: Person–environment transactions), *Temporal* (the horizontal dimension: A person's life trajectory toward maturity and aging), and *Developmental Vectors* (the diagonal dimension: The contextual-temporal emergence of novel properties); first published in Dai, 2017.

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unit of analysis: *Person-in-context*, meaning that a person is investigated and understood *as a developing person functioning in specific social-cultural contexts at a specific developmental juncture, with a particular timescale of the course of an action*.

Based on this three-dimensional conceptual foundation, a theory of TD needs to:

(a) explicate *what* emerges and evolves in terms of structural and functional changes as the result of specific ways of engaging, representing, modeling, and acting upon a particular task and social environment (the diagonal vector or *structural regularities*);
(b) explicate the developmental process of *how* some new properties emerge and develop, and what drives and regulates the process for the exploratory period as well as for the more advanced talent development period (the vertical vector or *process regularities*);
(c) identify *when* some new properties emerge or some regulatory forces kick in, for instance, the *developmental timing and duration* of relevant developmental events, the *temporal sequences or progressions* of developmental changes and transitions (the horizontal dimension or *temporal regularities*); and
(d) identify various constraints imposed by macro-level social-historical conditions (the question of *where*) such as social structure, technological advances, and cultural tools and resources as well as values and norms.

Through this developmental lens, one can simply define TD as a prolonged process of human adaptation resulting in outstanding human accomplishments, which are manifested in three ways:

(a) stretching human limits in terms of extraordinary skilled performance (e.g., in sports and the performing arts);
(b) making eminent creative contributions that significantly improve human conditions (e.g., philosophy, science, literature, art, and technology); or
(c) showing distinct social leadership in technology, business, and social organization.

As shown in Figure 1.1, the contextual and temporal dimensions of human transactional experiences intersect to produce developmental changes in structure and function, which feed back to transactional processes in an iterative fashion. Hence the first proposition of ECT.

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> **Proposition 1a**: Talent is a structural and functional property of the person contextually and temporarily emergent through maturation and adaptive transactions with certain social-cultural environments, with ever-evolving complexity, and thus cannot be "explained away" by lower-level components that are part of the developmental system in question.

Proposition 1a highlights the evolving nature of talent, and its *contextual-temporal emergence*; talent is an emergent property of person–task interactions that is further evolving, which changes the dynamics of this interaction, and propels its further development. To further explain such "ever-evolving complexity," several key developmental concepts become guiding principles: *probabilistic epigenesis* (Gottlieb, 1998), *proximal processes* (Bronfenbrenner & Ceci, 1994), and *self-organization* toward higher-order coherence (Lewis, 2000).

Principle 1: probabilistic epigenesis. Gottlieb (1998, 2007) proposed *probabilistic epigenesis* as a guiding principle for individual development, as opposed to the dogma of unidirectional genetic determinism. In this probabilistic-epigenesis framework, four factors operating at different levels (environmental, behavioral, neural, and genetic) interact with one another in a bidirectional, reciprocal manner, leading to structural and functional changes over the course of individual development.

Development is *probabilistic* because it is contingent on reciprocal interaction of the person with impinging environmental experiences at multiple levels. Development is *epigenetic* because the behavior patterning, neural paths, and genetic expressions are all contingent on environmental input and activity in a cascade of effects. This conception bears similarities with Bandura's (1986) formulation of the triadic reciprocation of environmental, behavioral, and internal factors, except that probabilistic epigenesis refers to a developmental process.

From a TD perspective, many cognitive-affective processes responsible for the emergence of talent are bootstrapped through this reciprocal interaction, rather than predetermined by genetic programming. For example, when a baby is listening to music, the music is also building an apparatus that enables recognition of rhythmic and tonal patterns, or even an aesthetic or expressive modality in the baby's brain. Later, I will further elaborate on the epigenetic nature of development as "norms of reaction" as opposed to the "reaction range" notion of genetical potential.

