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Are Adolescents the Victims of Raging Hormones: Evidence for Activational Effects of Hormones on Moods and Behavior at Adolescence

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The literatures on hormone changes at adolescence, hormonal influences on moods and behavior in nonhuman animals and adult humans, and mood and behavioral changes at adolescence and the small but burgeoning literature on hormonal influences at adolescence are examined. The focus is on moods and behaviors often identified as typically adolescent (e.g., mood lability, mood intensity, irritability, conflict with parents) and the primary hormones of puberty (i.e., the adrenal androgens, gonadotropins, and sex steroids). Through an integration of these literatures evidence is assessed for specific hormone–mood and hormone–behavior associations, as well as for more general types of hormone–outcome relations that transcend specific hormones or outcomes. Nonbiological factors that appear to be important in moderating the role of hormones in adolescent moods and behavior are identified. Implications for the design of future studies in this area are detailed.

The adolescent period in most Western cultures is marked by change. Internal physiological changes spark outward morphological changes; school environments often change; expectations of parents, peers, and self also change. Alterations of mood, attitudes, and behavior are believed to occur as well. Historically, most of the changes in mood and behavior were presumed to be negative and to be the result of biological factors, particularly of hormones (e.g., Blos, 1965; A. Freud, 1969; S. Freud, 1905/1953; Hall, 1904; Kestenberg, 1967a, 1967b). More recently, psychologists have questioned both the prevalence of such negative changes and their hypothesized biological roots (e.g., Coe, Hayashi, & Levine, 1988; Offer, 1969; Offer & Offer, 1975; Rutter, Graham, Chadwick, & Yule, 1976). Emphasis has shifted to contextual (i.e., family, school, peer group) and psychological (i.e., self-esteem, gender role orientation) factors as determinants of adjustment in adolescence, as well as to the interaction of these factors with biological characteristics, particularly outward pubertal changes.

Despite the shift away from "storm and stress" conceptualizations of adolescence and despite the mounting evidence that biological changes interact with and can be overridden by contextual and psychological factors in affecting behavior, traditional assumptions and stereotypes about adolescence persist in the media (e.g., "Teen Rage," 1987), in popular literature (e.g., Bell, 1987), in policy reports (e.g., New York State Department of Education, 1987), and even in scientific writing (e.g., Finkelstein, 1980). For example, in one self-help book, adolescents are told: "You may feel full of energy or lie around and sleep a lot. Your moods may shift quickly, uncontrollably, surprising you. There are reasons for these changes" (Bell, 1987, p. 5). The discussion then moves on to the pubertal and hormonal changes of adolescence. Can these two views be reconciled?

It is true that the recent shift in scholarly thinking rests on a limited research base. Although many studies have indicated that adolescence is not necessarily a time of storm and stress, very little research has assessed the developmental patterns in the affective and attitudinal characteristics often associated with the adolescent period (e.g., moodiness, shifts in energy, irritability, restlessness) or linked these patterns to the hormonal changes of puberty, particularly in normal children, until quite recently.

Our goal in this article is to generate and evaluate hypotheses regarding hormone–behavior relations at adolescence. To do this, we integrate several research fields. First, we present theoretical views of the possible hormone–behavior links. Second, we describe the hormonal changes of this developmental period. Third, we summarize evidence for hormone–behavior relations from research on both animals and adult humans and use this evidence to generate hypotheses about associations that might exist during adolescence. Finally, we integrate available information on affective and behavioral changes during adolescence—to evaluate the evidence that behaviors potentially associated with hormones actually do change during this time—with data from those few studies that have assessed hormone–behavior relations among adolescents. Although the research base in some of these areas—particularly for hormone–behavior relations at adolescence—is still relatively new, enough work

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has been done to warrant an attempt at integration, so that concrete recommendations can be made to guide future research.

Throughout, we focus on (a) moods and behaviors most likely to be tied to hormones and (b) moods and behaviors typically believed to change during the adolescent period. We have limited the scope of our review by omitting sexual moods and behaviors.[1] Although we draw on knowledge that spans the adolescent years (roughly age 9 to 18), we focus primarily on the pre- to early adolescent period (approximately age 9 to 14) for several reasons. First, the biological changes of puberty are likely to be especially salient in the pre- and early pubertal years because this is when they begin and because later in adolescence biological changes are likely to be overshadowed by other issues (e.g., peers, dating, career goals). Second, evidence points to early adolescence as a critical time in terms of the emergence and development of emotional, psychological, and behavioral problems (e.g., Hamburg, 1974; Offer, 1969). Last, because many hormonal changes begin in advance of the outward physical changes with which they are associated, the pre- and early adolescent years constitute a time period in which the independent effects of hormones on behavior, apart from resulting morphological changes, can potentially be studied.

Theoretical Views of Hormonal and Behavioral Change at Adolescence

A Psychological View: The Psychoanalytic Approach to Adolescence

Historically, psychoanalytic theorists have been the major proponents of the storm and stress view and its link to internal, physiological, drives during adolescence (e.g., A. Freud, 1969; Friedman, 1975; Jacobson, 1961). Hormones were believed to reawaken latent oedipal feelings and to stimulate new sexual urges (Kestenberg, 1967a, 1967b; H. Lerner, 1987). These feelings were assumed to create anxiety and psychological instability because (a) sexual feelings were morally unacceptable and needed to be sublimated or channeled into a more acceptable outlet, often leading to aggression, and (b) sexual urges were unfamiliar impulses that the adolescent did not have the knowledge or experience to handle (Blos, 1965; Jacobson, 1961). Numerous behavioral consequences were predicted to result from this instability. For example, swings between rebelliousness and depression, between sexual or aggressive acting out and strict morality, general defiance, aggressiveness, argumentativeness, unpredictable behavior, confusion, withdrawal from parents, self-consciousness, lack of concentration, daydreaming, and a dramatic flux of identifications, aspirations, and self-esteem were all said to result from the psychic reorganization prompted by the upsurge in sexual instincts (e.g., A. Freud, 1966; Geleerd, 1961; Jacobson, 1961; Kestenberg, 1967b; Spiegel, 1961). The form this expression of instincts would take depended on individual and contextual factors (Douvan & Adelson, 1966; A. Freud, 1966), so that one adolescent might eat compulsively, another diet; one might be defiant, another compliant. In addition, one child might respond in varying ways at different times.

Out of classic psychoanalytic drive theories have come models of adolescent development that still consider biological changes important, although not in the unidimensional and inevitable way that they were considered originally (H. Lerner, 1987). It is now acknowledged that many adolescents do not experience extreme turmoil (e.g., Douvan & Adelson, 1966; Offer, 1969) but not because the stress of biological change is minimal. Instead, "most adolescents bring to bear a system of defense and coping skills that enable them to successfully negotiate these stresses" (H. Lerner, 1987, p. 67). Thus, modern psychoanalytic literature still suggests that the adolescent period is a time of internal flux and instability that is likely to be reflected in the behavior of many adolescents but adds that adolescents with healthy egos can adapt to these changes without extreme or even observable signs of stress.

A Physiological View: Possible Mechanisms of Hormone–Behavior Changes at Adolescence

From a physiological standpoint, hormones act on the brain to affect behavior in two basic ways. (a) *Organizational effects:* Sex hormones can influence personality and behavior through direct effects on the course of early brain development. These effects are permanent and do not depend on subsequent hormonal actions. (b) *Activational effects:* Hormones may activate specific behaviors through their contemporaneous impact on both peripheral and neural-based processes. These effects tend to be immediate or slightly delayed. Some activational effects are dependent on earlier organizational effects of hormones on brain development. Behaviors in which there are sex differences in the activational effects of hormones often fall into this category. This review focuses on activational effects only.[2]

Beach (1975) summarized several general mechanisms of activational hormone–behavior relations that both co-occur and interact with each other. We draw heavily on his categorizations here. First, hormone concentrations can alter discrete structures necessary for carrying out particular behaviors. For example, during the breeding season, hormones stimulate an increase in the size of the laryngeal apparatus of male frogs and toads, allowing them to perform the sex call necessary to attract females (Beach, 1975). During human puberty, changes in a person's body may influence both the ability and inclination to behave in certain ways. For example, increased strength in boys may lead to increased use of aggression to achieve one's goals.

Second, hormones can influence activity in peripheral systems. For example, it is likely that hormone variations contribute to gender differences and menstrual cycle variations in taste, vision, touch, audition, smell, and temperature sensitivity (see Gandelman, 1983, and Parlee, 1983, for reviews of this

[1] For discussions of the role of hormones in sexual behavior at adolescence, see Paikoff and Brooks-Gunn (1990a), Udry (1988), Udry and Billy (1987), and Udry, Billy, Morris, Groff, and Raj (1985).

[2] For discussions of the hormonal events of the prenatal and infancy period and their implications for adolescent development, see Brooks-Gunn (1988), Coe, Hayashi, and Levine (1988), Money and Erhardt (1972) and Paikoff and Brooks-Gunn (1990a).

literature). Hormone changes could, then, influence moods and behaviors indirectly because they influence the nature of one's sensory experiences. For example, a higher sensitivity to the environment in general could lead to more feelings of well-being; more sensitivity to painful stimuli could result in greater irritability.

Third, hormones can influence more central systems, such as autonomic activity or enzyme systems (and thus, cellular permeability to electrolytes, water, or nutrients); (D. Becker, Creutzfeldt, Schwibbe, & Wuttke, 1980, 1982; Johnson & Everitt, 1984; Little & Zahn, 1974). Changes in basal metabolic rate, blood pressure and blood vessel excitability, sympathetic/parasympathetic tone, heart rate, or water and sodium retention may contribute to sensory changes or to changes in overall physical well-being, both of which can have behavioral manifestations. For instance, higher autonomic activity could be associated with faster reaction times and feelings of more energy, and thus, enhanced well-being. Slowing of, or sudden changes in, metabolic activity could produce feelings of lethargy or even depression.

Finally, hormones may influence behavior and moods by acting on central nervous system structures thought to be important for affect and for perception and interpretation of sensory information. Identification of brain regions that contain receptors for peripheral hormones informs our hypotheses about hormone–behavior links. For example, because receptors for luteinizing hormone (LH) and follicle-stimulating hormone (FSH) have not been found in any brain region of any species studied to date, it is unlikely that these hormones have direct effects on the brain (Johnson & Everitt, 1984; Norman & Litwack, 1987). Consistent with this suggestion, no behavioral effects of these hormones are found when they are administered to nonhuman animals. These data argue that if associations between LH or FSH and behavior are found in humans, they are mediated indirectly through the impact of the gonadotropin on gonadal steroid secretion. In contrast, receptors for the gonadal and adrenal steroid hormones are found throughout the brain, but predominantly in the hypothalamus, amygdala, septal nucleus, and hippocampus and possibly the midbrain central gray and spinal cord. The involvement of these brain regions in moods and affective behaviors has been indicated in several studies (e.g., Aggleton & Mishkin, 1986; Fonberg, 1986; Henry, 1986).

In summary, to the extent that the brain or peripheral mechanisms are influenced by fluctuations in hormone concentrations, one's perception of the environment and resulting behavior may be influenced as well. Given that hormones are in flux during early adolescence, it is possible that the behavioral changes and moodiness often attributed to the pubertal developmental period are, in part, a consequence of hormone activity. What, then, are the hormone changes that occur?

Hormonal Events of the Prepubertal and Pubertal Period

Between the ages of 5 and 9 years, the hypothalamic–pituitary–adrenal axis is activated, resulting in increased production and secretion of numerous adrenal steroid hormones, including androstenedione, dehydroepiandrosterone (DHEA) and its sulfate derivative, dehydroepiandrosterone sulfate (DHEAS; Grumbach, Grave, & Mayer, 1974; Norman & Litwack, 1987; Sklar, Kaplan, & Grumbach, 1980). *Adrenarche,* as this rise in adrenal steroids is called, precedes other endocrine changes of puberty and the onset of external physical changes, sometimes by several years (Apter, 1980; Cutler & Loriaux, 1980).

In adults, the hypothalamic–pituitary–gonadal axis maintains appropriate gonadal steroid concentrations in the blood by secretion of gonadotropin-releasing hormone (GnRH) from the hypothalamus. GnRH increases secretion of the gonadotropins, LH and FSH, from the pituitary. In turn, these hormones act to increase the secretion of sex steroids (Johnson & Everitt, 1984; Yen & Jaffe, 1978). Thus, the feedback system responds to low levels of sex-appropriate gonadal steroids (i.e., estrogen for girls and testosterone for boys) by increasing GnRH secretion, which in turn stimulates release of LH and FSH to promote steroidogenesis.

During childhood, LH and FSH release from the pituitary is suppressed, even though the amounts of estrogen and testosterone produced by the gonads are very low. At the onset of puberty, the ability of estrogen and testosterone to suppress gonadotropin secretion diminishes, with resulting increases in circulating concentrations of LH and FSH. It is believed that the increased gonadotropin output at puberty is due to a change in the sensitivity of hypothalamic control mechanisms. Exactly how this mechanism works, and why it is suppressed before puberty, is uncertain (Grumbach, 1980; Johnson & Everitt, 1984). What is clear is that maturation of the hypothalamic–pituitary–gonadal axis results in gradually increasing levels of gonadotropins, which in turn lead to gradually increasing levels of gonadal steroids (Burger & deKretser, 1981; Finkelstein, 1980).

In general, then, LH and FSH concentrations in blood are low before age 8 or 9 years. The first increases in these hormones are seen during sleep as episodic or pulsatile patterns. Later, in mid- to late puberty, both FSH and LH are also released in pulsatile patterns during the day (Finkelstein, 1980; Johnson & Everitt, 1984; Yen & Jaffe, 1978).

Although LH and FSH concentrations are highly correlated, some differences do exist in concentrations and cycles of these hormones within and between sexes. In both sexes, the initial FSH rise typically occurs before both the LH rise and external physical changes. In girls, FSH rises more rapidly than LH, but for boys FSH tends to rise more slowly than LH (Grumbach, 1980; Yen & Jaffe, 1978). Consequently, the ratio of FSH to LH in boys reverses once LH starts to rise (Burger & deKretser, 1981).

Gonadal Hormone Changes During Puberty in Girls

Estradiol is a gonadal steroid secreted by girls' ovaries in response to FSH and LH. Estradiol begins to show significant increases after about age 9 or 10 years (Apter, 1980; Faiman & Winter, 1974; Vihko & Apter, 1981). The increase continues through about 13.5 to 14 years (Faiman & Winter, 1974; Vihko & Apter, 1981) with occasional periods of accelerated increase (Apter, 1980). Irregular cycling of gonadotropins, prompting

cycles of estradiol, begins about 18 months before menarche (Hanson, Hoffman, & Ross, 1975); cycles continue to be irregular until about 12–18 months after menarche.

Progesterone secretion increases in association with the onset of ovulation (Lee, Xenakis, Winer, & Matsenbaugh, 1976). Progesterone is produced by the corpus luteum (the part of the follicle remaining in the ovary after ovulation) and functions to help regulate gonadotropin output and to prepare the body for a possible pregnancy (Johnson & Everitt, 1984). Given space limitations, and in keeping with our focus on the hormones of early puberty, our consideration of progesterone is limited to its impact on the potential behavioral effects of estradiol.

Low levels of testosterone are produced by the ovaries in girls primarily as a precursor to estradiol (Yen & Jaffe, 1978). Although increases in testosterone secretion occur during puberty, these increases are smaller than those of estrogen (Apter & Vihko, 1977; Gupta, Attanasio, & Raaf, 1975; Nottelmann, Susman, Dorn, et al., 1987). Consequently, the ratio of testosterone to estradiol concentrations declines over the early and middle adolescent years (Gupta et al., 1975; Nottelmann, Susman, Dorn, et al., 1987).

Gonadal Hormone Changes During Puberty in Boys

Testosterone is the primary gonadal hormone stimulated by LH and FSH in boys (Tepperman, 1987; Yen & Jaffe, 1978). Testosterone begins to rise at night in response to LH sleep increases at around age 10 years. Approximately a half-year later, after the accelerated LH rise, daytime concentrations of testosterone begin to increase (Grumbach, 1980; Lee, Jaffe, & Midgley, 1974; Reiter & Root, 1975). Testosterone concentrations can increase as much as 20 times their initial concentrations between the ages of 10 and 17 years (Faiman & Winter, 1974), with the greatest increases occurring between 12 and 14 years (Lee et al., 1974).

Estradiol in boys is derived primarily from testosterone metabolism (Grumbach, 1980; Johnson & Everitt, 1984; Lee & Migeon, 1975; Marcus & Korenman, 1976). The ratio of testosterone to estradiol is larger in boys than in girls, and increases with age (Nottelmann, Susman, Dorn, et al., 1987). Progesterone in boys is present primarily as a precursor to testosterone and other steroid hormones. Before about age 11 years, most of these hormones, especially LH and testosterone, are detected only during sleep.

Puberty: Approaching Adult Patterns of Hormone Secretion

The presence of hormones in adults can be conceptualized in several ways (Grumbach, 1980). Low, *tonic* concentrations of hormones can be found in both sexes at all ages. *Episodic* changes, or periodic pulses of hormone release at approximately 1-to-2-hr intervals, are also characteristic of adult hormone activity. The overall mean concentrations of hormones in women between menarche and menopause undergo regular *cyclic* changes as well.

