CHAPTER ONE

What Is Adolescence?

Learning Objectives

- What is adolescence?
- What is the history of adolescence?
- What are the current theories of adolescent brain development?
- What is the "function" of adolescence?
- A roadmap for using this book.

1.1 Introduction

Adolescence is an exciting time in life when individuals are more excitable, volatile, and exploratory than they will ever be. It is when children begin the long journey toward independence that is central to becoming well-adjusted adults. The term "adolescence" stems from the Latin *adolescere*, which means "to grow up" or "to grow to maturity" (Slee, Campbell, and Spears, 2012). Across the world and across different species, adolescence serves an important function: it is the time when individuals move from a state of dependence on caregivers to one of relative independence. This transition period lends itself to many changes that include physical growth and biological development, increasing cognitive sophistication, and changes in psychosocial skills. It is therefore no surprise that adolescents become more self-aware, capable of appreciating abstract concepts, interested in new ideas, and passionate leaders of causes they believe in.

Although adolescence has long been recognized as an important transitional period in our society, it has recently drawn more attention from policymakers and scholars. Adolescence is now a forefront topic of health reports (UN, 2011), advocacy documents (UN, 2012), and publications in academic journals. There is also worldwide attention to adolescents and their health, illustrated by several recent United Nations initiatives (Ki-moon, 2013). Together, this focus on adolescence has encouraged a lively discourse on how to treat, protect, and support youth. This book will focus on the role of brain and physical development on these important topics as they relate to adolescent well-being. We will also

explore how the advent of brain imaging tools gave us the ability to peek into the adolescent brain to determine how its development contributes to characteristic adolescent behaviors.

1.2 Periods of Development

Development is the study of change across the lifespan. Patterns of developmental change begin at conception and continue through until death. These include physical, neural, physiological, and behavioral changes that all occur in distinct ways depending on the period of development. Some of these changes are biologically driven, which means they are caused by genes or physiology, and some are environmentally driven, meaning they are influenced by things in the person's environment, including parents, siblings, peers, and neighborhoods; most changes are the product of the interactions between biology and environment.

Although developmental psychologists and developmental cognitive neuroscientists who study adolescence mainly focus on individuals who are adolescents, they appreciate that understanding the developmental periods that precede and follow adolescence is equally important. In general, there are three developmental periods: childhood, adolescence, and adulthood.

1.2.1 Childhood

Childhood is comprised of the prenatal period, infancy, early childhood, and late childhood. The **prenatal period** is the development that occurs from the point of conception until birth. In humans, this period lasts approximately 9 months and is a time of significant growth: the organism morphs from a single cell to one complete with all the organs it will ever have in its lifetime. During this time, there is complete dependence on the mother for nutrients. **Infancy** encompasses the period from birth through approximately 18 months of age. Many important psychological activities and much physical learning occur during this time and there is extreme dependence on adult caregivers. Infants engage in active sensorimotor coordination, gross motor skill learning (e.g. walking), language learning, and intense social engagement, particularly between parent and child. **Early childhood** is the developmental period that follows the end of infancy and extends through about 5–6 years of age (approximately when a child enrolls in kindergarten). During this time, there is a focus on becoming more self-sufficient, as children begin to spend many hours playing alone and with peers. It is also during this time that they begin

more complex language and reading skills. **Middle and late childhood** is the developmental period that extends from about kindergarten to right before adolescence (10 or 11 years of age). Significant academic learning occurs during this time, as children become more engaged in the fundamental skills of reading, writing, and arithmetic. Self-regulation of behavior increases during this time.

1.2.2 Adolescence

Given all the learning, skill emergence, and social interactions that occur prior to adolescence, childhood sets up adolescents with a rich developmental history. The combination of genetic background and childhood developmental history contributes to the course of adolescent development and associated brain development during this time. This is important to remember as we learn about the changes that occur during adolescence. Adolescent researchers face a daunting task in deciding how to define the "adolescent" group in their research studies. Most scientists have identified adolescence as "the gradual period of transition from childhood to adulthood" (Spear, 2000). Some neuroscience studies on human adolescents define adolescence by age, grade level, or pubertal status.

