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The Tinderbox in the Teenage Brain

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Teenagers write immortal poetry; crusade to overthrow dictatorships; volunteer for suicide bombings; drive (or take drugs or have sex) as though they were invincible; think the unthinkable in science and philosophy; join cults; and dedicate their lives to peace, monastic contemplation, or the eradication of poverty. They are successively inspired, alienated, infuriated, devastated, impassioned, and inconsolably bored. To begin to comprehend how so much vulnerability and potential can coexist in one brief interval of life, writes Ronald Dahl, M.D., we must look beyond the intensity of the passions and craving for excitement that characterize so many adolescents. What is neuroscience discovering about the adolescent's brain and emotions, the several sets of hormonal changes that come with puberty, and the vexed social role of those who are neither children nor adults?

In adolescence, physical health is approaching its peak. Adolescents are not only bigger and stronger than children, but also show developmental increases in a wide range of

mental and physical abilities, including reaction time, reasoning skills, problem solving, immune function, and capacity to cope with many kinds of stresses and challenges. Yet, during this period of resilient health, burgeoning energy, and new-found capabilities, we witness a dramatic increase in death and disability: soaring rates of serious accidents, suicide, homicide, aggression and violence, use of alcohol and illegal drugs, emotional disorders, and health consequences of risky sexual behavior. Behind this paradox lies the complex story of adolescent development. This story is not comprehensible simply in terms of old ideas about the "raging hormones" of puberty. To understand it, we must consider the maturing adolescent brain, as well as the impact of social context and experience on the development of biological systems.

Adolescence, the interval between the onset of sexual maturation and the attainment of adulthood, is a time of dramatic changes. The long-held idea that human brain development is virtually complete within the first few years of life is a serious misconception. Many aspects of brain maturation continue throughout childhood and well into the late teenage years.[1] Neural systems continue to exhibit a natural plasticity or capacity to be molded and sculpted by the individual's experiences. In particular, systems involved in emotion and motivation appear to undergo significant changes during adolescence.

One important aspect of adolescent emotional development, all too familiar to parents, teachers, and others who have to deal regularly with teenagers, is a natural proclivity toward high-intensity feelings. This is not simply a matter of brooding and moodiness, which tend to emerge at puberty. It appears that new activation patterns for some emotional states—feelings that are triggered more quickly or with greater intensity—are linked to biological changes occurring with puberty.

In one experiment, for example, investigators observed parent-child interactions during a structured discussion of a contentious topic and examined the behavioral and emotional responses of young adolescents who were about the same age but differed in their level of pubertal maturation. They discovered that pubertal maturation was not associated with a greater likelihood of conflict, but it was linked to the intensity of anger expressed by the youth in response to conflicts. In other words, a prepubertal 13-year-old boy was just as likely to become argumentative with his parents as a 13-year-old with a brain awash in pubertal hormones, but the latter was more likely to show a rapid escalation of anger in this situation.

Adolescents like intensity, excitement, and arousal. They are drawn to music videos that bombard the senses, flock to horror and slasher movies, and dominate queues for the high-adrenaline rides at amusement parks. Sex, drugs, very loud music, and other high-stimulation experiences take on great appeal. An appetite for adventure, a predilection for risks, and a desire for novelty and thrills seem to reach naturally high levels in adolescence. This greater inclination to seek experiences that create high-intensity feelings is borne out by research. For example, studies of sensation seeking—a measure of how much an individual wants to experience risks, thrills, excitement, and intensity—reveal a developmental increase that is specifically linked to puberty.

Although these patterns of emotional changes at puberty are evident in most adolescents to some degree, individual differences range widely. For some adolescents, the tendency to activate strong emotions and an affinity for excitement can be subtle and easily managed. In other adolescents, these inclinations can lead to charged and reckless

behaviors and, at times, to impulsive decisions by seemingly intelligent youth that are completely outrageous.