Puberty introduces changes in all of these hormone characteristics. During early adolescence, both tonic and pulsatile hormone activity change and, for girls, monthly cycles begin to emerge. As noted, several different hormones increase throughout puberty, and the relations of concentrations, and changes in concentrations, of different hormones to each other is likely to be important when considering potential activational effects of hormones on behavior. In addition, the entire system is in flux and takes some time to stabilize into the adult pattern. This process of stabilization undoubtedly has implications for behavioral and affective patterns during this period of development. These implications are discussed later. First, we summarize the link between these hormonal changes and the morphological changes associated with puberty.

Relations Between Hormonal and Morphological Changes

Later, we discuss possible links between the morphological and behavioral changes of puberty. Because morphological changes reflect hormonal changes, we cover the relations between these two here. Adrenal androgens influence the growth of pubic, axillary, and facial hair (Higham, 1980; Johnson & Everitt, 1984; Root, 1973; Tanner, 1975). They may also play a role in skeletal growth (Root, 1973). As already noted, LH and FSH are necessary for normal development of gonadal function; they have no known direct effect on secondary sex characteristics, however.

Testosterone, along with the adrenal androgens, stimulates the development of male primary and secondary characteristics including growth and development of the male reproductive system, muscle development, enlargement of testes and penis, bone growth, growth of body hair, deepening of voice, and increased sebacious gland activity. In girls, growth of pubic and axillary hair, growth of the clitoris, and bone growth are influenced by testosterone (Root, 1973; Tepperman, 1987; Yen & Jaffe, 1978). Estrogens, however, are responsible for the development and maintenance of the female reproductive organs, breast development, change in body fat distribution, development of pubic and axillary hair, skeletal growth, and closure of the epiphyseal plates (Katchadourian, 1977; Root, 1973).

Despite the close relations between them, hormonal changes and indexes of outward physical growth do not correspond perfectly, and the magnitude of correlations between them varies across studies (Apter, 1980; Nottelmann, Susman, Blue, et al., 1987; Winter & Faiman, 1973). For example, among 9- to 14-year-olds, Nottelmann, Susman, Blue, et al. found the strongest correlations between testosterone and physical indexes in boys (correlations ranging from .62 to .79) and between androstenedione and physical indexes in girls. Estradiol was the strongest correlate of the onset on menstruation in girls. In contrast, among 16-year-old boys in Olweus, Mattsson, Schalling, and Löw (1980), testosterone was correlated most highly with pubic hair development ($r = .44$); it correlated less strongly with genital development ($r = .15$) and height ($r = .27$) and was uncorrelated with measures of strength-related body build. The difference in the strength of correlations between testosterone and various physical indexes in these two studies likely results from the fact that boys in the Nottelmann, Susman, Blue et al. sample were younger and were more likely to be in earlier stages of

puberty. Correlations between hormones and morphological changes may be higher in the early-to-middle stages of hormonal and morphological change; later on, changes may be slowing, and, therefore, they may show less variation and weaker correlations.

Summary

In summary, increases in adrenal steroids are the earliest sign of hormonal maturation. These changes are followed by increased activity of gonadotropins and then sex steroids. Sex steroids are the hormones most directly linked to outward physical changes. *Adrenal* androgens initially increase without producing observable physical change; FSH and LH affect outward changes indirectly, through their influence on the secretion of gonadal steroids. Imperfect relations between hormones and morphological changes during adolescence serve to underscore the complexity of the systems regulating physical development and the existence of individual differences in responses to hormones. Physical maturation is most likely a result of the complex interactions between the current hormonal milieu, previous hormone exposure, and the genetics of the developing person. If this is true for the relations between hormones and physical development, certainly relations between hormones and behavior will not be less complex.

Hormonal Influences on Behavior in Nonhuman Animals and Adult Humans

Hormones have been found to influence a wide range of behaviors in humans and nonhuman animals. Because many of the moods and behaviors of interest in this review are inferred processes that cannot be easily studied in nonhuman animals, our discussion of the immense nonhuman literature is minimal. Activity and aggression, however, have been extensively studied in rodents and other animals. Thus, our discussion of these particular behaviors incorporates information about hormone–behavior links in nonhuman animals.[3]

Our discussion of hormone–behavior relations in adult humans draws on studies of the menstrual cycle, pregnancy, childbirth, and menopause in women. Unfortunately, many of these studies are marked by methodological and interpretive difficulties (for more extensive discussions of these problems, see Mazur, 1983; Parlee, 1973, 1974, 1978; Ruble, 1977; Sommer, 1983). Despite the problems, however, certain patterns of relations occur fairly consistently across studies, including studies that are more methodologically sound. Therefore, we include discussions of these patterns, realizing that the experiences we describe are complex phenomena and not necessarily applicable to all women.

Activity

In general, adult female rodents are more active than males. The feminine pattern of activity emerges after puberty if the brain is not exposed to androgens during the critical period of sexual differentiation of the brain (Stewart & Cygan, 1980). Because treatment of adult rats with estrogen increases running wheel activity in both females and males, sex differences in activity appear to depend on both hormone-induced organizational and activational effects on behavior (Beatty, 1979).

Links between estrogen and activity levels have also been inferred from studies of the menstrual cycle: In the postovulatory period, as estrogen declines, women tend to be less active, and postmenstrually, when estrogen is rising, activity increases (Coppen & Kessel, 1963; Southam & Gonzaga, 1965). Additionally, in a large study of elderly people, women with higher estrogen:androgen ratios reported more mental and physical energy than those with lower ratios (Persson, Nilsson, & Svanborg, 1983). It is not clear whether this result is due to concentrations of the steroids individually or to their relative concentrations.

Aggression

In most nonhuman species, aggression between two males is, in part, testosterone dependent. For example, testosterone treatment increases aggression, and castration reduces aggression in rats and mice (Beatty, 1979). The effect of castration, however, can take more than 3 weeks to develop, and aggression may be exhibited by males after long-term castration in the absence of testosterone. Thus, factors other than circulating testosterone also affect aggressive behavior. Organizational effects of gonadal steroids during sexual differentiation of the brain can also predispose animals to greater aggressive behavior as adults. Thus, adult females are less likely to exhibit aggressive behavior than adult males, even if treated with testosterone, and estrogen and progesterone tend to ameliorate aggression in females but not in males (Barfield, 1984).

Studies of humans indicate that violent criminals and repeat offenders have higher concentrations of testosterone than less violent prisoners (Rubin, Reinisch, & Hasket, 1981). What cannot be determined from the studies is whether the abnormal hormone concentrations resulted in the increased aggression or whether the behavior resulted in increased testosterone concentrations. Both effects have been reported to occur (Carlson, 1986). Men with extremely low concentrations of testosterone (Klinefelter's patients) are typically more passive and dependent than men with more average concentrations (Rubin et al., 1981). Testosterone therapy is successful in treating both the physical and behavioral concomitants of this latter abnormality.

Relations between testosterone and aggression in populations with more average concentrations of testosterone provide less consistent results (Mazur, 1983; Rubin et al., 1981). Some studies suggest that emotional and behavioral reactions to testosterone depend on individual differences such as sensitivity to a hormone or contextual factors and that moods and behaviors vary more in response to intraindividual variation in hormone concentrations than to interindividual variations (e.g., Dabbs & Morris, 1990; Doering et al., 1975).

Other studies indicate that testosterone may be associated

[3] See Beatty (1979) for a complete discussion of hormonal influences on nonreproductive behaviors in rodents.

with attitudes or behaviors that may, in turn, be related to aggression. For example, testosterone concentrations were related to females' ratings of their personality attributes; higher testosterone was associated with more "masculine" attributes (e.g., enterprising, resourceful, uninhibited, and impulsive, as opposed to helpful, kind, thoughtful, gloomy, and anxious; Baucom, Besch, & Callahan, 1985). Testosterone concentrations have also been positively correlated with disinhibition, or the tendency to display high levels of sensation-seeking behavior among college-age men (Daitzman & Zuckerman, 1980; Daitzman, Zuckerman, Sammelwitz, & Venkateseshu, 1978).

Concentrations of estrogen, alone or in relation to other hormones such as progesterone or testosterone, may also be related to aggression. In some women, the low concentrations of estrogen and progesterone that occur premenstrually have been associated with competitiveness, irritability, outbursts of emotion, tension, and mood swings, phenomena that could potentially be related to increased aggression as well (e.g., Bardwick, 1976; Coppen & Kessel, 1963). It has also been claimed that a higher frequency of accidents, suicides, and crimes occurs by females during the premenstrual period (Dalton, 1960a; 1960b, 1961; Mandell & Mandell, 1967). Among elderly men, higher androgen:estrogen ratios were related to higher self-ratings of irritability and aggression (Persson et al., 1983). Again, it is not clear whether the association is due to relative or absolute sex-steroid concentrations.

Moods and Affect

Because of the difficulty in studying moods and affect in nonhuman animals, the bulk of evidence reviewed in this section is from studies of adult humans. Work with animals, however, demonstrates hormonal influences on the excitability of the nervous system: Estrogen lowers excitation thresholds in both male and female rats, whereas progesterone raises brain thresholds of excitation in female rats (Kawakami & Sawyer, 1967; Wooley & Timiras, 1962). Because of these antagonistic effects, the ratio of progesterone to estrogen may be more important in behavior than either progesterone or estrogen alone. In particular, estrogen may have more of an excitatory effect during early adolescence than at other developmental periods, given the relative absence of progesterone during this time.

The most general statement that can be made about hormones and affect based on research with adult humans is that estrogen may be associated with more positive moods and lack of estrogen with depression and negative affect, mainly in women (e.g., Bardwick, 1976; deLignieres & Vincens, 1982; Melges & Hamburg, 1977; Southam & Gonzaga, 1965). Because most of the data relevant to hormone associations with moods and affect come from studies of women at different times of life, we have organized this section around studies of the menstrual cycle and studies of pregnancy, childbirth, and menopause. There is also, however, evidence for the influence of estrogen and testosterone on affect in both sexes at times unrelated to specific hormonal change. Some studies we have already cited are relevant (e.g., the finding that testosterone is related to disinhibition and extraversion). Additionally, estrogen treatment for people with depressive illness has resulted in improvement of symptoms (McEwen, 1982).

Studies of the menstrual cycle. Because we discuss menstrual-cycle-dependent variation in behavior, we summarize the hormonal events of the menstrual cycle briefly. After menstruation, estrogen increases, peaking at the end of the follicular phase. An LH surge, induced by the estrogen peak, triggers ovulation. Subsequently, estrogen declines while progesterone starts to rise, leading to a progesterone-dominant luteal phase. A second, smaller, but more prolonged increase in estrogen also occurs during the luteal phase. After this, both progesterone and estrogen decline until both are at very low levels, preceding and resulting in menstruation (Johnson & Everitt, 1984).

Data from recent studies of the menstrual cycle suggest that affect is influenced by naturally cycling hormone concentrations and fluctuations, even if the results are not necessarily applicable to all women (e.g., Backström et al., 1983; Bardwick, 1976; Rossi & Rossi, 1980; Sanders, Warner, Backström, & Bancroft, 1983). For example, Rossi and Rossi (1980) found cyclical variations in positive and negative mood states in women not taking oral contraceptives that did not occur among women using oral contraceptives. Haemmerlie and Montgomery (1987), studying only women not using oral contraceptives, found differences in frankness, objectivity, sensitivity, hostility, self-discipline, honesty, and concern with physical symptoms between premenstrual and nonpremenstrual women. Specific differences varied with the age of the women. Both premenstrual and nonpremenstrual women, however, scored within one standard deviation of normal on the personality tests used.

Asso (1986) went a step beyond the traditional studies by measuring plausible neurological mediators of the hormone–mood relationship: cortical and autonomic activity. Using a within-subjects design and controlling for order of testing effects and oral contraceptive use, she found that positive moods and comfort were higher at midcycle than premenstrually and that both cortical alertness (lower premenstrually) and perceptions of autonomic reactivity (higher premenstrually) predicted self-reports of negative mood and physical discomfort during the premenstrual phase.

Another study examined adolescent (10th- and 11th-grade) girls' menstrual cycles (Golub & Harrington, 1981). Although girls complained of menstrual distress—especially in regard to pain and negative affect—on a menstrual distress questionnaire, a comparison of pre- and intermenstrual mood scores showed no differences. The findings lend support to the role of expectations in negative mood and behavioral symptoms associated with the menstrual cycle (see Ruble, 1977).

The studies cited above relied on self-reports of cycling to infer hormone states over the month. What about studies that have actually measured hormones, as well as affect, at different phases of the menstrual cycle? Backström et al. (1983) found no difference in the degree of cyclical mood changes by mean concentrations of estrogen, progesterone, androstenedione, or testosterone. In this study, women with apparently normal hormone cycles reported premenstrual syndrome (PMS) symptoms; in another study, women with PMS symptoms did not show major endocrine abnormalities (Adamopoulos, Loraine, Lunn, Coppen, & Daly, 1972). Backström et al. (1983) raise the

possibility that women vary in their sensitivity to the same concentrations of hormones.

Other work suggests that irregular or atypical hormone activity throughout the menstrual cycle is related to PMS symptoms. Dennerstein, Spencer-Gardner, Brown, Smith, and Burrows (1984) reported several hormonal differences in the cycles of women with and without PMS. Characteristics of the PMS cycles, as compared to controls, included lower preovulatory estradiol peak values and either higher or lower estradiol concentrations during the luteal phase. Similarly, Backström, Wide, Södergård, and Carstensen (1976) found several hormone irregularities in a premenstrual tension (PMT) group as compared to a non-PMT group. The PMT group had lower estradiol on Days 9 and 8 premenstrually, but higher estradiol from Day 5 (before menstruation) through menstruation. Progesterone was lower in PMTs than in non-PMTs on Days 10 to 4 premenstrually. PMT women also showed an abnormal luteal rise in FSH that the authors hypothesized may have stimulated a second set of ovarian follicles. Finally, Coppen and Kessel (1963) found an association between irregular menstrual cycles, in the sense that women could not predict when they would menstruate from month to month, and neuroticism. Thus, irregular hormone activity may contribute to mood and behavioral symptoms of the menstrual cycle. The evidence, however, that some women with apparently normal hormonal cycles (Backström et al., 1983) also experience PMS symptoms suggests that environmental components are also important.

Studies of pregnancy, childbirth, and menopause. Relations between hormones and behavior have also been studied in women during pregnancy or after menopause to investigate effects during other periods of natural variations in hormonal secretion. A pregnant woman experiences gradual increases in hormones throughout her pregnancy (Johnson & Everitt, 1984). In the 6 to 8 days after childbirth, there is a very sharp drop in both estrogen and progesterone. Although precise numbers are hard to pinpoint, it is not uncommon for women to experience emotional lability, crying, increased sensitivity, and even depression during the postpartum days (Hopkins, Marcus, & Campbell, 1984; Kumar & Robson, 1984; Melges & Hamburg, 1977; Paykel, Emms, Fletcher, & Rassaby, 1980; Pitt, 1973). Again in this instance, lack of—or decreases in—estrogen and progesterone are, theoretically, associated with labile and negative affect. Studies actually examining the evidence for physiological effects on mood at this time are few in number and equivocal in their results (see Hopkins et al., 1984). Nonhormonal factors (e.g., lack of sleep, inadequate social support, changes in roles and lifestyle) are certainly important. At present, however, hormonal contributions to the postpartum experience have not been adequately tested.

Women at menopause also experience a decline in estrogen concentration, as well as increases in FSH, LH, and androgens (Fedor-Freybergh, 1977; Johnson & Everitt, 1984; Lauritzen, 1975). Menopause is often said to be accompanied by depression, hot flashes, and decreased sexual excitability, in addition to heightened irritability, anxiety, and fatigue (Fedor-Freybergh, 1977; Johnson & Everitt, 1984; Lauritzen & Van Keep, 1978; Melges & Hamburg, 1977). The same criticisms levied against most of the menstrual and pregnancy–childbirth literature apply here. Stereotypes about menopause abound, and these and other psychosocial variables are often left unmeasured. Yet, estrogen therapy has often been used successfully to treat psychological and emotional, as well as physical, problems that arise during this time of life (deLignieres & Vincens, 1982; Fedor-Freybergh, 1977; Lauritzen & Van Keep, 1978).

For example, in one study (deLignieres & Vincens, 1982), estrogen and progesterone were administered to postmenopausal women with low levels of estradiol. Eighty percent of the women were experiencing symptoms of depression, and 90% had symptoms of anxiety before hormone treatment. Aggressive symptoms were uncommon. After estrogen treatment, women who still had low estradiol levels showed the same psychological profile of high depression and anxiety and low aggression. Women whose estradiol levels had reached a moderate level showed no unpleasant symptoms. When estradiol levels had increased excessively, however, depression was low, and aggression and anxiety were high. In two cases, progesterone moderated the effects of estradiol: (a) Among women with low estradiol, administration of progesterone lowered anxiety but not depression, and (b) among women with high estradiol, progesterone led to sharply decreased aggression and anxiety.

Although this study had no placebo control group and did not report how feelings of depression, anxiety, and aggression were measured, it had some strengths. Interviewers were blind to the hormonal status and treatment of the women, so that preconceived notions about the effects of estradiol and progesterone were not likely to have influenced their ratings of depression, anxiety, and aggression. Also, despite the lack of control group, it is unlikely that the women could have predicted their posttreatment hormone concentrations. Thus, it would have been difficult for them to report their moods in accordance with their own beliefs about what the effects of treatment should be. This study, then, provides support for the hypothesis that moderate levels of estrogen are related to positive feelings and that too little or too much estrogen has behavioral manifestations in depression and aggression, respectively.