Principle 2: proximal processes. Bronfenbrenner & Ceci (1994) defined proximal processes as follows.

> [G]enetic potentials for development are not merely passive possibilities but active dispositions expressed in selective patterns of attention, action, and responses . . .
>
> [H]uman development takes place through processes of progressively more complex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate environment. To be effective, the interaction must occur on a fairly regular basis over extended periods of time. Such enduring forms of interaction in the immediate environment are referred to as proximal processes. (p. 572)

Ceci et al. (2016) elaborated on three properties of the workings of proximal processes in TD.

(a) TD involves an enduring process of progressively more complex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate environment (i.e., *the tenet of endurance*).
(b) TD involves emergent organization, namely, the specific form, content, and direction of TD emerges from the interaction of the developing person, with distinct personal characteristics, and the impinging environment, immediate or symbolically mediated (i.e., *the tenet of transaction*).
(c) TD involves the efficacy of this proximal processes, namely, proximal processes activate biological potential for effectively dealing with relevant tasks and social challenges, and the efficacy of these processes for sustainability for further development is contingent on genetical potential, environmental demands and constraints, and current developmental outcomes (i.e., *the tenet of efficacy*).

To push further the ant/human analogy discussed earlier to illustrate the tenets or properties of endurance, transaction, and efficacy undergirding proximal processes, unlike ants, a person shows their talent by effectively creating a device (e.g., a raft) that floats and carries people across the river, and then the person may further master the principle of displacement and make a functional boat with larger capacity. What appears to be a static talent is actually undergoing dynamic changes all the time (Yan & Fischer, 2002; see also Kanevsky, 2020).

Principle 3: self-organization toward higher-order coherence. Self-organization is the core concept of dynamic systems theory. When applied to individual development, biological or psychological, the principle of self-organization claims that "all developmental outcomes can be

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explained as the spontaneous emergence of coherent, higher-order forms through recursive interaction among simpler components . . . Human development is just one exemplar of a universal tendency toward higher-order coherence" (Lewis, 2000: p. 36). This "higher-order coherence" indicates a form of adaptive self-organization on which ECT is predicated.

In short, the three principles can be summarized as follows. The principle of *probabilistic epigenesis* helps clarify what we mean by "genetic potential." The principle of *proximal processes* explains how sustained, efficacious engagement gives rise to new forms, contents, and directions. Finally, the principle of *self-organization* toward higher-order coherence shows how these new forms and properties can emerge, and how a developmental system builds its higher-order coherence responsible for highly sophisticated performance or creative productivity, which has to be explained not by any lower-order components alone, biological, psychosocial, or environmental, but by a developmental systems perspective that integrates all these levels of analysis through a developmental synthesis. Based on the three principles, we can state the primacy of action and interaction as to how genetic potential will express itself.

> **Proposition 1b**: A person's talent potential is not a fixed capacity but depends on the person's environmental opportunities, resources, and transactional experiences (i.e., proximal processes; Bronfenbrenner & Ceci, 1994); therefore, talent potential is dynamically evolving through probabilistic epigenesis (Gottlieb, 1998), contingent on extended formal and informal learning and productive experiences that reciprocate with one's biological system at specific developmental junctures.

Proposition 1b argues that the nature of talent reflects a specific type of structured task experiences; thus, any outstanding performance is a joint function of "being" and "doing," contextualized in a given social context. There are two ways of conceptualizing genetic potential in this context: *reaction range* (Bouchard, 1997) and *norms of reaction* (Lewontin, 2000; Gottlieb, 2007). The notion of reaction range alludes to genotype-phenotype correspondence; *how much* of one's genetic potential is actualized or *unleashed* depends on whether environments are impoverished, normal, or enriched. The notion of norms of reaction suggests that the genotype does not specify a unique outcome of development. Instead, it specifies specific patterns of developmental outcomes under different environmental conditions. In other words, the gene–environment relationship is a two-way street; how genes express themselves is contingent on the nature of environmental input and stimulation. In the main, the

reaction range interpretation of genetic potential emphasizes unidirectional, quantitative genetic differences, and the norms of reaction interpretation stresses the didirectional, qualitative aspects of genetic potential.