The tragic consequences of such adolescent inclinations are duly recorded in the statistics on adolescent death and disability. These statistics are reason enough to investigate the maturational changes in brain systems underlying emotional and motivational changes at puberty. A brief vignette to illustrate the emotional intensity that can be ignited at this point in development will help to highlight some key issues.

A NATURAL TINDERBOX FOR IGNITING PASSIONS

A young guy scanning the crowd at a party notices a girl who he finds strikingly attractive. Immediately smitten, he approaches her and launches a shower of compliments. She tries to rebuff his flattery but finds something about the young man quite appealing. Romantic feelings kindle quickly. As he departs, with a kiss followed by a second kiss, emotions are flaring.

On the basis of one brief meeting, a conversation of less than a hundred words, and two kisses, the emotional lives of two adolescents have been turned upside down. Each cannot stop thinking about the other and is obsessed with a desire to meet again. They manage a clandestine late-night rendezvous. Passionate feelings now accelerate at a feverish pitch. Their motivation to be together quickly rises above all competing priorities. They are willing to spurn friends and family, disregard dangers, ignore pain, and begin to act as if being together is more important than life itself—even though they just met four days before and barely know each other.

If evaluated by a psychiatrist who did not understand youthful passions, these two could easily be judged as meeting diagnostic criteria for serious mental disorders or cognitive impairments. Previously learned abilities to think logically and behave rationally seem to have evaporated in a matter of hours. When viewed with a sense of emotional detachment—without some feeling for the heat and power of young love—this scenario of adolescent behavior would appear simply ludicrous.

Yet the story of *Romeo and Juliet* has moved audiences to tears for centuries. It has evoked sympathetic responses through many translations, across many cultures, because of a nearly universal human appreciation for the emotional intensity—and potential for tragedy—of rapidly igniting adolescent passions. It is interesting to reflect on Juliet's age. In an early version of the story penned in 1535 by Luigi da Porto (who first placed the scene in Verona and named the feuding families Montecchi and Capellati), Juliet (Giuletta) was 18 years old and the courtship developed over a few weeks. In 1595, though, Shakespeare portrayed the events in a more dramatic fashion. He made Juliet 13 years old and compressed the action into four days.

One can only speculate why Shakespeare created so young a heroine for his romantic tragedy. It seems likely, however, he was intentionally juxtaposing adultlike passions with the naïveté of a very young teenager because he believed this contributed to a more effective drama. Perhaps he had noted what many have observed about early adolescence, that it seems to create a natural tinderbox for igniting passions.

Clearly, some aspects of these emotional changes in adolescence have been well recognized for many centuries. Over the past half century, developmental psychology has added much to the empirical basis of our knowledge of adolescent cognitive and emotional development. But the tools of modern neuroscience are creating a still deeper

understanding, contributing a framework of knowledge about adolescent brain development that generates new insights into the roots of emotional changes that emerge at puberty. This work is also beginning to illuminate the role of strong emotions in the difficulties that many adolescents experience with real-life decision making—the tendency for intelligent youth to act impulsively, even recklessly, under the influence of strong emotions.

BEYOND "RAGING HORMONES"

Early efforts to understand the tumultuous emotional changes at adolescence focused on the storm of hormones flooding the body during puberty. No clear picture emerged. These studies did suggest some connection between rapid increases in blood levels of the primary sex hormones (estrogen and testosterone) and some emotional and motivational changes in adolescence. But the links between hormone levels and measures of adolescent behavior were often weak—sometimes difficult to detect at all.

It appears that the direct effects of hormones on most measures of emotion and behavior are probably quite small. Certainly, high levels of sex hormones are not the cause of emotional problems in adolescents; many adolescents with peak hormone levels experience no emotional difficulties at all. The interactions among rising levels of hormones, brain development, and emotional changes in adolescence produce a far more complex set of relationships.[2]

To begin, it is essential to realize that puberty itself is a process with multiple components, including maturational changes in at least three different hormone systems. The first system involves a cascade of hormones that activates the gonads (ovaries and testes) to mature and begin to produce high levels of estrogen and testosterone. This process is called "gonadarche," the endocrine events that result in reproductive capability and fertility.