Summary of hormonal relations with mood and affect. Despite flaws in the literature, there is a relatively high degree of consensus in both theoretical and empirical accounts that estradiol has a positive influence on adult behavior, at least in moderate amounts, and that its effect can be influenced by the presence of progesterone. Environmental, social, and cultural factors certainly play a role in the behaviors linked with estrogen—depression, anxiety, aggression, irritability, general feelings of well-being—and perhaps themselves influence hormone concentrations. The fact that environment is important, however, does not rule out the possibility that hormones do, in fact, exert some influence over moods and behavior.

Three additional conclusions from this literature seem especially relevant to our understanding of possible hormonal effects during adolescent development. Given that adolescence is a time when some children's hormones are fluctuating widely on a daily basis and when hormone activity may be inconsistent, the finding that women with irregular hormone activity during their menstrual cycle may be more susceptible to PMS seems especially relevant. Adolescence may be a time when hormones are most likely to have an impact on affective states

because of irregularities in their cycling patterns rather than, or in addition to, increases in their average concentrations. Furthermore, the fact that women with unusually high levels of estrogen experienced different affect than women with moderate levels of estrogen (deLignieres & Vincens, 1982) suggests that there may be curvilinear, as well as linear, relations between hormone concentrations and affect. This could be especially important at early adolescence when even small absolute changes in concentrations may lead to extreme reactions in a body not yet adjusted to these concentrations. Finally, evidence that beliefs can moderate reaction to hormonal cycles is important to our understanding of hormonal effects in adolescence given that adolescence is a period of life about which people have strong stereotypical beliefs, especially concerning biological influences (Buchanan et al., 1991). If people believe that adolescence is a time of storm and stress and that hormones are an important cause of such stress, they may label even minor affective changes as hormonally caused and react in ways that create a self-fulfilling prophecy.

Summary of Hormone–Behavior Relations in Animals and in Adult Humans

As already noted, research on hormonal effects on behavior among humans is often rudimentary and methodologically flawed. Many criticisms can be levied against a great deal of it, not the least of which is failure to look comprehensively at other potential influences on behavior. Ultimately the biological and psychosocial streams cannot remain separate; both are important, and they affect each other. To examine issues of hormones and behavior comprehensively, more sophisticated, multidisciplinary research needs to be undertaken.

Despite the problems and gaps in research, some general patterns of hormone–behavior relations have emerged. One is that the sex steroids (testosterone and estradiol) have activating effects on the nervous system. Moderate concentrations of estradiol have been consistently associated with positive aspects of mood and behavior—including mental alertness, concentration, and happiness; lack of estradiol seems potentially tied to depression and emotional lability. Overly high concentrations of sex steroids, however, may result in negative symptoms such as anxiety and aggression. In addition, the arousal effects of sex steroids may be most likely to emerge under circumstances that provoke positive or negative moods or behavior (also see Kreuz & Rose, 1972, for this argument regarding testosterone and aggressive crimes).

Issues relevant to future research also arise from this review. First, people may vary in their sensitivity to hormone concentrations, so that a given concentration in one person may not have the same effects neurologically or psychologically in another person. This suggests that a fruitful area of exploration is within-subject effects, rather than the more typical between-subjects analyses. Second, we reiterate the potential importance of considering regularity of hormone activity. Third, ratios of hormones to one another (e.g., estrogen to progesterone, testosterone to estradiol) need further study. Fourth, effects of abnormal hormone levels may be less noticeable in normal populations in which social etiquette and environmental circumstances overshadow physiological effects. Negative effects of very low or very high concentrations may be more apt to show up in less typical populations, among people already prone to psychiatric disturbance or among people in environmental situations that exacerbate negative behavior and emotions. Last, stereotypes and expectations regarding hormonal effects on behavior may exacerbate true hormonal effects on behavior.

Evidence for the Role of Hormones in Adolescent Moods and Behavior

We now turn to the role of hormones in mood and behavior changes during adolescence. Two assumptions are embedded in the question, "are adolescents victims of raging hormones?": first, that moods and behaviors differ between adolescence and other developmental periods and second, that hormones account, at least in part, for the differences. Thus, our strategy for addressing this question is to examine evidence that changes in specific moods and behaviors indeed occur at adolescence and to summarize data from the few studies that have directly measured hormones and behavior among adolescents. In reviewing evidence for mood and behavior changes, we examine evidence for changes with both age and pubertal status. Both are correlated with hormonal changes and may provide indirect clues concerning associations between hormones and behavior. Before reviewing the evidence, however, we provide some background on the studies to be reviewed and propose some general types of effects that hormones might have at this stage of life.

Changes in Mood and Behavior at Adolescence: General Concerns

Tables 1 and 2 contain summary information about the major data-based studies included in this review. In reviewing the studies on developmental changes in moods and behavior, the following issues need to be considered. First, although there are more data on changes in moods and behavior with age or puberty than there are direct data on hormones and behavior at adolescence, few studies have actually examined those behaviors and affective states (such as fluctuations in moods or energy levels, intensity of moods, restlessness, or impulsive behavior) that are assumed to be linked to adolescent emotional lability. Most research on adolescent development examines behaviors and attitudes that may be affected by changes in these more basic moods and feelings—such as family conflict, self-image, and deviant behaviors. In addition, although relevant longitudinal studies on moods and behavior spanning the late elementary to high school years are emerging (e.g., Block & Block, 1980; Brooks-Gunn, Warren, & Rosso, 1988; Kagan & Moss, 1962; Petersen, Sarigiani & Kennedy, 1991; Simmons & Blyth, 1987), most published research is cross-sectional and focused on a narrow time period. To know if children's moods and behaviors change as they enter adolescence, we need to follow them from late childhood and prepuberty through the beginnings of physical change and then through the ensuing adolescent period.

An evaluation of the studies that address changes in mood or behavior during adolescence is further complicated by two

(*text continues on page 76*)

Table 1
Summary of Studies That Have Examined Associations Between Age or Grade and Moods or Behaviors During Adolescence

Author	Measure	*N*	Design	Results
		Mood swings and mood intensity		
Bence (1990)	Self-report	75 adolescents in Grades 7, 9, and 11	Cross-sectional	Moods of 11th graders were more likely to change slowly than moods of 9th graders. Moods of 7th graders were more likely to change quickly than moods of 11th graders. No grade differences in the variability of moods as measured by standard deviation.
Diener, Sandvik, & Larsen (1985)	Self-report	Sample 1: 242 people from 63 families, 16–68 years of age; Sample 2: 190 people —college students, their parents, and their siblings	Cross-sectional	Small but clear age differences in emotional intensity, with intensity decreasing across the age span.
Larson & Lampman-Petraitis (1989)	Self-report	473 5th–9th graders	Cross-sectional	Slight positive correlation between age and emotional variability only among girls and only for 2 of 6 mood states measured. A significant negative correlation between age and reports of extreme positive mood states.
Larson, Csikszentmihalyi, & Graef (1980)	Self-report	75 high school students and 107 adults, 19–65 years old	Cross-sectional	Adolescents' moods were more extreme and more changeable than those of adults.
Stapley & Haviland (1988)	Self-report	74 5th, 58 7th, 68 9th, and 62 11th graders	Cross-sectional	Little difference in salience (frequency, duration, intensity) of emotions in different grades. For shyness, fear, shame, contempt, and disgust there was a decrease in salience with grade.
		Depression		
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	Older clinical children more unhappy, sad, depressed, and suicidal; clinical subjects in middle childhood most likely to harm self, feel unloved, worthless. Younger children rated as most lonely.
Albert & Beck (1975)	Self-report	31 7th graders and 32 8th graders, 11–15 years old	Cross-sectional	33% of children reported moderate-to-severe depression; higher depression in 8th graders, especially among girls.
Baron & Joly (1988)	Self-report	152 girls, 97 boys, 12–17 years old, all with Beck Depression Inventory scores indicating at least mild depression	Cross-sectional	No association of age with degree of depression.
Baydar, Brooks-Gunn, & Warren (1989)	Self-report and mother report	10–14-year-old girls followed for 4 years; $n = 164$ at Wave 1, $n = 80$ at Wave 4	Longitudinal	Age trends in depressed affect differed depending on measure used. The percentage of girls classified as depressed did not increase with age.
Bettes & Walker (1986)	Psychiatric diagnosis	7,828 11–18-year-old psychiatric patients	Cross-sectional	Older children had more internalizing and somatic symptoms and more suicidal behavior.
Brooks-Gunn & Warren (1989)	Self-report	100 girls, 10–14 years old	Cross-sectional	Age not related to depressed withdrawal.
Brooks-Gunn, Rock, & Warren (1989)	Self-report	662 girls in Grades 7–12	Cross-sectional	Junior high school girls (Grades 7–8) had lower emotional tone (more depressive affect) than high school girls.
Elliott, Huizinga, & Menard (1989)	Self-report	1,725 youths aged 11–17 years at the first wave, followed annually for 6 years. National probability sample.	Cross-sectional and longitudinal	Depression increased linearly with age for both boys and girls.
Jessor & Jessor (1977)	Self-report	Initial sample of 483 junior high school students followed into adulthood	Longitudinal	Depression increased with age for both boys and girls.

Table 1 (*continued*)

Author	Measure	*N*	Design	Results
		Depression (*continued*)		
Kandel & Davies (1982)	Self-report of both child and parent	8,206 14–18-year-olds 5,574 parents (4,204 families)	Cross-sectional	Children reported more depression than parents did for themselves. Girls more depressed than boys. No meaningful age differences within the adolescent group.
Kaplan, Hong, & Weinhold (1984)	Self-report	385 junior and senior high school students	Cross-sectional	8.6% of subjects reported moderate-to-severe depression. Except in areas of attractiveness and weight loss, 11–13-year-olds less depressed than older children.
Larson & Lampman-Petraitis (1989)	Self-report	473 5th through 9th graders	Cross-sectional	Older children more likely to report dysphoric mood states.
Magnusson (1988)	Self-, parent, and teacher report	3,244 children from three cohorts (ages 10, 13, and 15 years at start of data collection)	Longitudinal	Increase in rates of depression among females from ages 10–14 years and 15–19 years. Biggest change occurred after age 14. No clear age trend for males.
Paikoff, Brooks-Gunn, & Warren (1991)	Self-report	72 girls, 10–14 years, 5th–7th grade at Time 1; 11–15 years, 6th–8th grade at Time 2	Longitudinal	No age differences in depression.
Petersen & Crockett (1985)	Self-report	335 6th–8th graders	Longitudinal	Sad affect decreased from 6th to 8th grade; largest decline between 6th and 7th grade.
Petersen, Sarigiani, & Kennedy (1991)	Self-report	169 adolescents followed from 6th through 12th grade	Longitudinal	Depressive affect increased from 8th through 12th grade, especially for girls.
Rutter, Graham, Chadwick, & Yule (1976), Rutter (1980, 1986)	Self-, mother, teacher report; psychiatric diagnosis on subsample	Full sample: over 2,000 14–15-year-olds on the Isle of Wight. Subsamples chosen for intensive study: (a) random subsample of general population (n = 200), (b) all children with "deviant" scores on the questionnaires (n = 304), and (c) children who had a psychiatric disorder at age 10 according to a previous study (n = 126). Longitudinal follow-up at age 18.	Cross-sectional (epidemiological) and longitudinal	According to psychiatrist ratings, about half of 14-year-olds expressed unhappiness with self and life; according to self-reports, about one fourth of boys and girls felt miserable and depressed. Incidence of depression increased from age 10 to 18, especially among girls and among children with a history of psychiatric problems.
Simmons & Blyth (1987)	Self-report	310 adolescents in 6th, 7th, 9th, and 10th grades	Longitudinal	No age differences in depressive affect.
Simmons, Rosenberg, & Rosenberg (1973)	Self-report	1,917 children Grades 3–12	Cross-sectional	Adolescents (age 12 and older) showed more depressive affect than 8–11-year-olds.
Susman, Inoff-Germain, et al. (1987)	Self-report	52 girls, 56 boys, 9–14 years old	Cross-sectional	Sad affect positively correlated with age for boys. No correlation for girls.
		Energy level		
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	Older clinical children reported as more fatigued.
Larson, Csikszentmihalhyi, & Graef (1980)	Self-report	75 high school students and 107 adults, 19–65 years old	Cross-sectional	Adolescents had more extreme swings in alertness/drowsiness, and in activity/passivity than adults; adults had more reports of activation.

(*table continues*)

Table 1 (*continued*)

Author	Measure	*N*	Design	Results
		Restlessness and concentration		
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	Younger children had more problems concentrating; clinical subjects did more daydreaming in middle childhood.
Larson et al. (1980)	Self-report	75 high school students and 107 adults, 19–65 years old	Cross-sectional	Adolescents had lower concentration than adults.
		Irritability		
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	No age differences in moodiness or sulking; younger children more whiny, crying, stubborn, sullen, irritable. Older children more often refused to talk.
		Impulsiveness		
Abramowitz, Petersen, & Schulenberg (1984)	Self-report	254 children followed 6th–8th grade (114 boys, 140 girls)	Longitudinal	Better impulse control in 7th grade than in 6th or 8th grade.
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	No difference in impulsiveness by age.
Douvan & Adelson (1966)	Self- and parent report	1,405 girls, Grades 7–12; 2,005 boys, Grades 6–12	Cross-sectional	A minority of boys expressed concern over impulse control; those who did were most likely to recall it from early-adolescent years.
Offer (1969), Offer & Offer (1975)	Self- and parent report	73 normal 14-year-old boys, 61 followed into adulthood	Longitudinal	Both parents and sons recalled that sons had most difficulty with impulse control before high school.
Susman, Inoff-Germain, et al. (1987)	Self-report	52 girls, 56 boys, 9–14 years old	Cross-sectional	No age differences in impulse control.
Zuckerman, Eysenck, & Eysenck (1978)	Self-report	254 males, 693 females, ranging in age from 16 to 70	Cross-sectional	Thrill seeking highest in 16–19-year-olds.
		Anxiety and worry		
Abe & Suzuki (1986)	Self-report	6,034 9–60-year-olds from Japan	Cross-sectional	Anxiety symptoms peaked at 13–15 years; recurrent headaches also peaked at this age.
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	Highest worrying among 8–9- and 14–15-year-olds; no age effects on other measures of anxiety.
Susman, Inoff-Germain, et al. (1987)	Self-report	52 girls, 56 boys, 9–14 years old	Cross-sectional	No age differences in anxiety.
		Aggression, behavior problems, and delinquency		
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	For normal children, disobedience at school rose slightly in adolescence, but disobedience at home, behavior problems, and fighting declined. For clinical children, deviant behavior was higher in older children.
Brooks-Gunn, Warren, & Rosso (1988)	Self-report	152 girls, 10–13 years old, 5th–7th grade	Cross-sectional	Age not related to behavior problems.
Cairns, Cairns, Neckerman, Ferguson, & Gariepy (1989)	Self-, peer, and teacher report	116 girls, 104 boys, 4th through 9th grade (age 10–15 years)	Longitudinal	Number of subjects rated as highly aggressive decreased with age. Among boys, themes of direct confrontation and brutality in conflict situations persisted across time; among girls, there was an increase in the use of social aggression (ostracism) in conflictual situations.

Table 1 (*continued*)

Author	Measure	*N*	Design	Results
		Aggression, behavior problems, and delinquency (*continued*)		
Douvan & Adelson (1966)	Self- and parent report	1,405 girls, Grades 7–12 2,005 boys, Grades 6–12	Cross-sectional	A minority of boys expressed concern over aggressive feelings; feelings were constant over the adolescent years. Almost all boys admitted to breaking a rule at one time. Girls did not express the same concerns.
Elliott et al. (1989)	Self-report	1,725 youth age 11–17 years at the first wave, followed annually for 6 years. National probability sample.	Cross-sectional and longitudinal	Delinquent behavior started to increase at age 12–13 years, peaked at age 15–17, and declined after age 18. Minor assault (fighting) and vandalism peaked at age 11, then declined.
Farrington & West (1981); Farrington (1988)	Self-, parent, and teacher report; official school and criminal records	411 boys initially 8–9 years old, followed biannually until age 18 and again at ages 21, 24, and 32.	Longitudinal	Incidence of delinquent behavior peaked at age 17. A few boys committed many crimes and evidenced an early beginning in, and a consistently high rate of, criminal behaviors. These boys were also likely to have been troublemakers and high risk takers when they were 8–10 years old.
Jessor & Jessor (1977); Jessor (1984)	Self-report	Initial sample of 483 junior high school students followed into adulthood	Longitudinal	Incidence of problem behaviors increased through high school and then decreased. Problem behaviors tended to covary within the person.
Magnusson (1988)	Self-, parent, and teacher report; data from public records of school performance and interactions with the criminal justice system	3,244 children from three cohorts (ages 10, 13, and 15 years at start of data collection)	Longtudinal	Increase in incidence of criminal behaviors, especially violent crimes, throughout adolescence and the early 20s, and then a decrease. Highest rates occurred between ages 15 and 17 years for males. Age trends less clear for females, and peak occurred between ages 18 and 23 years.
Offer (1969); Offer & Offer (1975)	Self- and parent report	73 normal 14-year-old boys; 61 followed into adulthood	Longitudinal	Most difficulty with aggression and rebellious behavior during early adolescence, before high school.
Osgood, O'Malley, Bachman, & Johnston (1989)				
A	Self-report	Appoximately 4,000 17- to 23-year-olds	Longitudinal	Consistent declines across all offenses, and for both sexes, from 17 to 23 years of age.
B	National arrest statistics	1.3–1.7 million people from 17 to 23 years of age	Cross-sectional	Arrests for nonviolent offenses decreased with age. Arrests for nonviolent offenses changed little with age.
Paikoff et al. (1991)	Self-report	72 girls, 10–14 years, 5th–7th grade at Time 1; 11–15 years, 6th–8th grade at Time 2	Longitudinal	No age differences in behavior problems.
Simmons & Blyth (1987)	Self-report	310 adolescents in 6th, 7th, 9th, and 10th grades	Longitudinal	Increases in truancy and school suspensions with age. No change in self-reported problem behavior.
Susman, Inoff-Germain, et al. (1987)	Mother report	56 boys (10–14 years); 52 girls (9–14 years)	Cross-sectional	No age differences in problem behavior.
Zuckerman et al. (1978)	Self-report	254 males, 693 females, ranging in age from 16 to 70	Cross-sectional	Disinhibition highest among 16–19-year-olds.