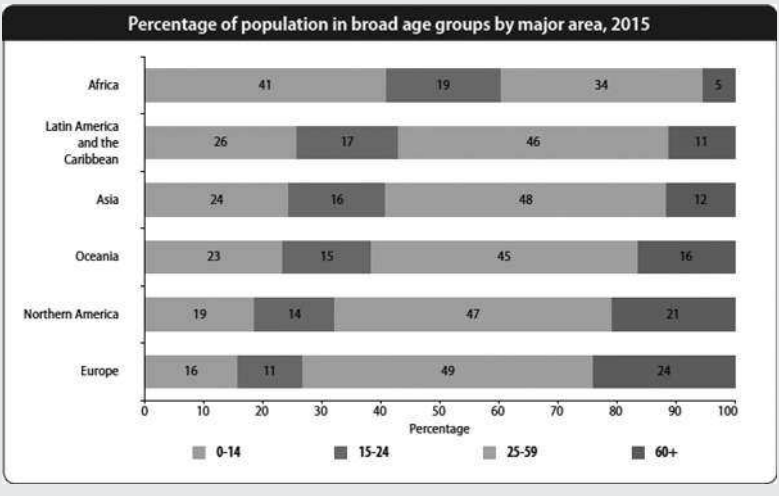
The exact timing of adolescence is not as clear-cut as that of childhood because its definition encompasses multiple factors, a topic we will return to later in this chapter. The age range of adolescence also varies with cultural and historical circumstances. In the United States, adolescence begins at approximately 11 to 13 years of age and ends in the late teenage years (approximately 18–19 years of age). **Early adolescence** typically encompasses the period from the middle school years and includes most of the pubertal development that characterizes the early part of adolescence (reviewed in greater detail in Chapter 2). **Late adolescence** refers approximately to the period after the majority of the pubertal transition. Significant psychosocial and cognitive changes occur during this time, including increases in orientation toward peers, romantic interests, and identity exploration, as well as more sophisticated cognitive abilities, including abstract thought, future planning and goal setting, and career exploration.

1.2.3 Adulthood

Similar to childhood and adolescence, adulthood is a heterogenous period of development that is not characterized by any one behavior or

Box 1.1 Adolescent Population Worldwide

- In 2015, the 3.1 billion people under the age of 25 represent about 42 percent of the world's total population.
- Africa, Asia and Latin America and the Caribbean are home to 90 percent of the world's young people: 1.7 billion youth aged 0–14 years old and 1.1 billion aged 15–24 years old.
- The number of young people are projected to grow to 3.4 billion by 2050.



Source: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects 2015 – Data Booklet (ST/ESA/SER.A/377)

developmental milestone. It is the period of development that spans the greatest number of years as it includes early, middle, and late adulthood. **Early adulthood** (sometimes referred to as emerging adulthood: Arnett, 2011) refers to the late adolescent years and early 20s and lasts through the mid-30s. This period of life is very important in establishing complete financial and personal independence and is often when individuals attend college away from home as well as focus on career development. There is also a high prevalence of marriage in the late 20s. **Middle adulthood** begins at approximately 35 to 40 years of age and ends at some point between approximately 55 and 65 years of age. This period is when most child-rearing occurs, as individuals in this age group tend to have children undergoing childhood or adolescence. **Late adulthood** is the

developmental period that lasts from approximately 65 years of age until death. In the United States, the average life expectancy is 77.4 and 82.2 for males and females, respectively.