A second set of hormonal changes is called "adrenarche." The main action here centers on the release of testosterone-like hormones from the outer part of the adrenal glands, which sit atop the kidneys. These adrenal hormone levels usually begin to rise by 6 to 9 years of age (typically before gonadarche) and steadily increase for more than a decade, peaking in the early 20s. This hormonal system contributes to adolescent changes in skin (including acne), as well as the development of pubic and underarm hair.

A third group of changes involves growth hormone (GH), which is released in pulses from the pituitary gland, near the base of the brain. The rate and patterns of GH secretion undergo changes during puberty in ways that contribute significantly to the rapid physical growth in adolescence.

Puberty also brings changes in other hormone systems. For example, the regulation of cortisol, a major stress hormone, undergoes modifications during puberty. Researchers have also become interested in adolescent changes in oxytocin, a hormone that has been associated with both pair-bonding and parental behaviors in animals.

So puberty is not a singular process that can be tracked through one hormonal system. It involves a suite of changes whose various components are loosely synchronized. The relative timing—the relationship between adrenarche, gonadarche, GH changes, and other aspects of puberty—varies among individuals. Thus, measuring the level of a particular hormone in the blood or saliva will only provide a glimpse into one component within this suite of maturational changes.

Moreover, the pattern of hormone release within a system can be more important than the total amount secreted. The sequence and timing of hormone surges are sometimes a fundamental part of the physiological signal being transmitted by the neuroendocrine system. For example, a crucial step in the onset of gonadarche requires pulses of gonadatrophin-releasing hormone (GnRH) to be released in bursts every 60 to 90 minutes from an area of the brain called the hypothalamus. This specific frequency is a signal that begins a cascade of changes in the body, causing the pituitary gland to secrete additional hormones in a pattern that then creates activation and maturation in the testes or ovaries. Interestingly, in contrast to this amplification effect from small well-timed pulses of this hormone, high sustained levels of GnRH will actually inhibit pubertal development of the gonads.

It should not be surprising that many early studies failed to find direct relationships between the level of a particular hormone and the emotional changes in adolescence. Hormones are primarily involved in the regulation of physiological systems in the body. Understanding maturational changes in emotion, motivation, and behavior requires investigation of adolescent brain development.

FROM THE BRAIN TO HORMONES TO THE BRAIN

At least one group of maturational brain changes in adolescence is upstream from the bodily changes of puberty. The cascade of pulsing hormones that create the physical changes of puberty begins in the brain. This means that some neural alterations must be occurring well before any increases in blood levels of hormones. Pubertal hormones are not causing these brain changes, brain maturation is causing the hormonal increases.

Once the hormones begin surging through the blood, however, they can be carried back to the brain where they may exert downstream effects. Yet only some of these hormones cross the blood-brain barrier into the cerebrospinal fluid and so can reach neural systems. Moreover, these hormones can affect only brain cells that have specific receptors to bind to them.

Early neuroendocrine research seemed to indicate that only a few brain areas had receptors for gonadal hormones. More recently, however, scientists have discovered additional types of receptors (such as estrogen receptor beta), which are distributed widely across several brain regions and appear to underpin the effects of some gonadal hormones on higher cognitive functions, mood, and other brain functions.[3] As a result of advances in understanding specific mechanisms of action, scientists are beginning to shed light on some downstream effects—how a particular hormone released into the blood at puberty can have a specific effect on a particular group of neurons in the brain. For example, serotonin neurons in the dorsal raphe of the brain have estrogen receptors. Researchers have also found evidence that rising levels of these hormones (as occurs at puberty) have a direct effect on the regulation of the neurotransmitter serotonin, which is important in the regulation of mood and arousal. Given the strong links between serotonin regulation and depression, including the effectiveness of medications that selectively inhibit serotonin reuptake in the brain (SSRIs)—and the increase in depression that is most striking in girls at puberty—there is a great deal of interest in understanding these hormonal effects.