(*table continues*)

Table 1 (*continued*)

Author	Measure	*N*	Design	Results
		Family relationships		
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	No age differences in reports of arguing. Younger children were more disobedient at home. Boys in the clinical sample most likely to run away from home at age 12–16. Older children had more friends and better peer relationships but did not have more contact with friends than did younger children.
Douvan & Adelson (1966)	Child and parent report	1,405 girls, Grades 7–12; 2,005 boys, Grades 6–12	Cross-sectional	Family relationships mostly positive: Children felt that rules were fair and that parents were not old-fashioned.
Eccles et al. (in press)	Child report	1,013 girls and 842 boys followed through 6th and 7th grades	Longitudinal	Both boys and girls reported increases in parental control, and decreases in decision-making opportunities, from 6th to 7th grade.
Hill & Holmbeck (1987)	Child and parent report	100 7th grade boys, 100 7th grade girls	Descriptive	More disagreements about personal habits and family obligations than peer relationships, low frequency of disagreements over peer relationships.
Inoff-Germain et al. (1988)	Observation of family interaction	30 boys, 30 girls, 9–14 years old	Cross-sectional	Older boys more likely to show anger when provoked.
Jessor & Jessor (1977)	Child report	Initial sample of 483 junior high school students followed into adulthood	Longitudinal	Depression increased with age for both boys and girls.
Montemayor (1982)	Child report	64 families		Early adolescents perceived parents as more controlling than did younger and older children.
Offer (1969), Offer & Offer (1975)	Child and parent report	73 normal 14-year-old boys, 61 followed through adulthood	Longitudinal	Little conflict reported overall; subjects recalled that the 7th- and 8th-grade years had been the ones of most disagreements.
Papini & Savage (1987)	Child report	279 7th, 9th, and 11th graders	Cross-sectional	7th and 9th graders reported more conflict than 11th graders over school and household behavior issues.
Petersen & Crockett (1985)	Child report	335 children in 6th–8th grade	Longitudinal	Quality of family relationships showed a decline from 6th to 8th grade, with the greatest drop occurring between Grades 7 and 8.
Rutter et al. (1976)	Child and mother report	200 normal 14-year-olds; 304 14-year-old children with psychiatric disorder (actual analyses use 123 controls and 156 psychiatric children)	Epidemiological	Relationships between parents and children mostly good. About one third of children reported arguments with and criticisms of parents (less by parent account). Disagreements 2–3 times more common in the clinical group.
Smetana (1988, 1989)	Child and parent report, observations of parent–child interactions.	102 children equally divided into four grade groups: 5th–6th grade, 7th–8th grade, 9th–10th grade, and 11th–12th grade	Cross-sectional	Overall, no age differences in frequency of conflicts. Reported conflicts over family rules and homework, and with father, most frequent during the early age periods. Conflict over chores most frequent in older age groups. Mother–daughter relationship especially poor during the 7th–8th grades. Although actual frequencies of conflict were relatively high, conflicts were not seen as very serious and tended to focus on mundane, everyday issues.

Table 1 (*continued*)

Author	Measure	*N*	Design	Results
		Self-consciousness		
Abe & Suzuki (1986)	Self-report	6,034 9–60-year-olds from Japan	Cross-sectional	Fear of blushing and being looked at highest from 11–19 years (peaked at 16). Beliefs that one was being talked about highest from 9–13 years.
Achenbach & Edelbrock (1981)	Parent report	2,600 parents of children age 4–16; half clinical, half normal	Cross-sectional	Young children were most shy and timid; self-consciousness peaked during middle childhood for clinical children only.
Brooks-Gunn et al. (1989)	Self-report	662 girls in Grades 7–12	Cross-sectional	Self-consciousness decreased with grade.
Rutter et al. (1976)	Psychiatric interview with child	200 normal 14-year-olds	Epidemiological	About one-fourth of normal 14-year-olds experienced feelings of being looked at, laughed at, or talked about.
Simmons & Blyth (1987)	Self-report	310 adolescents in 6th, 7th, 9th, and 10th grades	Longitudinal	Self-consciousness increased with age.
Simmons et al. (1973)	Self-report	1,917 children in Grades 3–12	Cross-sectional	Adolescents (age 12 and up) were more self-conscious than 8–11-year-olds. Steepest increase occurred between ages 10 and 13. Age effects strongest for children who moved to junior high schools at age 12.
		Self-esteem and perceived competence		
Abramowitz et al. (1984)	Self-report	254 children (114 boys, 140 girls) followed from 6th through 8th grade	Longitudinal	Self-image increased with age in areas of emotional tone, social relationships, mastery, and psychopathology; decreased in areas of body image, superior adjustment. Impulse control peaked in 7th grade. No change in family relationships or vocational–educational goals. For both increases and decreases, changes greatest between 6th and 7th grades.
Brooks-Gunn et al. (1988)	Self-report	152 girls, 10–13 years old, 5th–7th grade	Cross-sectional	Age not related to self-image.
Eccles et al. (1983), Eccles, Midgley, & Adler (1984)	Self-, parent, and teacher report; classroom observation; grades	668 children, Grades 5–12	Cross-sectional	Attitudes and expectancies regarding math ability declined with increasing grade. No drop in attitudes about English.
Eccles et al. (1989)	Self-report	1,450 boys and girls in 6th and 7th grades	Longitudinal	A drop in general self-esteem occurred between 6th and 7th grade; self-esteem increased again in 7th grade. General self-esteem more stable in 7th than 6th grade. Different changes over time occurred for specific domains of perceived competence (math, English, social, sports).
Jessor & Jessor (1977)	Self-report	Initial sample of 483 junior high school students followed into adulthood	Longitudinal	Increased general self-esteem and positive expectations for affection, achievement, and independence with age.
Katz & Zigler (1967)	Self-report	120 5th, 8th, and 11th graders	Cross-sectional	Greater disparity between real and ideal self with increasing grade.
McCarthy & Hoge (1982)	Self-report	1,852 7th, 9th, and 11th graders assessed at two times, 1 year apart	Cross-sectional/ longitudinal	Mixed results cross-sectionally. In longitudinal analyses, self-esteem scores increased slightly from Year 1 to Year 2.
Nottelmann, Susman, Blue, et al. (1987)	Self-report	52 girls, 56 boys, 9–14 years old	Cross-sectional	Older boys had worse self-image in several domains. No age differences in self-image for girls.

(*table continues*)

Table 1 (*continued*)

Author	Measure	*N*	Design	Results
Simmons et al. (1973)	Self-report	1,917 children, Grades 3–12	Cross-sectional	12–14-year-olds had lower global self-esteem than 8–11-year-olds or 15+-year-olds. More instability in self-image among 12- to 14-year-olds than among younger age groups. 12–14-year-olds also had lower self-esteem on specific dimensions than did younger children.
Simmons & Blyth (1987)	Self-report	310 adolescents in 6th, 7th, 9th, and 10th grades	Longitudinal	Slight increase in general self-esteem and perceptions of popularity with the opposite sex with age. Slight decrease in beliefs about competence in sports and schoolwork. Decline in general self-esteem for girls who moved to a junior high school after 6th grade.
Thornburg & Jones (1982)	Self-report	2,561 children, Grades 4–9	Cross-sectional	General decline in self-esteem with grade and age (largest drop occurred between age 9–11 and 12–15 years [Grades 4–8]). Age a more potent mediator of change than grade.

characteristics of the work: (a) Many different measures have been used to assess similar constructs, and (b) the studies vary in whether they use child, parent, or observer reports of mood and behavior. Several studies suggest that children's reports of their own feelings and actions can differ significantly from reports of parents or others (e.g. Achenbach, McConaughy, & Howell, 1987; Hill & Holmbeck, 1987; Rutter et al., 1976; Steinberg, 1987a).

Hormone–Behavior Relations at Adolescence: Possible Types of Association

Within the past decade, several research groups have begun to explore the relations between hormones and nonsexual moods and behavior during adolescence. The major methodological features of the studies we draw on are provided in Table 3.

How might hormones affect behavior during early adolescence? The literature on hormone–behavior relations in adults suggests the following potential effects:

1. *Activation effects.* Rising tonic or average concentrations of hormones might lead to heightened or reduced levels of moods or behavior. Similarly, cyclical increases and decreases in hormones might correspond to changes in associated moods and behaviors.

2. *Adjustment effects.* Because early adolescence is a time when relatively constant and low concentrations of gonadotropins and sex steroids begin to be replaced by higher concentrations, mood and behavior might reflect an adaptation to this heightened hormone activity. One might see more extreme effects of hormones on behavior during pre- and early adolescence than in middle or later adolescence, because by the middle and later adolescent years, teenagers have adapted to higher tonic concentrations. Furthermore, these associations might look different than the associations typically reported in adults. For example, although estrogen is typically associated with higher general activation and greater feelings of well-being in animals and adult humans, it is associated with higher levels of depression during the time of most rapid rise in early-adolescent girls (Brooks-Gunn & Warren, 1989). Findings that high hormones for one's age are associated with more negative mood states (e.g., Nottelmann, Susman, Blue et al., 1987, Nottelman, Susman, Inoff-Germain et al., 1987; Susman et al., 1985) are consistent with this notion of an adjustment period early in puberty.

3. *Irregularity effects.* Irregular or atypical pulsatile or cyclical activity has been associated with negative mood and behavioral symptoms in adult women (e.g., Backström et al., 1976; Coppen & Kessel, 1963; Dennerstein et al., 1984). In early adolescence, the gonadotropins and sex steroids increase not only in concentration but also in variability. Episodic and cyclical patterns of hormone release begin, and these patterns can be quite irregular during the early part of the developmental process. Fluctuations of hormones, especially if irregular, might lead to instability of nervous functioning, with potential implications for mood and behavior. Only one study to date has examined *fluctuation* of hormones in adolescent children in relation to adolescent moods and behavior (Eccles et al., 1988), and only preliminary data from this study are currently available.

4. *Complex interactions.* Each of these types of effects is likely to be interactional in nature, with effects depending not only on the hormonal environment but on individual sensitivity to hormones, individual predispositions toward certain behaviors, and contextual factors.

With this background, we now move to consider evidence for hormonal influences on specific moods and behaviors at adolescence. We look first at affective states, followed by behaviors and self-perceptions that may be linked to affective changes. Although there are no known direct effects of gonadotropins

on brain receptors, we consider relations between gonadotropins (as well as sex steroids) and behavior because gonadotropins may reflect activity of the sex steroids. Given that gonadotropins increase earlier than sex steroids, they can be more easily and reliably measured in the early stages of puberty than can the sex steroids. Although small changes in steroids may be difficult to measure, they may, in fact, have important effects physiologically. Examination of gonadotropic activity is likely to increase the probability of detecting these.

Affective States

Mood swings and mood intensity. Both testosterone and estrogen are linked to heightened activity and excitability and to a more ready and rapid response to stimulation (e.g., Beatty, 1979; Wooley & Timiras, 1962). Thus, with rising testosterone and estrogen (especially before the rise in progesterone), one might expect adolescents to become increasingly sensitive to stimuli in the environment. If so, their affect would depend on the nature of these stimuli. Increased tendencies to snap back, to cry from anger or frustration, or to lash out at another might be expected in bad circumstances; easy laughter, activity, or intense interest would be expected in good circumstances. As pleasant or exciting events alternate with unpleasant events, mood changes would become more noticeable. Mood instability could also result from the fact that the cycles of sex steroids (or gonadotropins or adrenal hormones) are irregular and unpredictable until late in pubertal development (e.g., a year or two following menarche for estrogen). Finally, even though moderate concentrations of estrogen have been associated with more positive mood states (deLignieres & Vincens, 1982), adjustment to new concentrations and pulses of estrogen may lead to more negative moods (Brooks-Gunn & Warren, 1989).

Despite the popular belief that adolescents are often moody and emotional (e.g., Bell, 1987; Hamburg, 1974) and despite evidence that the hormonal changes of puberty could lead to increased moodiness, few relevant studies of moodiness exist, especially if moodiness is defined in terms of intensity and fluctuations in mood rather than as a gloomy or depressed state. The existing studies suggest that (a) moodiness may be more characteristic of adolescence than adulthood, but not more than childhood and (b) that moodiness may be associated with the early stages of pubertal development, although the evidence for this is less consistent.

Larson, Csikszentmihalyi, and Graef (1980) used a time-sampling procedure to study mood intensity and mood variability during adolescence. Subjects carried electronic pagers for 1 week and, when signaled, answered questions about their mood, its intensity, the situation they were presently in, and recent events in that situation. Adolescents reported more rapid and more extreme swings in both positive and negative moods than did adults, even when analyses were done within specific situations. Similarly, Diener, Sandvik, and Larsen (1985) found a decline in reports of emotional intensity from late adolescence through adulthood.

In a more recent study, Larson and Lampman-Petraitis (1989) examined whether adolescent moods are more variable or more intense than those in childhood. They found little evidence of age differences in emotional variability among their 5th–9th graders. A weak positive correlation between age and variability was found only for girls and only on two of six mood scales. Grade was negatively correlated with extreme positive mood states but uncorrelated with extreme negative mood states. Similarly, Stapley and Haviland (1988) found that the frequency, duration, and intensity of moods were constant across Grades 5–11. A study by Bence (1990), however, suggests that rates of mood change may be greater in early adolescence than in later adolescence even if variability of mood does not change. Using spectral analysis to plot the timing of mood changes, she found that 7th graders' moods were more likely to change quickly than 11th graders' moods, and 11th graders' moods were more likely to change slowly than the moods of 9th graders.

These studies suggest small or no differences in emotional variability or intensity between late childhood or early adolescence and mid-adolescence; however, further investigation using younger age groups and using a variety of mood lability measures is necessary to determine whether moods are less stable or more intense in late childhood and early adolescence than they are earlier in childhood. This is critical, because hormonal changes begin quite early and the most marked independent impact of hormones on affective states like moodiness may well occur in late childhood or very early in adolescence, before children also experience several more socially ladened changes such as school transitions, outward pubertal changes, or changes in the degree of involvement with peers. The finding that the younger children in Larson and Lampman-Petraitis (1989) reported more intense positive moods than older children is consistent with this suggestion.

Does moodiness vary by pubertal stage? The results are mixed. Two studies found no evidence of a relation between pubertal status and self-assessed moodiness among early adolescents (Crockett & Petersen, 1987; Miller, 1988). Parent reports of girls' moodiness over the course of a day also did not differ by the girl's pubertal status (Miller, 1988). In contrast, when moodiness has been measured by looking at the range and variability of specific moods rated over several days, associations between pubertal development and moodiness have been detected. Buchanan (1991) found greater variability of negative mood states in 9- to 10-year-old pubertal girls than in same-age prepubertal girls when moods were measured 3 days a week for 4 weeks. Similarly, Susman, Nottelmann, and Blue (1983), who obtained 5 consecutive days of mood ratings, found that boys who were more advanced pubertally showed a greater range of moods than other boys. Pubertal status was not related to range of moods among girls.

Taken together, these studies suggest that moodiness is associated with some aspects of adolescent development. Is there any evidence that hormonal events are associated with moodiness during this time of life? Larson et al. (1980) stated that "mood swings [do] not appear to be . . . arbitrary discharges of internally generated drives" (p. 487) on the basis of evidence in their sample that mood variability was not strongly related to an individual's "control" (i.e., concentration and control of actions) or psychosocial adjustment (i.e., alienation from others, ego development, grades, number of friends and leadership).