There is good reason to believe that norm-based reaction should be favored over reaction range in explaining talent phenomena, as researchers have consistently found that general intelligence (such as working memory and reasoning; Kyllonen & Christal, 1990) can predict performance across domains to some extent, indicating a system-wide pervasive influence; however, when it comes to specific types of achievement, more refined domain-specific predictors always work better than generic ones (Lohman, 2005; Wai et al., 2009), suggesting that *TD is typically based on the ideographically complex patterning of developmental potential rather than nomothetic rules subsumed under the reaction range theory*.

ECT adopts the *norms-of-reaction* supposition, or a nondeterministic, interactive point of view regarding talent potential. This stance is in line with probabilistic epigenesis as well as the notion of a *triple helix* (Lewontin, 2000) in the sense that there is organismic-level operation sitting between genetic-level and environment-level operations. Given such a nonreductionist view, ECT endorses *equifinality* (see also Simonton, 1999; Papierno & Ceci, 2005 for a similar position). For example, two people equally talented in music do not have to share the same set of genes or the same behavioral or psychological characteristics, or even the same pathway to their talent status. By the same token, the norms-of-reaction interpretation of genetic potential also is open to *multifinality*, in the sense that the same genetic potential (say, of the identical twin) might express itself differently as different aptitudes and dispositions, contingent on different experiences and conditions; one twin might become an engineer and the other an artist, or both (e.g., Da Vinci, the artist-engineer).

1.3 The Substance of ECT as "One Long Argument": What, How, When, and Where

As pointed out earlier, ECT discerns four main aspects of TD based on Figure 1.1. The four aspects of what, how, when, and where are intertwined, as suggested in the person-in-context as a unit of analysis (see Figure 1.1), addressing four essential questions regarding human TD and excellence: (a) **what** develops; (b) **how** it develops; (c) **when** certain internal or external events should take place; and (d) **where** it takes place, in terms of the social-historical context. In the following section, these four aspects of ECT will be briefly introduced, followed by the full-length treatment of each in the next six chapters.

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1.3.1 What *Develops in TD: Emergent Structures and Functions*

Traditional approaches to TD do not define talent domains as clearly. However, in what ways one demonstrates excellence and what constitutes talent domains need to be clearly defined. Talent development as defined by ECT refers to *emergent structural and functional properties, and increasing differentiation and integration of these structures and functions crucial for carrying out a specific type of challenging task*. For ECT, the distinction is made between bioecological forms of effectivity (e.g., hunting, singing, reasoning) in naturalistic settings, and culturally defined and institutionally created domains (e.g., sports, music, science). Everyday person–task interaction entails five basic forms of bioecological effectivity (psychomotor, social, technical, expressive, and intellectual), separate or in combination, manifested in the hunter-gatherer society as well as in modern society, and recognized by peers and parents. In contrast, culturally defined domains of talent have more formal, institutionalized structures and pathways, and talent in these domains is more formally recognized by cultural institutions, which always harness basic forms of bioecological effectivity or competence but develop their own talent more rigorously and systematically for their own functions and purposes (Gagné, 2020). In this sense, *talent is always a new machine made of "old parts"*; the basic enactive and representational capabilities of human brain/mind are incorporated in dealing with the complexities of the more formal task environments.