Research of this kind is consistent with the idea that at least some of the "downstream" hormonal effects on the adolescent brain occur through interactions

involving multiple interconnected neural systems. A rise in a particular hormone may simply alter the balance in a complex system, making certain behavioral or emotional tendencies more likely to emerge. To return to the example of beta-estrogen effects on serotonin regulation, any pubertal changes would also likely intereact with underlying genetic differences in serotonin systems that influence emotional reactivity.[4]

SLEEP PATTERNS: SIX HOURS OF JET LAG

So what is the effect of increased hormone binding to a particular neural system like serotonin regulation? The narrow biological effect varies considerably. For some individuals, in some environments, a small biological shift in a behavioral or motivational tendency at puberty can spiral into a dramatic set of changes. This concept is so crucial in understanding the huge differences in individual behavior in adolescence that it is worth exploring a specific example at length. It is one with which the parents of adolescents will identify (to say the least). Recent scientific studies of adolescent sleep patterns give us a fairly good picture of how biology interacts with environment to generate behavior changes that have confounded generations of parents.

Although the precise mechanism is not completely worked out, it is now clear that puberty is associated with a biologically based shift in sleep tendencies. In some ways, this biologic shift is subtle. It can be demonstrated experimentally by controlling all aspects of adolescent behavior and environment, including bedtime, activities, and exposure to light, and measuring the puberty-linked delay in the timing of the nocturnal rise in the hormone melatonin.[5] This hormonal change manifests behaviorally as a preference for going to sleep at a later phase in the 24-hour cycle. In other words, adolescents have a natural tendency to become a bit more like night owls, going to bed later and sleeping longer in the morning, with less of the larklike tendency to wake up early that is common in children before puberty.

This biologic shift in sleep preference does not initially force adolescents to stay up later at night; it simply increases the likelihood that they will choose to delay bedtimes when they have the opportunity. However, this behavioral tendency can lead to major changes in sleep patterns, and, once established, these new sleep patterns can be extremely difficult to reverse.

The situation is a bit like traveling steadily west through several times zones. The body’s circadian clock system adjusts easily to later sleep schedules, not so easily to earlier ones. Once set to the later phase—such as a teenager drifting into a summer schedule of sleeping from 3 a.m. until noon—the shift back to an earlier schedule —needing to get up at 6 a.m. for high school—is like the six hours of jet lag you suffer when flying from New York to Paris.

Interestingly, a second set of maturational changes in sleep regulation occurs at puberty. The physiological need for sleep appears to increase during this dynamic period of growth and development. This need can be seen typically emerging in early to midpuberty as an increase in overall sleepiness.

These two pubertal sleep changes—one tending toward later sleep times and the other an increase in overall sleepiness—collide at bedtime. For an adolescent living 150 years ago in a rural environment without electricity and with the habit of rising at dawn to work on the farm, these pubertal changes in sleep might have very little effect on behavior. When lying down in a dark room after a hard day of physical work, the feeling

of sleepiness will likely win out over the slight biologic shift toward wanting to stay up later. Reading by candlelight is not highly arousing when one is quite tired. Moreover, even if this 19th century teenager stayed up very late on a particular night, it is unlikely this one event would lead to a pattern of changes that gradually drift the equivalent of several times zones.

In contrast, the competing influences between these two pubertal sleep inclinations can be quite different in modern life. Nighttime exposure to bright artificial light (which has a direct influence on the circadian clock) combined with access to highly arousing activities can easily tip the balance at bedtime. Even if an adolescent is physiologically sleepy, he may not notice his tiredness. He may be watching exciting programs on TV or video, talking to friends on the phone, listening to loud music, choosing from among millions of interesting sites on the Internet, or interacting with peers through "instant messaging" on the computer—and, in some cases, several of these activities at the same time.