1.3 Adolescence: A Historical Perspective

Behaviors that typically emerge during adolescence have been noted throughout history: Aristotle (384–322 BC) observed that "youth are heated by Nature as drunken man by wine." Socrates characterized youth as inclined to "contradict their parents" and "tyrannize their teachers" (attributed to Socrates by Plato, and cited in Lazarus, 1963). However, before 1904 adolescence was not recognized as a unique period of development. This may be hard to imagine today because teenagers, or adolescents, constitute such an important role in our society. G. Stanley Hall was a psychologist who is often credited with being the first to acknowledge adolescence as an important period of human development that he referred to as a period of "storm and stress" (1904). This phrase was taken from the German *Sturm und Drang* movement, and comprised three key aspects: conflict with parents, mood disruptions, and risky behavior. Hall noted that this is characteristic of most adolescents, biologically based, and influenced by culture (Arnett, 2011). Psychoanalytic theorists, especially Anna Freud (1946, 1958, 1968), strongly endorsed Hall's proposed model of adolescence and attributed these characteristic behaviors to the hormonal changes of puberty, believing that they introduced significant distress for the adolescent. Similarly, Sigmund Freud, and later his daughter Anna Freud, believed that the surge in hormones leads to psychological conflict in ways that affect adolescent behavior. Erik Erikson's theory was centered on the idea that pubertal changes, in conjunction with pressures from society, lead to an identity crisis that forces the adolescent to examine and define who she is.

In contrast, Margaret Mead (1928) and Ruth Benedict (1934) believed that adolescence is a culturally defined experience. They led fellow anthropologists in countering the universality of storm and stress in adolescence by drawing on multiple examples in non-Western cultures in which the characteristic adolescent behavior was not observed (Mead, 1928). They argued that, based on their treatment of young people, societies create their own culture surrounding the period of adolescence: societies that treat adolescence as a troubling period of life that must simply be tolerated until it passes experience stressful and tumultuous adolescent periods while societies that celebrate adolescence exhibit a relaxed and unflustered adolescent experience. Although most

contemporary adolescent theorists no longer attribute adolescent behavior to "storm and stress" they do acknowledge its relevance to understanding behavioral changes during adolescence.

1.4 Adolescence across the Globe and across Species

Adolescent-related behaviors are observed world-wide, across different cultures (Schlegel, 2001) and species (Spear, 2000). Rodents in the developmental period that is equivalent to human adolescence, immediately prior to and following sexual maturation, exhibit behavioral changes that are similar to those commonly observed in human adolescents. These behaviors include increased peer-directed social interactions (Douglas, Varlinskaya, and Spear, 2004), occasional increases in fighting with parents (Csikszentmihalyi, Larson, and Prescott, 1977), increases in novelty-seeking, sensation-seeking, and risk-taking (Laviola, Macri, Morley-Fletcher, and Adriani, 2003), increased consummatory behavior (Friemel, Spanagel, and Schneider, 2010), and greater per occasion alcohol use (Doremus-Fitzwater, Varlinskaya, and Spear, 2010). The increased proclivity toward drug use that is observed in human adolescents is also observed in adolescent rats (Brenhouse and Andersen, 2008; Torres, Tejeda, Natividad, and O'Dell, 2008) and nonhuman primates (Nelson et al., 2009). These data suggest that some of the characteristic adolescent behaviors observed in humans may be embedded in an evolutionary history that has adapted in ways to facilitate behaviors that are important in the developing organism. Indeed, rapid progress is being achieved across laboratories in studies with animals and with human adolescents showing that neural changes in systems that underlie motivational, affective, and behavioral regulation influence the processing of and responding to events in the environment in ways that bias behavior.

Across different cultures and societies, adolescence is recognized as a distinct developmental period in which children begin to transition into adulthood. This typically occurs by the adoption of increasingly "adult-like" behaviors such as getting married, moving away from the family, and/or bearing children. However, anthropologists note that the extent to which adolescence is acknowledged and the way each society characterizes the transition from childhood to adulthood varies greatly by culture. In some traditional societies public ceremonies are used to commemorate the transition from child to adult social status. In contrast, modern industrialized societies rarely publicly acknowledge adolescence, in part because there are several developmental milestones (that occur

at different ages) that are considered critical to the transition from child to adult, including completion of secondary schooling, age of legal status, getting a job, getting married, or becoming a parent.