(*text continues on page 85*)

Table 2
Summary of Studies That Have Examined Associations Between Puberty and Moods or Behaviors During Adolescence

Author	Measure	Subjects	Design[a]	Measure of puberty	Results
			Mood swings and mood intensity		
Buchanan (1991), Miller (1988)	Self-report on several moods 3 days a week for 4 weeks	52 girls, 9–10 years old	Cross-sectional	Self-report on a variety of pubertal indexes[b]	No difference in direct self- or parent reports of moodiness by pubertal stage. Pubertal girls, however, showed more intense and variable negative mood states over the course of 1 month than prepubertal girls.
Crockett & Petersen (1987)	Self-report of mood changes	253 girls and boys in Grades 6, 7, and 8	Longitudinal	Self-report on a variety of pubertal indexes	Pubertal status not related to frequent mood changes that one cannot explain or control.
Susman, Nottelmann, & Blue (1983)	Self- and mother report over 5 consecutive days	24 girls, 9–13 years; 34 boys, 10–14 years	Cross-sectional	Physician ratings of genital (boys) and breast (girls) development	More pubertally advanced boys had greater variability of moods (self-report only).
			Depression		
Baydar, Brooks-Gunn, & Warren (1989)	Self- and mother report	10–14-year-old girls followed for 4 years. n = 164 at Wave 1; n = 80 at Wave 4.	Longitudinal	Nurse or physician rating of Tanner breast stage[c]; self-reports of menarche	No effects of pubertal status on depression. Late-developing girls experienced declines in depressive affect over the course of the study.
Brooks-Gunn & Warren (1989), Warren & Brooks-Gunn (1989)	Self-report	100 girls, 10–14 years old	Cross-sectional	Physician rating of breast and pubic hair Tanner stages[c]	Pubertal stage not related to depressive withdrawal. Negative events more likely to be associated with depressive affect in premenarcheal girls than post menarcheal girls.
Crockett & Petersen (1987); Dorn, Crockett, & Petersen (1988)	Self-report	235 girls and boys, Grades 6, 7, and 8	Longitudinal	Self-report on a variety of pubertal indexes	Pubertal boys showed less sad affect than prepubertal boys in 7th and 8th grade. No effect of pubertal status among girls.
Nottelmann, Susman, Inoff-Germain, et al. (1987)	Self-report	52 girls, 56 boys, 9–14 years old	Cross-sectional	Physician rating of genital (boys) and breast (girls) development	Late-maturing boys reported more sad affect. No effect of pubertal status or timing for girls.
Paikoff, Brooks-Gunn, & Warren (1991)	Self-report	72 girls, 10–14 years, 5th–7th grade at Time 1; 11–15 years, 6th–8th grade at Time 2	Longitudinal	Nurse or physician rating on Tanner stage[c]	No effects of pubertal status on depression.
Petersen, Sarigiani, & Kennedy (1991)	Self-report	169 adolescents followed from 6th through 12th grade	Longitudinal	Age at peak height velocity	Girls who were early maturers had the highest depressive affect in 12th grade.
Simmons & Blyth (1987); Simmons, Blyth, & McKinney (1983)	Self-report	310 adolescents in 6th, 7th, 9th, and 10th grades (1987); 237 6th-grade girls (1983)	Cross-sectional and longitudinal	Self-report of menarcheal status and its timing (girls; peak height velocity and its timing (boys)	No relations between pubertal status or timing and depressive affect.
Susman, Nottelmann, & Blue (1983)	Self- and mother report	24 girls, 9–13 years old; 34 boys, 10–14 years old	Cross-sectional	Physician rating of genital (boys) and breast (girls) development	More pubertally advanced girls happier and calmer (self-report only); more pubertally advanced boys sadder (self-report only).

Table 2 (*continued*)

Author	Measure	Subjects	Design[a]	Measure of puberty	Results
			Energy level		
Buchanan (1991)	Self-report 3 days a week for 4 weeks	52 girls, 9–10 years old	Cross-sectional	Self-report on a variety of pubertal indexes	No difference in energy levels by pubertal status. Variability of energy across 1 month higher for pubertal than prepubertal girls.
Sonis et al. (1985)	Parent report	33 girls with TPP, age 6–11 years; 33 matched controls	Cross-sectional	Presence of TPP diagnosis	TPP girls reported to be more fatigued and more overtired.
Susman et al. (1983)	Self- and mother report, 5 consecutive days	24 girls, 9–13 years old; 34 boys, 10–14 years old	Cross-sectional	Physician rating of genital (boys) and breast (girls) development	More pubertally advanced boys and girls were more tired (self- and mother report).
			Restlessness and concentration		
Buchanan (1991)	Self-report 3 days a week for 4 weeks	52 girls, 9–10 years old	Cross-sectional	Self-report on a variety of pubertal indexes	Pubertal girls showed more variable restlessness over the course of 1 month. Levels of restlessness did not differ by pubertal status.
Sonis et al. (1985)	Parent report	33 girls with TPP, age 6–11 years; 33 matched controls	Cross-sectional	Presence of TPP diagnosis	TPP girls reported to do more daydreaming than controls.
Stone & Barker (1939)	Self-report	564 postmenarcheal, 387 premenarcheal girls, 11–15.5 years old, Grades 7 to 9	Cross-sectional	Self-report of menarcheal status	Postmenarcheal girls daydreamed more than premenarcheal girls.
			Irritability		
Dorn et al. (1988)	Self-report	253 girls and boys, Grades 6, 7, and 8	Longitudinal	Self-report on a variety of pubertal indexes	Advanced pubertal girls less likely to become upset than less mature or more mature girls.
Sonis et al. (1985)	Parent report	33 girls with TPP, age 6–11 years; 33 matched controls	Cross-sectional	Presence of TPP diagnosis	TPP girls reported to do more sulking, crying, and whining than controls.
			Impulsiveness		
Petersen & Crockett (1985, 1986)	Self-report	335 children in 6th–8th grade	Cross-sectional	Self-report on a variety of pubertal indexes	Best impulse control in girls around time of menarche. Among 6th graders, worst impulse control in girls 6–12 months premenarche. Among 8th graders, worst impulse control in girls postmenarche by 1 year. Late maturers had better impulse control than early-maturing or on-time girls.

(*table continues*)

Table 2 (*continued*)

Author	Measure	Subjects	Design[a]	Measure of puberty	Results
			Anxiety and worry		
Jones & Bayley (1971)	Psychological records, including observation measures and reputation scores	16 early-maturing and 16 late-maturing boys	Longitudinal	Skeletal growth	Late-maturing boys more tense, more busy, active, and talkative, than early maturers.
Peskin (1967)	Interviewers' ratings of behavior	22 early-maturing and 18 late-maturing boys, followed from 5–16 years; comparisons made of boys at equivalent maturational ages	Longitudinal	Onset: 1 year before detectable signs of puberty as measured by yearly photos; timing: skeletal age at chronological age 17	Early-maturing boys more anxious than late maturers.
Sonis et al. (1985)	Parent report	33 girls with TPP age 6–11 years; 33 matched controls	Cross-sectional	Presence of TPP diagnosis	TPP girls reported to worry more than controls.
Stone & Barker (1939)	Self-report	564 postmenarcheal, 387 premenarcheal girls, 11–15.5 years old, Grades 7–9	Cross-sectional	Self-report of menarcheal status	Premenarcheal girls showed more fear and worry.
Susman, Dorn, & Chrousos (1991)	Self-report	56 10–15-year-old boys and 52 9–14-year-old girls	Cross-sectional and longitudinal	Physician rating of genital (boys), breast (girls) development	Higher genital stage related to higher anxiety among boys in cross-sectional analyses.
			Aggression, behavior problems, and delinquency		
Brooks-Gunn, Warren, & Rosso (1988)	Self-report	152 girls, 10–13 years old, 5th–7th grade	Cross-sectional	Menarcheal status	Pubertal status interacted with negative life events to predict behavior problems: When negative events occurred, premenarcheal girls showed more behavior problems than postmenarcheal girls; the opposite was true when no negative life events occurred.
Duncan, Ritter, Dornbusch, Gross, & Carlsmith (1985)	Self- and teacher report	5,735 12–17-year-olds	Cross-sectional	Physician's rating of Tanner stage[c]	Early-maturing boys showed more deviant behavior than other boys (self-report only).
Magnusson, Stattin, & Allen (1985); Magnusson (1988)	Self-report	466 girls, Grade 3 through adulthood	Longitudinal	Age at menarche	Early-maturing girls were more deviant than late maturers in mid-adolescence (around age 14).
Mussen & Jones (1957)	TAT projective	16 early-maturing and 16 late-maturing boys at age 17	Longitudinal	Skeletal age	Early maturers showed more aggression, both overt and verbal.
Nottelmann, Susman, Inoff-Germain, et al. (1987)	Mother report	52 girls, 56 boys, 9–14 years old	Cross-sectional	Physician rating of genital (boys) and breast (girls) development	Negative relation between pubertal development and reports of externalizing (delinquent, aggressive, cruel) behavior for girls.

Table 2 (*continued*)

Author	Measure	Subjects	Design[a]	Measure of puberty	Results
			Aggression, behavior problems, and delinquency		
Paikoff et al. (1991)	Self-report	72 girls, 10–14 years, 5th–7th grade at Time 1; 11–15 years, 6th–8th grade at Time 2	Longitudinal	Tanner stage[c]	Girls at Stages 3 and 4 reported more delinquent behavior than those at Stages 1 and 2.
Peskin (1967) A	Interviewers' ratings of behavior	22 early-maturing and 18 late-maturing boys compared at equivalent maturational ages	Longitudinal	Onset: 1 year before pubertal signs as indicated in yearly photos; timing: skeletal age at chronological age 17	Early-maturing boys showed more frequent and intense temper tantrums than late maturers at pubertal onset.
B	TAT projective	Same boys compared at age 17	Longitudinal	Same as above	Early maturers had more themes of primitive aggression than late maturers.
Silbereisen, Petersen, Albrecht, & Kracke (1989)	Self-report	62 early-adolescent girls (mean 11.5 years); 193 middle-adolescent girls (mean 14.7 years)	Cross-sectional and longitudinal	Self-report of perceived pubertal timing	Early maturers in the middle-adolescent cohort had more contact with deviant peers than on-time maturers.
Simmons & Blyth (1987), Simmons et al. (1983)	Self-report and parent report, probation and truancy reports	310 adolescents in 6th, 7th, 9th, and 10th grades (1987); 237 girls interviewed in Grades 6, 7, 9, and 10 (1983).	Cross-sectional and longitudinal	Self-report of menarcheal status and its timing (girls); peak height velocity and its timing (boys)	Girls who were menstruating in 6th and 7th grades showed more behavior problems in school. No relation between pubertal status or timing and problem behavior for boys.
Sonis et al. (1985)	Parent report (Child Behavior Checklist)	33 girls with TPP, age 6–11 years; 33 matched controls	Cross-sectional	Presence of TPP diagnosis	TPP girls reported to do more externalizing (e.g., lying, stealing, fighting).
			Family relationships		
Anderson, Hetherington, & Clingempeel (1989)	Child, parent, and observer report	N = 153 families with a child age 9–13 years at the first assessment, subjects studied at three times over 2 years	Cross-sectional and longitudinal	Mothers' ratings on a variety of pubertal indexes	Cross-sectional results indicated lower warmth and higher conflict for pubertally advanced children in nondivorced families. Evidence for heightened conflict at the apex of puberty for boys in nondivorced families. Longitudinal analyses showed few of the same associations.
Garwood & Allen (1979)	Child report	130 White girls, 102 Black girls; 7th grade	Cross-sectional	Self-report of menstrual status	Postmenarcheal girls reported more problems with home and family.
Hill, Holmbeck, Marlow, Green, & Lynch (1985a); Hill & Holmbeck (1987)	Family report	100 7th-grade girls and their families	Cross-sectional	Menarcheal status (self- and parent report)	Perturbations between mothers and daughters around menarche; perturbations lasted if girl was an early maturer.

(*table continues*)

Table 2 (*continued*)

Author	Measure	Subjects	Design[a]	Measure of puberty	Results
			Family relationships		
Hill, Holmbeck, Marlow, Green, & Lynch (1985b); Hill & Holmbeck (1987)	Family report	100 7th-grade boys and their families	Cross-sectional	Observer ratings of physical development	More problems in mother–son relationships for boys at the peak of pubertal growth than for boys more or less physically mature.
Hill (1988)	Observation of family interactions	115 7th-grade girls and their parents	Cross-sectional	Self-report of menarche	Less yielding (more passive resistance) toward fathers and more interruptions in conversations with mothers with increasing pubertal maturity.
Inoff-Germain et al. (1988)	Observation of family interaction	30 boys, 30 girls, 9–14 years old	Cross-sectional	Physician's rating of Tanner genital (for boys) and breast (for girls) stage[c]	Pubertally advanced boys were less likely to show no anger when provoked.
Papini & Savage (1987)	Child report	279 7th, 9th, and 11th graders	Cross-sectional	Self-report on several indexes	"Transpubertal" adolescents reported higher conflict with parents over responsibility issues than did pre- or postpubertal adolescents.
Papini & Sebby (1987)	Child, mother, and father report	51 family triads, 7th graders (13–14 years old)	Cross-sectional	Self-report on a variety of pubertal indexes	Transitional phase of puberty predicted by more dissatisfaction in father–child relationships and by higher maternal control.
Papini & Sebby (1988)	Child, mother, and father report	63 family triads, 7th graders (13 years old)	Cross-sectional	Self-report on a variety of pubertal indexes	More conflict over leisure time and time management between parents and prepubertal or transpubertal children than between parents and children in the later stages of puberty.
Savin-Williams & Small (1986)	Child and parent report	133 families with 10–17-year-olds	Cross-sectional	Interviewer rating on physical maturity scale	More conflict with late-maturing boys (parent report only) and early-maturing girls (child report).
Simmons & Blyth (1987); Simmons et al. (1983)	Child report	310 adolescents in 6th, 7th, 9th, and 10th grades (1987); 237 6th-grade girls (1983)	Cross-sectional and longitudinal	Self-report of menarcheal status and its timing	Menstruating and early-developing girls more independent than other girls in the 6th and 7th grades. Effects of timing gone by Grades 9 and 10, with only a slight tendency for early maturers to still have more independence in 9th grade.
Steinberg & Hill (1978); Steinberg (1981)	Observation of family in decision-making situation	31 11–14-year-old boys and their parents	Cross-sectional Longitudinal	Interviewer rating on physical maturity scale	Temporary increase in conflict between mothers and sons in the early and middle stages of puberty.
Steinberg (1987a)	Child and parent report	27 11–14-year-old boys 204 families of firstborns age 10–15 years.	Cross-sectional	Observer rating of physical maturity	Increased pubertal development (for girls) and early timing of development (for boys) predicted conflict with mothers.
Steinberg (1988, 1989)	Child and parent report	157 firstborn children (aged 11–16 years) and their families assessed twice over a period of 1 year	Longitudinal	Observer rating of physical maturity	Parent–child conflict increased and parent–child closeness decreased with pubertal maturation.

Table 2 (*continued*)

Author	Measure	Subjects	Design[a]	Measure of puberty	Results
			Self-consciousness		
Blyth et al. (1981)	Self-report	274 boys, 7th grade	Cross-sectional	Rate of height growth	No relation between rate of height growth and self-consciousness.
Ruble & Brooks-Gunn (1982)	Self-report	639 girls, 5th–8th, 11th–12th grades	Cross-sectional	Self-report of menarcheal status (compared pre- and postmenarcheal girls in the same grade)	Postmenarcheal girls who felt unprepared for menarche reported more self-consciousness than postmenarcheal girls who felt prepared (true only for the 7th and 8th graders).
Simmons & Blyth (1987); Simmons et al. (1983)	Self-report	310 adolescents in 6th, 7th, 9th, and 10th grades (1987); 237 6th-grade girls (1983)	Cross-sectional and longitudinal	Self-report of menarcheal status and its timing (girls); peak height velocity and its timing (boys)	No relations between puberty and self-consciousness.
			Self-esteem and perceived competence		
Blyth et al. (1981)	Self-report	274 boys in 7th grade	Cross-sectional	Rate of height growth between 6th and 7th grade	With height and weight controlled, there was a positive association between rapid height growth and satisfaction with body and general self-esteem.
Duncan et al. (1985)	Self-report	5,735 12–17-year-olds	Cross-sectional	Physician's rating of Tanner stage[c]	Among boys, early maturers most satisfied with weight and height. Among girls, early maturers least satisfied with weight. All girls became more dissatisfied with weight as they matured.
Gargiulo, Attie, Brooks-Gunn, & Warren (1987)	Self-report	387 girls: 139 7th graders, 118 8th graders, 130 9th graders; 12–15 years old; 328 nondancers and 59 dancers	Cross-sectional	Mother ratings of Tanner stage[c]; self-report of menarche and perceived timing	On-time girls had more positive body images; body image decreased with breast development only for dancers.
Garwood & Allen (1979)	Self-report	130 White girls, 102 Black girls, 7th grade	Cross-sectional	Self-report of menarcheal status	Postmenarcheal girls had higher self-concept and better overall adjustment on a clinical self-concept scale; no difference on a counseling scale. Different patterns of self-concept emerged by five levels of menarcheal status, with girls in initial and middle stages scoring higher.
Mussen & Jones (1957)	TAT projective	16 early maturers, 17 late maturers; boys, age 17 years	Longitudinal	Skeletal age	Late maturers told stories with more negative characteristics about self.
Nottelmann, Susman, Blue, et al. (1987)	Self-report	52 girls, 56 boys, 9–14 years old	Cross-sectional	Physician's rating of genital (boys) and breast (girls) development	Late maturation was associated with more problems in self-image for boys only.