So now the pubertal inclination to delay bedtime frequently wins out over the sleepiness. However, in the morning these two systems converge rather than compete—both the phase-delay and sleepiness promote the tendency to sleep in as late as possible. Gradually, this convergence can spiral into changing patterns of behavior that cause the circadian systems to settle into very delayed timing. After much of the summer on a 3 a.m. to noon sleep schedule, on the first day back at school the adolescent faces an abrupt challenge to the sleep system. Now, even if he tries to go to bed at 10 p.m., he may have an extremely difficult time going to sleep. His body—including levels of hormone secretion, core body temperature, and some brain circuits associated with arousal—have adapted to the late night schedule. He faces a situation like that of a shift worker who regularly sleeps from 11 p.m. to 7 a.m. but must try to shift her sleep from 6 p.m. to 2 a.m.

If the adolescent manages to fall asleep "early," by 1 a.m., it is still a bit of a shock to the system when a parent tries to wake him at 6 a.m. for school. This pattern may continue for the rest of the week, with a motivated adolescent being able to struggle through the day on 5 to 6 hours of sleep. However, just at the point that his biological clock is beginning to make the adjustment to the earlier sleep schedule, the weekend rolls around. On Friday night at 10 p.m., the opportunity (and motivation) to stay up can be quite powerful, and in many cases bedtime reverts quickly to the late schedule. Now, however, with the added debt of sleep deprivation from the previous week, sleeping-in on Saturday morning might go very late. Saturday night and Sunday morning are likely to repeat (or further amplify) this pattern, and by Sunday night, the adolescent is back where he started—unable to go to sleep until well after midnight and in a painful struggle to wake up at 6 a.m. on Monday morning.

Many of the "coping" behaviors for chronic sleep deprivation—such as the use of caffeine, nicotine, and other stimulants, or sleeping during the day—can have additional negative consequences. Moreover, when the problem becomes very severe, adolescents begin to oversleep on weekday mornings and are often late for school or fall asleep during early classes. This pattern of behavior can lead to a vicious cycle in adolescents, with severe chronic sleep deprivation and very late as well as erratic sleep patterns. Moreover, sleep deprivation can also contribute to other difficulties, such as irritability and difficulty with focused attention, further amplifying the problems.

I have dwelt on this example of pubertal changes in the sleep system because it illustrates an important principle. A slight shift in a motivational tendency, which is linked to a biological component of pubertal maturation, can—in some individuals, in some environments—end up in major problems.

THE THINKING/PLANNING BRAIN AND THE EMOTIONAL BRAIN PART WAYS

In the realms of emotional intensity, sleep and arousal, and the drive to seek stimulation, we observe the striking direct influence of puberty on neural systems. If these were all the changes, adolescent development would still be complex, but perhaps it would not be quite the interval of conflict—of bewildering disparities between knowing and feeling, understanding and behaving—that we so often witness. To understand how adolescence, at times, can seem to combine the worst aspects of adulthood and childhood—confronting us with big, strong, intelligent people who may sometimes act like two-year-olds—we must consider some very different aspects of adolescent brain development: the maturation of neural systems involved in the intricate control of behavior through thinking, planning, reasoning, and rationally weighing the long-term consequences of one's actions.