1.5 Theoretical Models of Adolescent Brain Development

What is the general construction of the brain? Developmental psychologists and neuroscientists have pondered over this question for decades. Long gone are the outdated debates about "nature versus nurture," as we can now all agree that the brain is a product of both a genetic or biological outline and the environment. However, it is still fascinating that the brain gets constructed in ways that are both similar across humans (for instance, the general anatomy of the brain is similar across individuals) and yet different at the same time (everyone's brain processes information slightly differently). The developmental psychologist Esther Thelen devoted her career to addressing this question: How do we make more from something less? How does a walking and talking toddler emerge from a helpless infant? Read about her dynamic systems theory in Box 1.2.

What is the general construction of the adolescent brain? This section introduces the prevailing neurobiological models of adolescence. As with every period of development, applying theoretical perspectives to empirical research helps researchers gain a better understanding about the behaviors and changes often observed during adolescence. Although they differ slightly in their focus, these models tend to highlight the differences in maturation rates of brain systems implicated in emotion, social, and reward processing from those that are important for regulation of behavior. These different systems have sometimes been referred to as "hot" and "cold" systems, respectively. The hot system generally refers to regions that are responsive to affective events in the organism's environment, including fears, desires, pleasure, and reflexes. In contrast, the cold system generally refers to regions that are implicated in cognition and goal-planning, and are less engaged during emotional reactivity. Each of these models is illustrated in Figure 1.1 (Casey, 2015).

1.5.1 Dual Systems Model (Figure 1.1a)

Steinberg and colleagues (2008) describe adolescent behavior in the domains of sensation-seeking and risky decisions in terms of a dual

Box 1.2 Dynamic Systems Theory

Esther Thelen, a renowned developmental psychologist, viewed development as a change within a complex dynamic system. This framework posits that developing organisms are complex systems composed of very many individual elements embedded within, and open to, a complex environment that can exhibit coherent behavior (Smith and Thelen, 2003). For instance, applied to brain development specifically, this theory would suggest that the brain (the complex system) is composed of individual brain regions (individual elements) that can work together to produce an output. Furthermore, these regions (and thus the complex system overall) develop and change through a process called "self-organization" which refers to the changes that occur after repeated experience and because of organic, naturally occurring development. In this sense, brain development occurs both as an unfolding of normative development (informed by a genetic blueprint, as in the case of puberty) and because of the brain's response to the environment. Smith and Thelan go on to say that development, therefore, can be thought of as a "series of evolving and dissolving patterns of varying dynamic stability, rather than an inevitable march towards maturity." This is an important concept because it encompasses many of the themes we will review in this book: plasticity (the ability to change), normative biological development (puberty), evolving patterns (change based on the environment), dissolving patterns (pruning of neural connections that cease being useful), and maturity (and the challenge to define it). They provide an example that nicely illustrates this point: infant crawling. They write, "Crawling is a coherent behaviour that infants use to locomote when they have sufficient strength and coordination to assume a hands-and-knees posture, but are not balanced and strong enough to walk upright. Crawling is a stable behaviour for several months. But when infants learn to walk, the crawling pattern becomes destablilized by the patterns of standing and walking. There is no 'programme' for crawling assembled in the genes or wired in the nervous system. It self-organizes as a solution to a problem (move across the room), later to be replaced by a more efficient solution."

systems model. According to this model, risky decision-making in adolescence is the product of the interaction of two neurobiological systems: the socioemotional system, comprised of limbic regions including the amygdala, ventral striatum, orbitofrontal cortex, and medial prefrontal cortex, and the cognitive control system, comprised of the lateral prefrontal and parietal cortices. Around the time of puberty, the