The primary assumption of TD under ECT is *a person–task interaction situated in specific social contexts that define the purpose, structure, and adaptive value of the task*. This assumption is at variance with the assumption of a talent domain as inherently coherent and self-sufficient. The second assumption of ECT, a somewhat derivative one, is that talent is indicative of a proficiency in productive or performing activity, rather than merely "knowing a lot" about a domain. A person knowing a lot about music does not make them a talented musician, unless they can sing well or play an instrument well, or even can compose music or write about the intricacies of music. By the same token, a person being erudite in psychology does not make them a talented psychologist unless they can develop compelling arguments in academic settings or make insightful assessments in professional settings. This qualification of what it means to be talented is often ignored. What follows is the third assumption of ECT, that talent always starts in a nebulous form of competence and gradually becomes more fine-tuned (i.e., differentiated) and sophisticated in dealing with the task demands (Dai, 2021). This position is in line with the expert

performance perspective (Ericsson et al., 2005, 2007), albeit the fact that ETC fully acknowledges the role of individual differences with respect to different rates of learning and asymptotic performance or productivity, even when deliberate practice is taken into account.

There are three levels of domains based on ECT: (a) five forms of bioecological effectivity; (b) culturally defined domains; and (c) the personal sphere of actions, an ever-complex repertoire of competences, values, and interests (see Dai & Chen, 2014). Each can be cast in the larger scheme of connections the person makes with the world. How ECT explains the emergence of specific forms, structures, and properties of competence we call "talent" is elaborated in Chapter 2.

1.3.2 How *Talent Develops: Two Invisible Hands and Three Main Drivers of Talent Development*

The question of how talent develops addresses what drives, regulates, and sustains TD. The question helps address how talent trajectories are shaped for individuals, and how TD is sustained and advanced to higher levels. None of the existing models of TD have adequately addressed these questions, simply because most researchers, whether focused on the gifted and talented or on expertise and creativity, pay little attention to *developmental processes*. Simonton (1999) was the first to map out the emergence of new talent from an emergenic-epigenetic viewpoint, but the model does not address the question of *how* in terms of regulatory forces that propel TD. The problem of motivational and regulatory processes is an essential one, as we cannot assume that talent components would come together in a mystical way without the person exercising their agency in the transactional interaction with a task and social environment. The problem becomes more critical when TD typically does not take place endogenously in the way that language or emotional development takes place; rather, as part of nonuniversal development (Feldman, 1994), choice is always there for individuals not to engage in a particular line of development or to opt out of it at some critical juncture. Framed more positively, TD involves actively seeking opportunities or changing directions in individual development (e.g., finding one's own way of achieving personal aspirations and ambitions instead of following institutionalized pathways).

How, then, can we explain diverse talent trajectories and pathways in terms of motivational and regulatory forces? Although some talent models suggest possible "environmental and intrapersonal catalysts" (Gagné, 2005, 2020), such as interest (Lubinski & Benbow, 2021) or grit (Duckworth, 2016), the

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question cannot be adequately solved without a research provision that looks into the "proximal processes" head-on (Bronfenbrenner & Ceci, 1994). Motivational and regulatory processes are emphasized by Subotnik et al. (2011) in their emphasis on "psychosocial skills," especially when one experiences setbacks, adversities, and competing life priorities, which are not only common but inherent in TD, which often challenges human limits and demands total commitment.

Recall that ECT specifies three fundamental aspects of TD: biology, personal agency, and culture. For personal agency, ECT particularly stresses the self-directed and self-regulated nature of human development, which becomes more distinct when one reaches the point of autonomy in individual development at which one does not rely on evocative reactions of significant others for direction but actively seeks out information and opportunities for self-development (Lerner, 2004; Wachs, 2000). The hallmark of regulatory personal agency is the emergence of the personal action space (PAS), and its most distinct role is reflected in the two most central regulatory concepts of ECT: characteristic adaptation (CA) and maximal adaptation (MA) (see Figure 1.2).