(*table continues*)

Table 2 (*continued*)

Author	Measure	Subjects	Design[a]	Measure of puberty	Results
			Self-esteem and perceived competence (*continued*)		
Simmons & Blyth (1987); Simmons et al. (1983)	Self-report	310 adolescents in 6th, 7th, 9th, and 10th grades (1987); 237 6th-grade girls (1983)	Cross-sectional and longitudinal	Self-report of menarcheal status and its timing (girls); peak height velocity and its timing (boys)	Early maturation positively associated with body image for boys and negatively associated with body image for girls. No effects of pubertal status or timing on global self-image.
Simmons, Blyth, Van Cleave, & Bush (1979)	Self-report	798 girls followed from 6th to 7th grade	Longitudinal	Self-report of menarcheal status (girls); rate of height growth (boys)	Puberty not related to overall self-esteem. Girls who had started to menstruate and also begun to date had lower self-esteem, especially after the transition to junior high school.
Simmons, Burgeson, Carlton-Ford, & Blyth (1987)	Self-report	447 6th-grade boys and girls at the transition to junior high school	Longitudinal	Onset of menstruation for girls; peak height velocity for boys	Cumulative change (of which pubertal change was one potential change) had a negative impact on self-image.
Tobin-Richards & Kavrell (1984)	Self-report	208 7th- and 8th-grade boys and girls	Cross-sectional	Self-report on a variety of pubertal indexes	More pubertally advanced children had lower self-images; effect was mediated by weight, satisfaction with weight, body image, peer relationships, and athletic involvement.
Tobin-Richards, Boxer, & Petersen (1983)	Self-report	70 girls, 52 boys; 7th grade	Cross-sectional	Self-report, perceived timing	Early-maturing boys perceived themselves more positively in terms of body image than did on-time and late-maturing boys; on-time girls and girls with more developed breasts had the highest body image among girls.

Note. TPP = true precocious puberty, TAT = Thematic Apperception Test (Murray, 1938).
[a] The use of *longitudinal* to describe studies of pubertal development indicates studes in which at least some of the analyses incorporated measures of pubertal development and behavior at separate points in time. It does not necessarily indicate that the authors looked at changing pubertal status in relation to the behaviors of interest; in fact, few of the studies have taken this approach (see Simmons, Burgeson, Carlton-Ford, & Blyth, 1987, for an exception). [b] In most cases, this indicates use of the Pubertal Development Scale (Petersen, Crockett, Richards, & Boxer, 1988) or an adaptation of this measure. [c] Tanner stages refer to stages of sexual maturation developed by Tanner (1962).

These lack of associations suggested to the authors that there was no "general turmoil" also causing mood problems. This does not necessarily indicate, however, that moods and their fluctuations do not have some basis in internal, physiological events. Hormone changes and imbalances might contribute to mood changes or fluctuations without endangering the child's overall adjustment. Perhaps only in cases in which adolescents are having emotional or psychological problems of a more extreme nature or in which environmental situations are particularly stressful would internal states contribute to problems with control and psychosocial functioning.

Just as little behavioral research has focused directly on mood intensity and mood changes during adolescence, there is very little in the adolescent hormone literature that examines these variables. Studying girls only, Buchanan (1989) found FSH to be the only significant hormonal predictor of variability in moods over the course of 1 month. FSH concentrations were positively related to mood variability and intensity, although the relation with mood intensity disappeared when controlling for pubertal status. Direct self-reports of moodiness over the course of the day (in contrast to moodiness measured as change in specific moods reported over several days) showed different associations with hormones: Lower estradiol and higher variability of estradiol and FSH predicted more moodiness in this case.

Although data on moodiness are sparse, they are provocative enough to suggest this is an area worth pursuing. Further work is obviously needed to answer critical questions: Are adolescents truly different from younger children in terms of moodiness? Is puberty in fact associated with mood fluctuations, and, if so, to what degree is this because of hormonal activity or to other aspects of pubertal development? For instance, is moodiness most marked in the early stages of physical pubertal development because, initially, a changing body leads to a changing sense of self, perhaps producing some psychological confusion that is reflected in moods? Or perhaps puberty is associated with mood swings because a child is now treated differently by adults and peers and may have trouble adjusting to different expectations. Note that all effects of age or pubertal status on moodiness were found in studies that measured moodiness by *repeatedly* measuring moods, rather than by asking children (or parents) directly about their moodiness. This suggests that adolescents themselves may not always be aware of the fluctuations in their moods. Or, because self- and parent reports of moodiness in Miller (1988) were based on moodiness within a day, mood swings may take longer to occur.

Depression. Very low concentrations of estrogen, or drops in the concentration of estrogen in relation to accustomed concentrations (as indicated in the menstrual, postpartum, or menopausal literature), have been associated with depression and related symptoms. Moderate-to-high concentrations of estrogen, on the other hand, have been associated with more positive moods (e.g., Asso, 1986; deLignieres & Vincens, 1982; Melges & Hamburg, 1977). Because girls approaching adolescence are not accustomed to high concentrations of estrogen, it is unlikely that prepubescent lack of estrogen is associated with negative mood. If it were, childhood depression would be common. In fact, early rises of estrogen and other hormones may initially be upsetting and therefore related to negative mood either because they are uncharacteristically high or because they are fluctuating more irregularly. Over time, as the body adapts to higher concentrations of estrogen and as cycles become more regular, the body may become more sensitive to decreases in this hormone. Symptoms of sadness or withdrawal may then occur during low estradiol phases.

Assessments of the prevalence of depression among early adolescents vary across studies. Figures derived from self-reports of depressed or sad affect range from 8.6% in a sample of junior and senior high school students to 33% in a sample of only junior high school students (Albert & Beck, 1975; Kaplan, Hong, & Weinhold, 1984; Rutter et al., 1976). Somewhat higher estimates of significant unhappiness (up to 50%) emerge when psychiatrists' assessments are used rather than self-report (e.g., Rutter et al., 1976). But how does the prevalence of depression in adolescence, especially early adolescence, compare with that at younger and older ages? In clinical samples of children using either parents' or psychiatrists' reports, depressive symptoms increase in frequency from childhood through adolescence both across and within adolescents, especially for girls and among persons who have experienced some form of depression during childhood (Achenbach & Edelbrock, 1981; Bettes & Walker, 1986; Rutter, 1986; Rutter et al., 1976).

Data from nonclinical samples of adolescents are less consistent but also point to increases in depressed affect throughout the adolescent years. Several studies report an increase in depressive affect, or dysphoric moods, for both sexes (Elliott, Huizinga, & Menard, 1989; Jessor & Jessor, 1977; Kaplan et al., 1984; Larson & Lampman-Petraitis, 1989; Rutter, 1980; Simmons, Rosenberg, & Rosenberg, 1973); other studies find the increase especially, or only, for girls (Albert & Beck, 1975; Jorm, 1987; Magnusson, 1988; Petersen et al., 1991; Rutter, 1986). One study found an increase only for boys (Susman, Inoff-Germain, et al., 1987). Some studies, however, report no age differences for either sex (Baron & Joly, 1988; Kandel & Davies, 1982; Simmons & Blyth, 1987) or among girls (Brooks-Gunn & Warren, 1989; Paikoff, Brooks-Gunn, & Warren, 1991; Susman, Inoff-Germain, et al., 1987). Two studies have actually found a decline in sad affect with increasing grade in school (Brooks-Gunn, Rock, & Warren, 1989; Petersen & Crockett, 1985). Baydar, Brooks-Gunn, and Warren (1989), studying girls, found evidence for different age trends depending on the scale of depression used: Using the Depressed–Withdrawal scale of the Youth Behavior Profile (Achenbach & Edelbrock, 1983, 1987), depression increased with age, and the probability of increase was constant from age 11 through age 16 years. Using the Center for Epidemiological Studies Depression Scale (Radloff, 1977), the probability of increase was highest between ages 13 and 14 years. Using either scale, the percentage of girls classified as depressed did not increase with age.

The reason for the differences between studies is not obvious. All studies had reasonable sample sizes, although most of the large longitudinal studies indicate an increase in depressive affect, at least for girls, over the adolescent years (e.g., Elliott et al., 1989; Jessor & Jessor, 1977; Magnusson, 1988; Petersen et al., 1991; Rutter, 1986). Studies that find no age differences, or decreases with age, tend to have more restricted age ranges

Table 3
Designs of Studies That Have Examined Associations Between Hormones and Behavior at Adolescence

Laboratory	Subjects	Measurement of hormones	Measurement of behavior	Design
		Carolina population center		
Udry & Talbert (1988)	102 boys, 78 girls; Grades 8–10; all girls were postmenarcheal	For boys, single samples of blood drawn between 3:00 and 7:00 p.m.; for girls, blood samples drawn on two separate occasions, once in the luteal phase (Days 5–9) and once in the follicular phase (Days 18–22) of their menstrual cycle	Self-report on adjective checklist administered during the same visit in which blood samples were taken	Cross-sectional
		Educational testing service		
Brooks-Gunn & Warren (1989); Warren & Brooks-Gunn (1989)	103 girls 10–14 years old (mean 12.6 years old)	Blood samples drawn once in late afternoon	Self- and mother reports on scales on affect and behavior, assessed same day as blood samples were drawn.	Cross-sectional
Paikoff, Brook-Gunn, & Warren (1991)	72 girls (subset of sample in previous enty)	Same as above	Same as above	Longitudinal
		University of Michigan		
Buchanan (1989, 1991); Eccles et al. (1988)	25 girls, 9–10 years old; 21 boys, 11–12 years old	Urine and saliva samples collected 3 mornings a week for 4 weeks; progesterone measured in saliva; estradiol, follicle-stimulating hormone, and luteinizing hormone measured in urine	Self-report of daily moods and behavior each evening of the days hormones were collected; self-report on a battery of psychosocial measures once at the end of the 4 weeks of data collection	Cross-sectional
		National Institutes of Health/National Institute of Mental Health		
Nottelmann, Susman, Blue, et al., (1987), Nottelmann, Susman, Inoff-Germain, et al. (1987), Nottelmann, Inoff-Germain, Susman, & Chrousos (1990), Susman et al. (1985), Susman, Inoff-Germain, et al. (1987), Susman, Nottelmann, et al. (1987), Susman, Dorn, & Chrousos (1991)	56 boys, 52 girls; 9–14 years old; Tanner Stages 1–5	Blood drawn three times between 8:00 a.m. and 10:00 a.m.; average hormone concentration over the three times used in analysis	Adolescent self-ratings of self-image (SIQYA); parent ratings of behavior problems (CBC) within a mean 2.3 days of blood drawings	Subjects examined longitudinally at 6-month intervals; most reports use cross-sectional data from first time of measurement, although some include longitudinal data (e.g., Nottelmann, Cutler, & Chrousos 1986; Susman et al., 1991).
Inoff-Germain et al. (1988)	30 boys and 30 girls (subset of above)	Same as above	Observation of family interaction	Cross-sectional

Table 3 (*continued*)

Laboratory	Subjects	Measurement of hormones	Measurement of behavior	Design
		Scandanavian studies		
Mattsson, Schalling, Olweus, Löw, & Svensson (1980)	40 boys, 14–19 years old (mean 16.2 years old) from an institution for youth offenders; compared these delinquent boys with sample from Olweus et al. (1980) described above	Blood samples taken three times within a 6–8-day period	Same as above	Cross-sectional
		University of Wisconsin		
Steinberg (1987b)	157 firstborn girls and boys, 11–16 years old	Measured testosterone from a sample of saliva	Adolescent report of emotional autonomy and parent–child conflict (frequency and intensity), cohesion, and decision making taken at the same home visit in which saliva was collected	Cross-sectional

Note. SIQYA = Self-Image Questionnaire for Young Adolescents (Petersen, Schulenberg, Abramowitz, Offer, & Jarcho, 1984), CBC = Child Behavior Checklist (Achenbach & Edelbrock, 1983).

(including some that focus only on early adolescence) or a cross-sectional design, or both. In addition, although scales may appear similar in content, subtle differences may influence the results obtained and conclusions drawn, as indicated by Baydar et al.'s (1989) finding that age trends in depressive affect differed depending on the self-report scale used. In addition, the varying results may suggest that age differences are small and that other factors are more important than age in predicting depression.

In several studies, pubertal status was unrelated to depression or depressive affect, at least for girls (Baydar et al., 1989; Brooks-Gunn & Warren, 1989; Crockett & Petersen, 1987; Dorn, Crockett, & Petersen, 1988; Nottelmann, Susman, Inoff-Germain, et al., 1987; Paikoff et al., 1991; Simmons & Blyth, 1987; Simmons, Blyth, & McKinney, 1983; Warren & Brooks-Gunn, 1989). Two studies, however, reported evidence for an association between pubertal status and depression or unhappiness that varied by sex. In Susman et al. (1983), when happiness was rated on a daily basis, more pubertally advanced girls were happier than less advanced girls, but more mature boys were sadder than less mature boys. In contrast to this latter finding, Crockett and Petersen (1987) found that boys' reports of sad affect decreased with increasing pubertal status.

Several studies suggest that timing of puberty is more important than pubertal status per se. These studies suggest that early maturation can be detrimental for girls but beneficial for boys; in contrast, late maturation may be beneficial for girls and difficult for boys. Petersen et al. (1991) found that girls who were early maturers in early adolescence reported the highest levels of sad affect in 12th grade, in comparison with girls who were on-time or late maturers. Baydar et al. (1989) reported that late-maturing girls showed reductions in depressive affect over the course of adolescence. Among boys, Nottelmann, Susman, Inoff-Germain, et al. (1987) found that sad affect was predicted by a combination of older age and less physical maturation, suggesting that late-maturing boys experience more sadness than boys who mature early or on time, at least in the early-to-mid-adolescent years. In contrast to these studies, Simmons et al. (1983; Simmons & Blyth, 1987) found no effect of pubertal timing on depressive affect among girls or boys, even when extreme groups of early and late developers were identified.

Taken together, these studies suggest that children, especially girls, may be more vulnerable to depressive affect or sadness during the adolescent years than during childhood, although increases may occur over several years and may not be large during early adolescence. Depression as a clinical syndrome is, however, more common, more intense, and of longer duration in middle adolescence than it is at earlier ages (also see Petersen & Craighead, 1986; Strober, 1986). For example, suicide increases slightly in early adolescence and again even more sharply after age 15 (Schaffer & Fisher, 1981). In an analysis of depression and other psychopathological states, Strober (1986) suggests that adolescence may be a period of vulnerability for individuals with a propensity toward clinical problems but that for the majority of adolescents such problems do not arise.

As for the role of pubertal development, physical status may have some influence on feelings of happiness and sadness on a daily basis (Susman et al., 1983), but generally it appears unre-

lated to depression. Indications that the timing of pubertal development is important suggest that expectations or context may play an important part in puberty's effects on depressed mood, but the different findings across studies suggest small and inconsistent effects, perhaps because of variations in the subjective meaning of pubertal timing. Evidence that pubertal status might affect the link between negative life events and depression comes from Brooks-Gunn and Warren (1989): Negative life events were more likely to be associated with depressive affect in premenarcheal girls than in postmenarcheal girls. Perhaps correlates of pubertal development such as more or stronger friendships (Paikoff & Brooks-Gunn, 1990b), or higher expectations for mature behavior from others, provide social supports or psychological maturity that facilitate the postpubertal girls' ability to cope effectively with adverse circumstances (see also Brooks-Gunn et al., 1988).

What is the direct evidence for hormone–depression relations in adolescence? The studies done to date yield a quite mixed set of findings, suggesting that these relations will be complex and dependent on a variety of factors. Concerning androgens and estrogens, Susman et al. (1985; Susman, Dorn, & Chrousos, 1991; Susman, Inoff-Germain et al., 1987) found that boys with low gonadal activity (defined by low-for-age estrogen and low-for-age ratio of testosterone to estradiol [T/E2] and high-for-age androstenedione reported more sad affect. When hormone concentrations were standardized within sex and age was controlled, the relation between the sex steroids and affect disappeared (Susman et al., 1985), suggesting that high or low concentrations of hormones for one's age are more important than high or low concentrations simply for one's sex.

In seemingly contradictory findings from the same laboratory, Nottelmann et al. (1985) reported that lower estradiol and a lower ratio of testosterone to estradiol were related to self- (for estradiol) and mother (for T/E_2) reports of greater happiness among boys. In this report, however, happiness was measured daily for 5 days. Perhaps daily reports of happiness differ from an overall measure of emotional tone (sad affect) on a one-time self-image assessment, although a positive correlation between the two would be expected. In another study that used repeated measures of mood over several days, positive mood in boys was related weakly to lower LH concentrations when a between-subjects analysis strategy was used (Eccles et al., 1988). When hormone–mood relations were examined within subjects, this relation did not emerge, and associations between hormones and mood varied in direction across individuals.

The National Institutes of Health/National Institute of Mental Health group turned up fewer concurrent relations between androgens and estrogens among girls than among boys. At one time of measurement, low concentrations of the adrenal androgen DHEAS were related to increased depression and withdrawal (Nottelmann, Inoff-Germain, Susman, & Chrousos, 1990; Nottelmann, Susman, Blue et al., 1987; Nottelmann, Susman, Inoff-Germain et al., 1987), whereas high-for-age FSH was related to more sad affect (Susman et al., 1985). Again, this latter relation only emerged when hormone levels standardized for age (within sex) were entered into the regression equation and not when levels standardized for sex were entered along with age as a control. A year later, girls' sad affect was predicted by concurrent high testosterone and high cortisol concentrations (Susman et al., 1991).