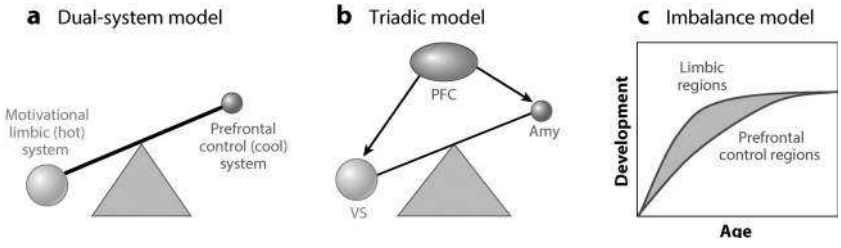


Figure 1.1 An illustration of the three prevailing models of adolescent behavior.

surge in dopaminergic activity within the socioemotional system leads to increases in sensation-seeking and risky decision-making, outpacing the development (and engagement of) the cognitive control system. This temporal gap leads to heightened vulnerability to these behaviors during adolescence (Steinberg, 2010).

1.5.2 Triadic Model (Figure 1.1b)

Ernst and colleagues (Ernst, Pine, and Hardin, 2006) proposed the *Triadic Model* of motivated behavior. This model attributes the determinants of motivated behavior to three functional neural systems, the prefrontal cortex, the striatum, and the amygdala, and focuses on how the maturational timing of each region contributes to age-related differences in motivated behavior as people mature (Ernst, 2014). The prefrontal cortex is implicated in the regulation aspect of motivated behavior. The striatum is implicated in the motivation aspects of the model and the amygdala is implicated in the emotion components of behavior. Together, these three nodes, and the constructs they are associated with, serve to coordinate the calculation of whether to approach (engage in) or avoid a particular behavior and the regulation of that calculation. This model has been used to describe typical adolescent behaviors, including cognitive impulsivity, risk-seeking, emotional intensity, and social orientation.

1.5.3 Imbalance Model (Figure 1.1c)

The imbalance model was developed by Casey and colleagues (Casey, Getz, and Galván, 2008). This model emerged from empirical studies that examined the developmental transition from childhood through adolescence and into adulthood and translation across species (nonhuman primate and rodent) (Casey, 2015). According to this model, developmental

changes in the neurochemical, structural, and functional composition of the brain proceed on distinct timelines, such that some brain regions exhibit the changes earlier in development than other brain regions. This leads to an imbalance of how these regions bias behavior because of differential engagement across different stages of development. For instance, it has been used to explain nonlinear changes in behavior during adolescence because regions implicated in reward (e.g. striatum) exhibit greater engagement, in terms of striatal activation and behavioral bias toward reward, relative to regions critical for behavioral regulation (e.g. prefrontal cortex). Importantly, unlike models that focus on specific brain regions, the Imbalance Model aims to attribute adolescent behavior to the coordinated integration of multiple brain circuits (Casey, Galván, and Somerville, 2015). This model focuses on the dynamic neurochemical, connectivity, and functional interactions across development in circuits that are essential for self-control.

1.5.4 Social Information Processing Model

This model, proposed by Nelson and colleagues, is similar to the other models of adolescent development (Nelson, Lieibenluft, McClure, and Pine, 2005). An added twist is that it describes risk-taking behavior in terms of an overactive affective node, including normative adolescent changes in the limbic system, due to a surge of gonadal hormone levels at puberty.

1.5.5 Fuzzy Trace Theory

Reyna and colleagues (Reyna and Farley, 2006) have applied fuzzy trace theory (FTT) as an explanatory framework for adolescent risk behavior. FTT posits that sophisticated "judgment and decision making is based on simple mental representations of choice ('fuzzy' memory traces) as opposed to more detailed, quantitative representations (verbatim memory traces)" (Rivers, Reyna, and Mills, 2008). According to FTT, decision-making becomes less computational and more intuitive as development proceeds. Earlier in development (in adolescence) risky decision-making involves precise calculations (e.g. does the exact amount of fun or money I will gain outweigh the exact amount of risk involved in achieving the fun or money?) whereas adults shift to a "fuzzier" calculation that simply ranks the options (e.g. ranking the potential rewards against the risk involved to get the reward). Fuzzy trace theory has been used to explain a myriad of real-world adolescent decision-making.