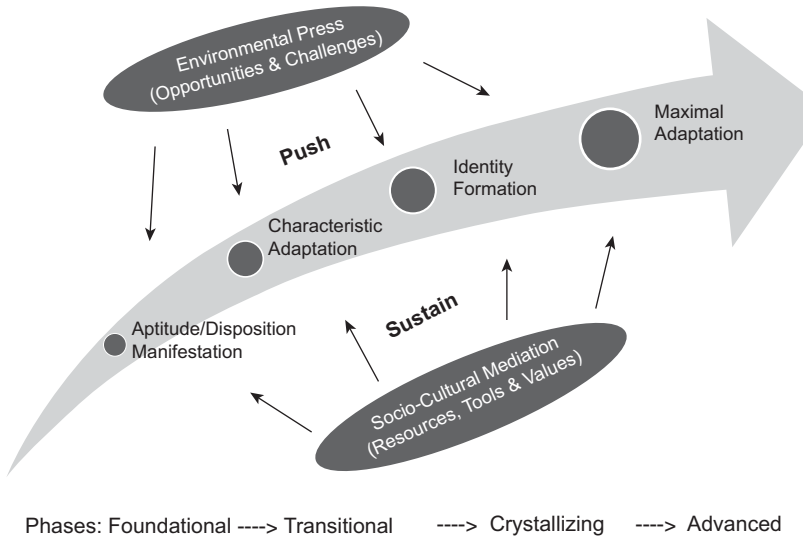

Figure 1.2 A schematic presentation of how the endogenous momentum of talent development is "pushed" and "sustained" by exogenous forces.
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As shown in Figure 1.2, ECT uses the push-sustain metaphor to characterize the person–environment transactional experiences that propel TD. The big arrow represents the developing person, with all their endogenous agency, interacting with two kinds of exogenous forces: environmental press (opportunities and challenges), on the one hand, and sociocultural support (resources, tools, and values), on the other. That ECT starts with "environmental press," rather than with a "talent" or "gift," distinguishes itself from trait theories of gifts and talents (e.g., Gagné, 2005). *Environmental press* refers to a situation that evokes a need within the organism that has adaptive consequences (Murray, 1938). To use the language of ecological psychology, environmental press *affords* certain opportunities to learn, to develop, to control, to enjoy, to achieve certain personal ambitions; in the meantime, however, it sets constraints and demands (i.e., challenges) that need to be met in order to materialize the affordances in question. In other words, there are always culture pressures and expectations that can be perceived as stressors that might evoke the need for self-protection; thus, environmental press can be a double-edged sword for individuals, simultaneously evoking the need for growth and the need for coping (Dai et al., 2015). The nature of such extended person–environmental transaction (i.e., proximal processes) determines, first and foremost, that TD for the most part is not a "natural" but a self-directed, self-regulated adaptive response to environmental opportunities and challenges. I use the "push-sustain" metaphor to denote this need-evoking, action-sustaining process. In short, there is an interplay of individual niche-picking and cultural selection pressure (i.e., two invisible hands) that helps sustain TD.

As a first approximation, ECT assumes that individuals in their lifetimes go through a progressive course of learning and talent development experiences, in the order of informal learning experiences (e.g., those facilitated at home or initiated by oneself) followed by formal education, advanced training, and ultimately cutting-edge work in particular domains. We can roughly view the long-term TD process as characterized by the emergence of CA, followed by a gradual transition to MA (note the changing phases of the TD path represented by the big arrow in Figure 1.2). In the foundational phase, TD is informal, driven by *effectivity or effectance motivation* (e.g., playing Pokémon or building gadgets; White, 1959). This effectivity motivation underlies many spontaneous activities to develop bioecological effectivities in children and is a source of interest very early on, which shows developmental stability over time (Gottfried & Gottfried, 2004). In the transitional phase, one's CA will manifest itself in the kind of activities, people, books, and games one seeks out. As a result, individual differences in CA are more likely to show through

(Ackerman, 2003); CA takes the form of self-organizing motivation (Fischer & Connell, 2003) in terms of interest-driven and self-sustained personal pursuits (Barron, 2006). In contrast, MA reflects a more committed and dedicated pursuit of a personal goal or career that often carries strong cultural prestige and institutional support. To further specify the developmental process in terms of the emergence of CA and MA, ECT postulates four phases of talent development. To use music as an illustration, demonstrating music-related effectivity in terms of aptitudes and dispositions (foundational phase) is one thing, and pursuing a musical interest (transitional phase) is another; becoming a musician (crystalizing phase) is one thing, and sustained effort to perfect one's music skills and exploring a new form or personal style of musical expression (advanced phase) is another. The game changes, so to speak, as the person moves to a later phase of TD.