Some changes in the maturing adolescent brain are completely independent of puberty (or its timing). This association is readily apparent to clinicians who work with adolescents who have an endocrine disorder in which puberty is severely delayed or completely absent. In these patients, cognitive development proceeds in a relatively normal pattern; overall intelligence, reasoning abilities, and most mental skills develop quite normally despite the absence of pubertal hormones. Well-controlled animal studies demonstrate that some brain systems seem to develop entirely as a function of age or experience in adolescence and are not influenced by if, when, or how long the brain is exposed to pubertal hormones. In particular, crucial aspects of cognitive development (such as the ability to reason, plan, and understand long-term consequences) seem to follow a trajectory relatively independent of puberty and continue to show some refinements long after puberty is over.[6]

This juxtaposition of aspects of cognitive development with puberty-linked developmental changes in emotion and motivation raises provocative questions about recent historical changes in the timing of puberty. Biological anthropologist Carol M. Worthman, Ph.D., writes, "The past 150 years have witnessed a quiet revolution that still sweeps across the globe today: children nearly everywhere are growing faster, reaching reproductive and physical maturity at earlier ages, and achieving larger adult sizes than perhaps ever in human history." Over this period, but especially the past century, the earlier onset of sexual maturation, particularly in girls, appears to have influenced the timing of some aspects of brain maturation, whereas other dimensions of development still proceed gradually and continue long after puberty.

We have made the point that changes in adolescent brain systems that are specifically linked to puberty have their primary effects on motivation and emotion. These changes manifest as mood swings, increased conflict with parents, a greater tendency for risk taking and rule breaking, an increased draw toward novel experiences and strong sensations, alterations in sleep/arousal regulation, and an increased risk of emotional disorders (particularly depression in adolescent girls). Last, but certainly not

least, are the alterations in romantic and sexual interests, which are also more closely linked to puberty than to age.

In contrast, the cognitive development that is necessary for the reliable control of behavior occurs primarily as a function of age and experience and continues long after puberty ends. Moreover, some aspects of cognitive control appear to mature very late in adolescence. One interesting example of this control comes from studies in the development of control over eye movements. It is a particularly clear example because the specific neural systems involved have been mapped and are amenable to careful developmental studies.

In brief, certain aspects of controlling eye-movement develop very early in childhood. In some simple visual tasks, such as looking at a flashing point of light, children can control eye movements with adultlike precision and accuracy. However, in a complex task—such as having to direct one's gaze in the direction exactly opposite from the point of light, children have difficulties suppressing the natural tendency to look toward the light. Even adolescents do not show adult patterns of brain activation on fMRI (functional magnetic resonance imaging) studies done in conjunction with these tasks;[7] adult levels of performance are not reached until the late teenage years.

The larger point that is illustrated here is that different aspects of maturation progress at different rates during adolescence. These aspects include changes in height, weight, muscle mass, body proportions, levels of sexual maturation, brain development, and levels of emotional skills, as well as different components of cognitive development such as abilities to think, reason, plan, strategize, understand consequences, and control behavior in precise or reliable ways. Moreover, each of these dimensions of development can proceed at different rates in different adolescents. Earlier timing of puberty, as we are observing now, activates more rapid development in only some of these dimensions. Accelerating the intensity of some emotional and motivational tendencies at an earlier point in cognitive development and experience may create a situation that is, metaphorically, like revving the engine without a skilled driver.

WHEN HAVE THEY GROWN UP?

What developmental yardsticks should we use to define adolescence? This question becomes far more than theoretical when we must make decisions about social roles. Children, by definition, require monitoring by a parent or guardian. Becoming an adult means taking responsibility for one's own behavior. But adolescence is the awkward transition between the roles of child and adult. Adolescents gradually develop the skills required to manage adult freedoms, and, as they acquire the mental and emotional abilities to take responsibility for their own actions, their need for monitoring by parents or other adults diminishes. The uncertainties that can result are a favorite topic of the high school editorialist, who plays on the paradox of a society that recruits soldiers at age 18 but will not serve them a beer at a bar.

There are no tidy answers. As we have seen, interposed with the adolescent's gradual acquisition of skills and entry into new social roles are those dramatic biological changes that occur at puberty. These biological changes can begin quite early—well before the teenage years. Many children start to show a rise in pubertal hormones (and the beginnings of bodily changes) between 9 and 11 years of age. Yet other dimensions of adolescent development—including some aspects of brain development and the

maturation of judgment and other skills needed for responsible adult behavior—continue to change and mature after age 18.