Concurrent associations between estrogen and depressive affect among girls have been reported by Brooks-Gunn and her colleagues (Brooks-Gunn & Warren, 1989; Paikoff et al., 1991; Warren & Brooks-Gunn, 1989). Among 10–14-year-olds, estrogen was positively associated with depressive affect, but only for girls in the early stages of puberty (and thus the stages characterized by the most rapid rise of the hormone). This finding emerged even when age was controlled. In longitudinal analyses, the curvilinear association between hormones and depressed affect was found to persist over the course of 1 year, although a linear relation (i.e., estradiol positively related to depression over all pubertal stages) was found when a different measure of depressive affect was used (Paikoff et al., 1991). Eccles et al. (1988), studying younger girls (9–10 years old), reported a positive between-subjects' relation between estrogen concentrations and positive mood measured over the course of a month. In within-subject analyses, estradiol and LH were both related to positive mood, but the direction of effect varied across individual girls.

In two studies that examined hormone–mood relations longitudinally, preexisting depression was more strongly related to later depression than were preexisting hormone levels (Paikoff et al., 1991; Susman et al., 1991). Both of these studies also examined interactions between hormones and prior depressive affect to see if hormonal associations with depression varied as a function of earlier depression. The interactions were not significant in Paikoff et al. (1991), and although they were not reported as significant in Susman et al. (1991), there were several interactions in this latter study that approached significance. These interactions were positive (i.e., stronger hormonal effects for girls with higher previous depression) for girls and negative for boys.

It is evident from this summary that relations between hormones and depression or happiness at adolescence are not necessarily the same as relations among these variables in adults. The emerging evidence suggests that some kind of adaptation occurs during adolescence. Adaptation may be especially difficult if concentrations rise earlier or higher than is typically the case in development and the body does not have time to gradually adapt to the new concentrations (Susman, Inoff-Germain et al., 1987; Susman et al., 1985). The lack of evidence for consistent or linear increases in depression during early adolescence, or in relation to hormones, suggests that any search for relations between adolescent development in general, or hormones in particular, and depressed mood needs to take other factors into account. For example, evidence that depressive problems are especially likely to increase at adolescence for already disturbed children (Achenbach & Edelbrock, 1981; Bettes & Walker, 1986; Rutter et al., 1976) suggests that if pubertal hormone changes do influence depression, the effects may be most pronounced for adolescents already prone to psychological problems or in environments likely to elicit a depressive reaction. Although such interaction effects did not emerge in Paikoff et al. (1991) and were not strong or consistent in direction in Susman et al. (1991), we believe such hypotheses are worth further exploration. Whether the tendency toward psychologi-

cal disturbance is biologically or environmentally based may not be the critical issue; hormonal upset may simply increase vulnerability.

Future studies also need to assess whether there are cycles of less extreme sadness associated with hormones that are not being picked up with current measures. Additional benefits might accrue from examining hormone lability and regularity. Last, for all adolescents, many social and cultural transitions take place, and such transitions are associated with psychological change (e.g., Eccles & Midgley, 1988; Simmons & Blyth, 1987). Thus, any attempt to fully explain adolescent depression must also take into account sociocultural changes.

Energy level. In general, androgens and estrogens are positively related to activity level in nonhuman animals (e.g., Beatty, 1979) and possibly in adult humans (Coppen & Kessel, 1963; Persson et al., 1983; Southam & Gonzaga, 1965). Do rising hormones during puberty, then, lead to increases in energy? Do fluctuations of these hormones lead to shifting energy levels?

First we look at the evidence for changes in energy level with age and pubertal status. The little evidence there is suggests that adolescents may have less energy and experience more fatigue than other age groups and that pubertal development may play a role in this. For example, in Larson et al. (1980), high school students reported more extreme swings in alertness/drowsiness and activity/passivity and lower average levels of activation (activity, alertness, strength) than adults. Similarly, in Achenbach and Edelbrock (1981), parents of disturbed adolescents were more likely to report excessive sleeping and underactivity by their adolescents than parents of younger disturbed children, and parents of both the disturbed and nondisturbed children were more likely to report hyperactivity and sleeping little for younger children.

Findings regarding pubertal development and energy levels lend some support to decreasing energy with increasing development. For example, parents were more likely to report problems with overtiredness in their daughters if their daughters were experiencing precocious puberty than if their daughters were not (Sonis et al., 1985). Similarly, in a sample of normally developing children, both boys and girls from 9 to 14 years of age were more likely to rate themselves as tired (rather than energetic) if they were in the later stages of puberty (Susman et al., 1983). On the other hand, among 9- and 10-year-old girls, there was no difference in energy level by pubertal status, although variability in energy across 1 month was slightly higher in pubertal (as opposed to prepubertal) girls (Buchanan, 1991).

Reported hormone–behavior relations among adolescents are also counter to expectations: Controlling for age and pubertal status, boys with lower androstenedione rated themselves as less tired and more energetic; boys with lower testosterone were rated in the same way by their mothers (Nottelmann et al., 1985). An endocrine profile of high androstenedione and low DHEAS, however, was related to mother reports of hyperactivity in boys (Nottelmann, Susman, Blue, et al., 1987; Nottelmann, Susman, Inoff-Germain, et al., 1987). No relations were found for girls.

Complex and inconsistent relations have also emerged between hormone concentrations and the daily energy level of early adolescents in the University of Michigan study (e.g., Buchanan, 1989; Eccles et al., 1988). Even though this sample is quite young in terms of both age and pubertal maturation, hormone–energy relations differed by pubertal status. For example, FSH concentration was negatively related to energy levels among pubertal boys; in contrast, LH was negatively related to energy levels but only among midpubertal girls (Eccles et al., 1988). These results emerged in between-subjects analyses but not in within-subject analyses. Finally, FSH concentrations were positively related to girls' variability in energy across the month (Buchanan, 1989).

As children and adolescents adjust to changing hormone concentrations, the general consequence may be more fatigue, or at least more unpredictable levels of energy. After adjustment to rising and pulsing hormones has occurred, positive associations between hormone concentrations and energy levels might occur. Alternatively, children who experience higher concentrations of hormones may expend more energy and eventually become more tired. This may explain why androstenedione was positively related both to tiredness and to hyperactivity.

Restlessness and concentration. It has been suggested that adolescents tend to daydream and cannot concentrate for long periods. Is this true, and is there any reason to believe that fluctuating hormones are to blame? Following the argument made earlier for mood variability, if estrogen increases activation and excitability, fluctuations of estrogen could cause fluctuations in attention span and restlessness, behaviors potentially linked to degree of excitability.

In support of the belief that adolescents may have problems concentrating, Larson et al. (1980) found some of the largest differences between adolescents and adults in the area of concentration. Responses to questions about level of concentration, difficulty concentrating, wish to be doing something else, and feelings of control over actions all suggested lower levels of concentration among high school students than adults. Furthermore, self-reported concentration changed more dramatically from one sampling time to the next among the adolescents.

Do adolescents also have more trouble concentrating than preadolescents? One of the few relevant studies suggests not: Parents of younger children reported that their children had more problems concentrating than did parents of older children; for the mid-to-late-childhood period, parents reported more daydreaming only for the older clinical children (Achenbach & Edelbrock, 1981). Thus, again, the picture is incomplete, and longitudinal research is needed to fill the gaps in understanding the progression of ability to concentrate with age.

How is puberty related to concentration? The little available research provides some evidence of increased restlessness and lowered concentration with pubertal development. Stone and Barker (1939) noted more daydreaming and imaginative activity in postmenarcheal girls than in premenarcheal girls of the same age. Similarly, according to parent reports, girls with precocious puberty daydreamed more than their prepubertal peers (Sonis et al., 1985). These studies are not ideal, however. The first is quite old, and the second confounds pubertal development with early pubertal development. Other evidence suggests that whereas pubertal girls may not be more restless on the

whole than prepubertal girls, their levels of restlessness vary more from day to day over 1 month (Buchanan, 1991).

In the one study that examined hormones and restlessness, only girls were considered, and FSH concentrations were positively related to variability in restlessness over 1 month (Buchanan, 1989). Restlessness as an outcome as not been measured explicitly in any other studies of hormones and behavior. There is an obvious need for more research in this area before any conclusions can be drawn.

Irritability. Although some studies of the menstrual cycle and moods have suggested a hormonal link with irritability, the evidence is questionable. But stereotypes of adolescents include the view that they are more irritable than other age groups. Unfortunately, there is little evidence addressing the question of whether irritability is any more characteristic of adolescence than of childhood or adulthood or whether it is associated with hormonal events. Very few studies of adolescent moods or behavior even assess irritability. The one that comes closest suggests that irritability is not necessarily more prevalent in adolescence than at younger ages. In Achenbach and Edelbrock (1981), younger children were more apt to whine, cry a lot, and be stubborn, sullen and irritable than adolescent children. In contrast, parents of older children more often reported that their children refused to talk.

There is also very little work on pubertal development and irritability, and the studies that do exist are not ideal for addressing the question of whether the two are related. Sonis et al. (1985) found that parents of girls with true precocious puberty (TPP) reported more sulking, crying, and whining than parents of normal girls of the same age. It is not clear in this study if the behavior differences were due to pubertal development alone or the fact that pubertal development was occurring at such an early age. Dorn et al. (1988) reported that in a sample of normally developing girls, advanced (Stage 4 of 5; Tanner, 1962) girls had less of a tendency to become upset than midpubertal (Stage 3) or postpubertal (Stage 5) girls in the eighth grade. In summary, although the data presented do not discount a relation between pubertal development and irritability, further work is needed to demonstrate convincingly that such a link exists.

Data relevant to the question of whether hormones are linked to irritability come from Olweus et al. (1980). In their study of 16-year-old boys, higher testosterone concentrations predicted lowered frustration tolerance, suggesting that testosterone might be linked to irritability or impatience in frustrating situations. Among younger children studied at the University of Michigan, positive relations between LH and anger–impatience were found for boys (Eccles et al., 1988). These data are few but suggest that increased hormonal concentrations may be related to irritability during adolescence among boys.

Impulsiveness. There is some evidence that testosterone is associated with a tendency toward impulsive behavior in college-age men (Daitzman et al., 1978; Daitzman & Zuckerman, 1980). But are there increases in impulsiveness at adolescence that might be associated with increasing hormones? Most research involving children and adolescents indicates no age differences in impulse control (Achenbach & Edelbrock, 1981; Susman, Inoff-Germain, et al., 1987), although a comparison of adolescents with adults suggests that thrill seeking and disinhibition—tendencies that have an element of impulsiveness—are higher in adolescence than in adulthood (Zuckerman, Eysenck, & Eysenck, 1978). Nonetheless, a minority of boys report problems with impulsiveness (Douvan & Adelson, 1966), and those who do are most likely to recall them from their early-adolescent years (Douvan & Adelson, 1966; Offer, 1969; Offer & Offer, 1975). In a longitudinal study, Abramowitz, Petersen, and Schulenberg (1984) found somewhat better impulse control in seventh grade than in sixth or eighth grade. Given the early-adolescent age range of their sample, we do not know how these levels of impulse control compare with those of younger and older children. Thus, impulsiveness may be lower in the early-adolescent years than in the late-adolescent years, but at present there is no evidence that early-adolescent children are more impulsive than younger children.

Petersen and Crockett (1986) suggest that impulse control improves around the time of menarche. In their study, impulsivity was not linearly associated with increasing pubertal status. Rather, they found that among sixth graders, the worst impulse control was in girls who were 6–12 months before menarche, whereas postmenarcheal girls showed the best impulse control. Eighth-grade girls showed the worst impulse control if they were postmenarcheal by 1 year. Girls who were generally late in developing also showed better impulse control than early or on-time developers (Petersen & Crockett, 1985).

Clearly there is not much research on associations between age or puberty and impulse control, although more studies look at developmental trends in behaviors potentially associated with impulsivity (e.g., aggression, behavior problems). These will be reviewed later. The evidence reviewed here suggests some fluctuations of impulsiveness with adolescent development, although perhaps not a linear increase.

Evidence that adolescent hormones are associated with impulsiveness during adolescence focuses on girls. As we noted above, impulsivity may increase in girls just before the onset of menarche (Abramowitz et al., 1984; Petersen & Crockett, 1986). This increase may be associated with the increasing, yet still unstable, concentrations of estrogen. Brooks-Gunn and Warren (1989; Warren & Brooks-Gunn, 1989) found a negative relation between estrogen and impulse control in the early stages of female puberty. Similarly, Nottelmann, Susman, Inoff-Germain, et al. (1987) found a relation between higher LH and problems in impulse control among girls. This latter study found no relation between estradiol and impulse control, but higher concentrations of LH may co-occur with higher (or more variable) estradiol. In boys, lower DHEAS was related to more problems with impulse control; testosterone was not associated with impulse control (Susman, Inoff-Germain, et al., 1987).

These studies provide some evidence for adjustment or irregularity effects of hormones: Estrogen and a tendency toward impulsivity may be linked early in girls' development, when estrogen is rising most rapidly and when cycles of hormones are still irregular. The one study of hormones and impulse control in boys, and studies of hormones and aggression (see below), suggests that testosterone is less important with regard to behavior in early adolescence than are the adrenal androgens.

Anxiety. Anxiety may be related to very low or very high

concentrations of estrogen in adults, especially when progesterone is low (deLignieres & Vincens, 1982). Do the increased and uncustomary concentrations of estrogen or other hormones during adolescence lead to increased anxiety?

The available research suggests that anxiety may be higher in the 13–15-year age range than in the years immediately before and after it. For example, among 4–16-year-olds in Achenbach and Edelbrock (1981), 8–9 and 14–15-year-olds were reported by their parents to worry more than other age groups. Similarly, in a broad-aged (9–60 years), cross-sectional study conducted in Japan, self-reports of anxiety symptoms such as shortness of breath, heart palpitations, recurrent headaches, and faintness peaked around the age of 13–15 (Abe & Suzuki, 1986). In contrast, Susman, Inoff-Germain, et al. (1987) found no age differences in self-reported anxiety among 9–14-year-old boys and girls. Given that anxiety was highest in the 8–9- and 13–15-year age range in the other studies, Susman, Inoff-Germain, et al.'s subjects may have fallen within an age range in which age differences were small and not easily detectable.

Evidence for the effects of pubertal status on anxiety is mixed, although there are indications that off-time development, especially early development, may be anxiety provoking. Early timing of maturation was associated with higher anxiety for boys in Peskin (1967) and for girls in Sonis et al. (1985). Peskin's finding that cautiousness and anxiety were more marked in early-maturing boys at the time of pubertal onset led him to believe that early maturers were more disrupted by the burgeoning pubertal impulses provoked by hormonal activity. Late-maturing boys, who had more time to mature psychologically and socially before hormonal upsets, were better able to manage the disruptions, thus showing less anxiety at pubertal onset. Jones and Bayley (1971), on the other hand, suggested that late development would be associated with more anxiety: Late-developing boys in their sample were rated as more tense, talkative, and active than early maturers. Their data, however, are now quite old (collected before 1950), and it is not clear whether their results reflect differences in anxiety or differences in activity level or extraversion.

Only two studies report data on anxiety and pubertal status (apart from timing), and one is quite old. Stone and Barker (1939) found that premenarcheal girls expressed more fear and worry than postmenarcheal girls. Susman et al. (1991) found higher anxiety among 10–15-year-old boys who were further along in puberty. Textbook accounts and reviews of clinical anxiety disorders claim that the frequency of clinical anxiety reactions increases from the beginning of puberty through young adulthood (e.g., Chapman, 1974; Petersen & Craighead, 1986). Thus, there is some evidence that anxiety is higher in adolescence (particularly around age 13–15 years) than in childhood and that off-time pubertal development is associated with higher anxiety levels than on-time development. The age differences reported are based on cross-sectional research, however, and the studies of pubertal development are all based on data from an earlier historical period in which pubertal development may have meant something different than it does today.

Is there any evidence in the adolescent hormone–behavior literature that supports a link between hormones and anxiety, perhaps only or especially among early developers? Not much. Olweus, Mattsson, Schalling, and Löw (1980, 1988) found no relation between testosterone concentrations and anxiety in their sample of 16-year-old boys. This does not tell us, however, whether one might find a relation among boys earlier in adolescence or boys who are early maturers. Perhaps by age 16, boys have already adjusted to the major hormonal changes of puberty. Susman, Inoff-Germain, et al. (1987), however, also found no relation between any hormone (gonadal, adrenal, or sex steroid) and self-report ratings of nervousness measured over 5 consecutive days among 9–14-year-old boys or girls. In contrast, Susman et al. (1991) did find evidence of some associations between hormones and anxiety when using a psychiatric assessment technique, rather than nervousness during the day, to measure anxiety. In this case, higher androstenedione was related to higher anxiety for boys, but only when age and pubertal stage were not controlled. In longitudinal analyses, higher adrenal androgens (DHEA and androstenedione) were related to higher anxiety for boys, whereas either higher LH or lower DHEAS (depending on the controls used) was related to higher anxiety among girls. In addition to these main effects, there were indications of interactions between preexisting depressive symptoms and hormone levels in predicting later anxiety, although these were not statistically significant considering the large number of analyses conducted.