It is important to point out that *how* talent develops is associated with the question of *what* develops. Aptitudes and dispositions are more spontaneously displayed tendencies and abilities, likely in response to activities that permit the expression of five basic forms of bioecological effectivity; they are more likely intrinsic, triggered by the environmental stimulation, rather than "calculated" responses. In this sense, aptitudes and dispositions (e.g., an early manifestation of mathematical or musical precocity or inclination) are a prelude to CA, just as crystalizing experiences and milestone achievements in culturally sanctioned undertakings (e.g., a science talent search project) are a prelude to MA (see Figure 1.2). Suffice it to say that when one negotiates a personal life path with the prospects of payoff, risks, and opportunity costs, what kind of commitment one makes (CA or MA) always reflects more than domain competence; that is, TD enters the realm of values and character. All these issues will be dealt with in depth in Chapter 3.

1.3.3 The Question of When Related Developmental Events Should Take Place: The Timing and Temporal Progression of Events of TD that Impose Constraints on the Issues of What Develops and How It Develops

The question of when (timing and temporal sequences) is inherently developmental (the horizontal dimension of the life cycle in Figure 1.1). Based on Figure 1.1., the contextualized transactional experiences always have a temporal dimension in three senses. First, the developmental timing matters in terms of at what age a TD-related developmental event takes place; a visit to Cape Canaveral carries different significance for an eight-year-old as compared to an eighteen-year-old. Second, any "extended proximal processes" have a temporal dimension; when Csikszentmihalyi

et al. (1993) conducted *experience sampling* of emotional or ideational states of talented teenagers, when one attempted to derive an observation of CA or MA patterns, there was always a temporal sequence of events to be interpreted with specific meaning attached to it. Third, "extended proximal processes" always lead to a new developmental state of interest. For ECT, the most relevant temporal issues are: (a) when certain environmental experiences should take place to induce a particular pattern of strengths and interests vis-à-vis task demands and characteristics, and how they lead to or sustain new activities; (b) how enduring a transactional experience occurs (e.g., an emergent interest in building a gadget or participating in *a cappella* in school); and (c) whether there is evidence of the contextual-temporal emergence of new properties or relationships (Figure 1.1) that can be viewed as *phase transitions* (e.g., a changing cope-and-grow pattern over the course of college; Dai et al., 2015).

The timing of onset and peak performance/productivity drew attention in the early years of TD research (Lehman, 1953; Simonton, 1988). However, this descriptive tradition does not provide details of the contextual-temporal emergence of structural and functional properties), nor does it specify the developmental processes underlying the temporal regularities. Nonetheless, it provides important clues for a more micro-level investigation that can reveal the nature of what and how talent develops for a particular type of talent achievement (e.g., sports versus academics, or poets versus playwrights).

For a temporal account of TD, ECT postulates three critical transitions to higher levels of excellence. It also proposes several terms that specify the contextual-temporal nature of TD events and opportunities, such as developmental windows and corridors. They are elaborated in Chapter 4.

1.3.4 How Cultural Evolution Changes Talent Development: A Macro-Environmental Issue

By "where," I mean specific social-historical periods of time with distinct respective social structures, value systems, and technological advances, which show qualitative distinction in terms of types of talent developed (the question of what), processes and constraints unique to specific historical periods (the question of how), and timing and duration changes thereof (the question of when). In short, it concerns how *phylogenetic and cultural* sources of support (e.g., infrastructure and capacity) influence *ontogenetic* patterns of TD. When larger patterns of structural changes transform people's ways of life in a fundamental way (e.g., from the agricultural to industrial ages), we

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witness cultural evolution in the form of new niche constructions or infrastructure-building (e.g., building guilds and institutionalizing schools and universities), which can change the way TD takes place.