Recently, the boundaries of the adolescent period have become increasingly blurry at both ends, exacerbating the challenges of an inherently difficult time. Earlier in human history, a specific event, initiation ceremony, or ritual would often mark a definitive change in social roles. In contemporary society, though, the end of childhood can be more ambiguous. At the same time the physical changes of puberty have been occurring at earlier and earlier ages, the process of preparing for and taking on adult roles has in many cases become more complicated and prolonged.

Although one can always split hairs about definitions and methods of classification, the root question here is more fundamental: How should we conceptualize adolescence if different dimensions of development—hormonal and neural—are proceeding at different rates in various individuals? Given such complexity and ambiguity, what principle should be used to make pragmatic decisions about the categories of childhood, adolescence, and adulthood? These issues are not simply fodder for intellectual debates among scientists who study development; a multitude of laws and policies in the United States (as in most industrialized nations) designate a specific birthday as marking the boundaries of freedom and responsibility.

Legislators, judges, and juries are frequently faced with the need to make, modify, or interpret laws about when a developing child should be able to make (and be held accountable for) his or her own decisions. These laws determine at what age an adolescent can quit school, buy cigarettes, get tattoos or body piercing without parental consent, have sex legally, have an abortion without parental consent, appear in a pornographic film, drink alcohol, drive a car, own guns, join the armed services, and vote for the individuals who make the laws.

These laws and policies—along with the attitudes of parents, teachers, coaches, and community leaders about when adolescents should be granted freedoms and responsibilities—have enormous influence on the lives of youth. They also provide a critical framework for considering the health risks that arise for adolescents. Addressing both of these issues becomes even more crucial in light of the inclination toward high-intensity feelings that emerges during puberty.

WHAT WILL THE PASSIONS SERVE?

The natural inclination toward novelty, arousal, and excitement that seems to emerge in association with puberty creates a period of increased vulnerability in many young lives. Teenagers are often willing to navigate great risks to achieve the high-intensity feelings that can be so appealing to them. It is as if puberty increases the appetite for a specific type of emotional experience, desire for surges of arousal, craving for exhilaration, and an appetite for a feeling that tends to move behavior in the direction of seeking more arousal, more stimulation—a natural desire to go faster and farther.

Fortunately, these emotional and motivational changes at puberty do not lead solely to bad outcomes. Sex, drugs, loud music, and reckless behavior are not the only ways to activate high-intensity feelings; effortful struggles to achieve challenging and heartfelt goals can also create them. The igniting passions can be aligned in healthy ways, in the service of a higher good. Feelings of passion have primal roots in the same deep brain systems as biologic drives and primitive elements of emotion. Yet, passion

intertwines with the highest levels of human endeavor: Passion for ideas and ideals. Passion for beauty. Passion to create music or art. Passion to succeed in a sport, business, or politics. Passion toward that one person, activity, object, or pursuit that inspires transcendent feelings.

One of the most important questions facing parents, teachers, clinicians treating adolescents, and political leaders is how to capture adolescent passions in modern society. How are these new and intense motivational systems in the adolescent brain being sculpted in ways that are healthy, or unhealthy? For example, the emergence of religious zeal in adolescents can fuel positive humanistic efforts to feed the poor and care for the sick; yet, it can also lead to dogmatic attitudes, intolerance, or even horrific terrorist actions. Igniting passions can lead to idealistic pursuits by youth who strive to make the world a better place by addressing global issues of great importance. Yet these same tendencies make youth vulnerable to the influence of leaders like Hitler or Bin Laden, who inspire a very different kind of passion.

These questions about emotional and motivational changes in adolescence have profound implications for our future. They are a compelling reason that continuing scientific research is needed to help us understand maturational processes—and to provide our society with further insights into the kinds of experiences that can help to shape these igniting passions in ways that serve larger humanistic goals.

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