Existing models of TD have typically defaulted this part as given, for instance, taking for granted that opportunities and resources are unlimited or evenly distributed in a population. The tacit assumption is that what holds for the onset and peak of creative careers observed in the industrial age (e.g., Lehman, 1953) should hold for the information age, which is a problematic assumption regarding the constancy-variability of the contextual-temporal emergence of talent and peak productivity. How changes in the macro-environment (e.g., the inventions of written language and printing) eventually trickled down, as it were, to micro-level environments (e.g., books at home), and how newly organized meso-level social systems (guilds or conservatories of music) created new life paths for individuals, should be seen from a developmental science perspective as part of intimately connected developmental systems.

A major argument of ECT is that institutional, pedagogical, and technological changes do not just *facilitate* the realization of human potential; rather, they also *enable* humans to stretch their limits (i.e., developmental potential) in many ways, very much like microscopes and telescopes stretch human vision, and mathematics helps us stretch and calibrate our sense of magnitude and scale (Dai, 2020b). The impact of social-historical changes, especially cultural evolution, on TD at the individual level will be elaborated in Chapter 5.

1.4 Putting It All Together: How ECT Explains Various Talent Achievements

Through explication of the issues of what, how, when, and where, ECT identifies two main sources of TD: *evolving individuality* in terms of the emergence of personal agency and higher levels of self-organization, and *cultural evolution*, in terms of cultural inheritance, variation, and selection. Together they explain talent achievements at two levels, individually and collectively. *Putting it all together means that an explanation of talent achievement should encompass biological, psychological, sociocultural, and personal levels of analysis to reveal its evolving complexity or self-organization toward higher-order coherence fit for purpose*. Such a developmental progression is epitomized by the levels of achievement attained by mono-savants, prodigies, expert performers, and consummated creative writers, artists, scientists, and entrepreneurs (see Chapter 6).

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Existing TD models and theories tend to be domain-centered, using culturally defined domains as boundaries for inquiry (music, sport, science, etc.). In comparison, ECT is a person-centered theory, using personal development to frame TD in such a way that domain is not treated as if TD always happens in a prearranged niche and fixed pipeline. Rather, ECT views cultural domains as a vehicle for achieving personal goals. ECT can explain a wider range of talent phenomena, such as polymathy, talent that was largely self-made (e.g., Michael Faraday), creative achievement that did not display a *conventional* talent development trajectory, as an expert performance perspective prescribed (e.g., Ericsson et al., 2007), or creative productivity in science and arts that largely takes place in a community of practitioners (the impressionist movement, or the birth of quantum mechanics). Ultimately, *ECT is a theory that attempts to explain human accomplishments as part of evolving individuality and cultural evolution*. More specifically, ECT follows the remarks of Bruner (1996, p. 167): "[T]he psychology of the future must, virtually as a condition of its fruitful existence, keep its eye on both the biological and the cultural, and do so with proper regard for how these shaping forces interact in the local situation."

Organization of the book. The preceding sections have delineated the "one long argument" as detailing ECT's exposition of what exactly develops in TD (Chapter 2), how it develops (Chapter 3), the temporal unfolding of what and how TD takes place (Chapter 4), and specific social-historical conditions (the issue of where) that significantly constrain the issue of what, how, and when (Chapter 5). The "one long argument" culminates in formulating an integrated explanation of five levels of talent achievement as realized through evolving individuality and cultural niche constructions (Chapter 6).

For the rest of the book, Chapter 7 compares ECT with existing models and theories of TD. Chapter 8 spells out implications of ECT for assessing and guiding TD. Chapter 9 articulates implications of ECT for education and optimal human development. Chapter 10 takes a prospective look at how ECT entails a new epistemology of TD and human excellence. The book ends with an Epilogue on the future of TD and human excellence when AI is looming large on the horizon of human civilization, posing a potential threat to human excellence.