Once again, high adrenal activity was related to negative symptoms among early-adolescent boys. The lack of a relation between testosterone and anxiety among boys later in puberty lends support to the hypothesis that it is mainly early hormonal changes that are linked with anxiety. Whether hormone–anxiety relations vary depending on the timing of puberty, as suggested by Peskin (1967), has not been explicitly examined. This research suggests, however, that measures and time lags used in assessing hormone–behavior links need careful consideration; different results emerged within the same sample when these design elements changed.

Summary of data on affective states. Obviously, more research is needed on affective states at adolescence. The data available, however, hint at promising avenues for future research. For example, it seems fruitful to examine the idea of adjustment to hormonal change, especially in the areas of depressive affect, energy levels, and impulsiveness. Hormonal change may negatively influence these affective states, at least until the body has a chance to adapt to higher concentrations.

More research is needed especially in the areas of moodiness (i.e., mood changes) and restlessness, which have barely been addressed, particularly with regard to their associations with hormones. Moodiness should be measured by assessing specific moods over time, rather than asking adolescents or parents directly about moodiness. In this way, the measure of moodiness will be less contaminated by social desirability or stereotypical expectations about adolescence. Studies should also assess aspects of individuals' life circumstances (e.g., stressors, transitions) and personality, to control for their effects and test for interactions between hormones and these other environmental or personality variables.

Behaviors Associated with Affective Changes

Given the relative sparsity of studies on affective changes associated with pubertal development, note the greater prevalence of studies on changes in behavior and relationships during this period. Perhaps this disparity reflects the relative ease of measuring behaviors versus affective states. This seems especially likely in light of the fact that many of the studies of behavioral change attribute these changes to the same biological processes presumed to underlie changes in mood states. The implicit, if not explicit, model used in these studies is mediational, with mood states presumably mediating between the biological and the behavioral changes under investigation. Given this model, these studies are relevant to our review. In this section, we review the evidence for hormonal influences in the two areas in which age and puberty have received the most systematic attention: aggression–behavior problems and family relationships.

Aggression and behavior problems. According to the psychoanalytic paradigm, rising hormones set off inner turmoil that is exhibited in behavior. Hormones lead to new, sexual, feelings and desires that are not understood by the child and not accepted by society and are thus converted into aggression, mood swings, depression, and general turbulence. G. Stanley Hall (1904) believed that criminal behavior blossomed at adolescence and that this blossoming was due to biological drives that had not yet come under control. According to this line of thought, when children experience general increases in hormones, they also experience emotional and behavioral upset. More recently, others (Olweus 1986; Susman, Nottelmann, Inoff-Germain, Dorn, & Chrousos, 1987) have also suggested that hormones may be related to arousal of emotions that could lead to aggression under the "right" conditions. Rather than emphasizing sexual emotions, however, they point to heightened restlessness, irritability, ability to tolerate frustration, or impulsiveness as potential precursors of aggressive behavior. Hormones may also change energy states in ways relevant to behavior. Testosterone, for example, has been linked both to heightened activity levels and heightened tendency to aggress in animals and possibly in humans as well.

Is there evidence that deviant or aggressive behavior increases at adolescence? According to several reports, most acts of deviant behavior increase beginning in late childhood or early adolescence and peak in middle-to-late adolescence, when they begin to decline (Elliott et al., 1989; Farrington, 1988; Farrington & West, 1981; Gold & Petronio, 1980; Jessor & Jessor, 1977; Magnusson, 1988; Osgood, O'Malley, Bachman, & Johnston, 1989). Substance use (which does not decline until early adulthood) and violent crimes (which peak in early adulthood) are exceptions. Although a majority of American adolescents claim they have committed at least one deviant act, or broken a rule, most are not very delinquent and do not engage in serious delinquent behavior (Douvan & Adelson, 1966; Elliott et al., 1989; Jessor & Jessor, 1977).

There is also not much evidence that aggression or other forms of risky or problem behavior are widespread at adolescence. Several studies suggest that certain aspects of aggressive behavior or behavior problems are stable or may actually decrease from childhood into adolescence, although school behavior problems and involvement in risky behaviors may increase. In a cross-sectional study (Achenbach & Edelbrock, 1981), parents reported slightly more disobedience at school but less disobedience at home, less fighting, and fewer overall behavior problems for a nonclinical sample of early-adolescent children as compared with younger children. A different pattern emerged among disturbed children: The older the child, the more likely he or she was to have parents report swearing, truancy, use of alcohol and drugs, and hanging around with children who get in trouble. But even among the clinical sample, there were no age differences in reports of lying, cheating, stealing, or vandalism. Simmons and Blyth (1987) found an increase in truancy and school suspensions from Grades 6–10, although there was no change in self-reported problem behavior. Several studies also report an increase in both the likelihood and frequency of involvement in risky behaviors such as unsafe driving practices, alcohol and drug abuse, unprotected sexual intercourse, and suicide attempts (Elliott et al., 1989; Jessor, 1984; Jessor & Jessor, 1977). In addition, Zuckerman et al. (1978) found that tendencies toward thrill-seeking and disinhibited behaviors were higher among 16–19-year-olds than among subjects age 20 and older.

Cairns, Cairns, Neckerman, Ferguson, and Gariepy (1989) studied aggression longitudinally in children from fourth through ninth grade. The number of subjects reported to be highly aggressive (by both self and teacher) decreased with age. Among boys, however, strategies used to deal with conflict were equally likely to involve direct confrontation and physical brutality over time. The authors suggest that violent crimes increase at adolescence not because more individuals act aggressively, but because those individuals who do act aggressively in conflict situations (primarily boys) have increased ability and opportunity to injure others. Minor problems with aggressive and impulsive behavior may be higher in early adolescence than they are in later adolescence, again especially among boys (Douvan & Adelson, 1966; Offer, 1969; Offer & Offer, 1975). Research with early-adolescent subjects suggests that within the 9–14-year age range, there are no age differences in behavior problems (Brooks-Gunn et al., 1988; Paikoff et al., 1991; Susman, Inoff-Germain, et al., 1987), but these studies do not rule out the possibility that problems are more frequent in the early-adolescent years than in the late-adolescent years.

Together, these studies suggest that adolescence can be a time of increased delinquency and behavior problems, but primarily for disturbed or troubled adolescents and perhaps for boys. Aggression, behavior problems, and delinquency, like depression, seem to increase with age among youths who exhibited behavior problems as children. This may result from changes in the nature of, and opportunities for, aggression rather than increases in the tendency toward aggression per se. Similarly, increases in school problems as measured by suspensions and truancy may reflect a change in teachers' or principals' tolerance for, or ways of dealing with, inappropriate behavior, more so than an increase in inappropriate behavior. Adolescents are, however, more likely to take part in risky behavior than younger or older individuals.

Is there any evidence that changes in aggressive or problem

behavior are linked to pubertal development as suggested by Hall (1904)? There is fairly consistent evidence that early timing of maturation, especially among girls, is associated with increased problem behavior. For girls, early maturation has been associated with behavior problems in school (Simmons & Blyth, 1987; Simmons et al., 1983), association with deviant peers (Silbereisen, Petersen, Albrecht, & Kracke, 1989), delinquent behavior (Magnusson, 1988; Magnusson, Stattin, & Allen, 1985), and aggression (Sonis et al., 1985). Early-maturing boys, at their pubertal onset, showed more frequent and intense temper tantrums than late maturers at their onset (Peskin, 1967). Early maturers also gave more frequent aggressive themes on the Thematic Apperception Test (Mussen & Jones, 1957; Peskin, 1967). In a national sample of adolescents age 12–17 years (Duncan, Ritter, Dornbusch, Gross, & Carlsmith, 1985), deviant behavior was more common among early-maturing boys than among late-maturing boys. In contrast to these studies, however, Simmons and Blyth (1987) found no association between either pubertal development or pubertal timing and school problems for the boys in their sample.

Too little data are available to draw conclusions about the relation between pubertal status and aggressive or delinquent behavior. For example, whereas one study noted increases in delinquent behavior after early puberty (Paikoff et al., 1991), one found a decrease (Nottelmann, Susman, Inoff-Germain et al., 1987). In another study, effects of pubertal status depended on life events: When no negative life events occurred, postmenarcheal girls showed more behavior problems, but when negative events did occur, problems were more prevalent among premenarcheal girls (Brooks-Gunn et al., 1988). As discussed in regard to depression, pubertal development may have advantages that bring increased strength in dealing with external difficulties, although under normal circumstances such maturity may not be evident.

Finally, what evidence exists that hormones are associated with adolescent aggressiveness or problem behaviors? Olweus, Mattsson, and their colleagues have looked in depth at testosterone concentrations and various types of aggression in adolescent boys. In their sample of normal boys, testosterone concentration was related to certain types of aggression or activation. Under conditions of threat or unfair treatment, boys with higher testosterone concentrations were more likely to respond aggressively, according to self- and peer reports. Unprovoked aggression was related to testosterone only indirectly, through the association between testosterone and frustration tolerance. These relations remained when controlling for pubertal status and for antecedent variables such as childhood temperament and aggressiveness (Olweus et al., 1980, 1988).

Among delinquent adolescent boys, Mattsson, Schalling, Olweus, Löw, and Svensson (1980) found that boys with higher testosterone scored higher on scales of verbal aggressiveness and aggressive attitude. When the delinquent group as a whole was compared with a normal population, the difference between testosterone concentrations was in the expected direction but it was not significant. Overall, then, the data from Scandinavia suggest that testosterone is positively related to aggression, but that the androgen's influence is more potent for (a) normal boys under circumstances of provocation and (b) boys prone to delinquency, perhaps because of personality characteristics or to provoking environmental situations.

Susman, Inoff-Germain et al. (1987) also documented significant relations between hormones and aggressive attributes for boys when controlling for age and pubertal status. Low estradiol and high androstenedione were related to more mother reports of delinquent behavior. High LH, high DHEA, and low FSH predicted rebelliousness. High androstenedione was related to mothers' reports of their sons' being nasty, although the overall regression predicting nasty with the set of hormones was not significant. Perhaps most interestingly, testosterone concentration was not significantly related to any of the psychosocial measures of aggression. Nottelmann and colleagues (Nottelmann, Susman, Blue et al., 1987; Nottelmann, Susman, Inoff-Germain, et al., 1987) found the same combination of low sex steroids and high adrenal androgens to be related to behavior problems in boys, especially older boys, and less pubertally mature boys. DHEAS was negatively related to mothers' ratings of delinquency among girls, but this relation disappeared when controlling for age and pubertal status. Similarly, Paikoff et al. (1991) found curvilinear relations between estradiol and both aggressive affect and delinquent behavior measured 1 year later, but the relations were reduced or eliminated when pubertal status or prior aggressive affect–delinquency scores were controlled.

Although these studies found few relations between hormones and girls' aggressive behavior, Inoff-Germain et al. (1988) examined aggression during family interactions and found hormone–aggression relations for girls as well as for boys. For girls, both estrogen and androstenedione were positively related to expressions of anger and aggression toward parents. The results for boys were similar to other reports by these investigators in that higher LH and DHEA predicted more aggression, as did lower DHEAS. In Udry and Talbert (1988), testosterone was positively related to a cluster of personality attributes depicting an outgoing, extraverted, and aggressive style. The association existed for both boys and girls, with smaller differences in testosterone associated with greater differences in the personality dimension for girls than for boys.

In another study, concentration of LH was related to aggressive behavior in early-pubertal girls, although the direction of effect depended on the time lag used: High aggressive behavior on one day predicted low LH the next morning, whereas higher morning LH predicted higher aggression later that evening (Eccles et al., 1988). In within-subject analyses, this association did not emerge.

In summary, all adolescents do not exhibit aggressive or delinquent behavior even though all experience hormone increases. Factors associated with changing roles, sociocultural expectations, and the timing of puberty explain much of the delinquency that occurs (e.g., Brooks-Gunn et al., 1988; Duncan et al., 1985; Elliott et al., 1989; Gold & Petronio, 1980; Jessor & Jessor, 1977; Magnusson et al., 1985; Simmons et al., 1983). Among boys, however, the activation effects of androgens may lead to more aggressive or rebellious behavior, especially if the higher concentrations occur in combination with environmental situations conducive to aggressive response. The Olweus et al. (1980) data indicate that when adolescent boys are provoked,

testosterone may affect aggressive response through lowering tolerance for frustration (Olweus, 1986; Olweus et al., 1988). Among people—adolescent or adult—already having problems with rebelliousness and antisocial behavior, testosterone seems to make a difference in the degree and direction of that behavior (Mattsson et al., 1980; Rubin et al., 1981).

Why the different results for boys and girls? Susman et al. (1985) discuss several possible reasons for fewer relations between hormones and aggressive behavior among girls. First, if girls are more aware of, and concerned with, socially appropriate behavior than boys, socialization pressures may outweigh potential effects of hormones for them. The fact that Udry and Talbert (1988) find testosterone as strongly related to an extraverted personality dimension in girls as in boys may lend evidence to the hypothesis that although girls' agentic, aggressive behavior may be equally stimulated by testosterone, girls may be socialized to inhibit aggressive impulses in situations evoking negative aggression. Females, however, may feel more freedom to express anger and aggression within the family than in other social situations, leading to the associations reported by Inoff-Germain et al. (1988). Second, there may be more variability in females' reports of specific acts of aggression than their ratings of self as aggressive on personality inventories. This may explain why relations between hormones and aggression emerge for girls when daily behavior is reported (Eccles et al., 1988) but not when overall personality attributes are measured. Third, Susman et al. (1985) suggest that boys may be more susceptible to the effects of androgens due to their early prenatal exposure. Finally, Paikoff and Brooks-Gunn (1990a) suggest that differing thresholds may be required for a hormone to have activational effects on behavior in different people. To the extent that these thresholds are less likely to be reached in certain individuals or subgroups (e.g., girls as opposed to boys), one would not expect to see the same associations with behavior.

The data collected from adolescents over a range of ages also indicate that relations between hormones and behavior may be different in early and later adolescence. For instance, adrenal androgens may be more influential early in adolescence (Nottelmann, Susman, Blue, et al., 1987; Nottelmann, Susman, Inoff-Germain, et al., 1987; Susman et al., 1985), whereas testosterone may become more important by mid- or late adolescence (Olweus et al., 1980; 1988).

Family relationships. Adolescents are typically believed to be more antagonistic toward parents than are younger children. Douvan and Adelson (1966) discuss how the "intrusion of instinct" can potentially complicate relationships between parents and children. Burgeoning sexual maturity can be threatening to both sides. Many scholars in this area have concluded, however, that the caricature of a tumultuous relationship between parents and child is overstated.

In an early study using a national sample of families with junior high and high school children, the majority of families reported basically positive relationships (Douvan & Adelson, 1966). Although children admitted to some conflict with parents, they also felt that family rules were generally fair and that their parents were not old-fashioned. Others have corroborated this early evidence (e.g., Achenbach & Edelbrock, 1981; Hill & Holmbeck, 1987; Offer, 1969; Offer & Offer, 1975; Rutter et al., 1976; Smetana, 1988, 1989). For example, Offer and Offer (1975) found little conflict between boys and their parents, most of which was recalled by parents as having occurred during early adolescence. In addition, identification of boys with their parents in areas of major importance was usually strong. Similarly, in both Hill and Holmbeck (1987) and Rutter et al. (1976), most children and parents reported good relationships. Although disagreements occurred, they were usually about personal habits or family obligations and not about deeper values. Where communication problems were reported, they often had existed before adolescence, according to the parents' recollection. And although Montemayor (1982, 1986) found frequency of arguing in families with adolescents to be relatively high when compared with frequency of arguments among distressed and nondistressed couples, he also concluded that most conflict between adolescents and parent was not serious; rather he attributed minor conflicts to family reorganization necessitated by the adolescents' increasing age and maturity.

Other studies examining age differences in parent–child conflict tend to support what Offer (1969; Offer & Offer, 1975) and Montemayor (1983, 1986) suggest is a temporary time of increased friction and reorganization during the early-adolescent years, followed by a return to more harmonious family relationships after about age 15 or 16 years. For example, studies of early adolescents often show increases in family problems during these years. Petersen and Crockett (1985) found that scores on the family relationship dimension of a self-image scale declined from 6th to 8th grade, with the largest drop occurring between Grades 7 and 8. Similarly, early adolescents in Eccles et al. (in press) felt that their opportunities for input into family decisions declined, and that their parents became more controlling, over the junior high school years (Grades 6–7). Jessor and Jessor (1977) also found that early adolescents, in comparison with both younger and older children, perceived their parents as more controlling. Finally, among 9–14-year-olds, older boys were more likely to respond to family members with anger when they were provoked (Inoff-Germain et al., 1988), whereas adolescents' reports of conflict with parents were lower among 11th graders than among 7th and 9th graders (Papini & Savage, 1987).

Where family problems exist in childhood, or where children already demonstrate clinical psychiatric disorders, increases in family problems at adolescence may be more acute and more serious. Rutter et al. (1976) found disagreements in the family to be two to three times more common in a clinical sample of adolescents as compared with a normal sample. And although Achenbach and Edelbrock (1981) found few differences in parent-reported family problems by age in their normal sample, boys in their clinical group were more likely to run away from home in adolescence than at earlier time periods.

In summary, as a child adjusts to his or her new adolescent status, there may be a time of increased turmoil, although the evidence suggests that the turmoil is not necessarily dramatic or damaging. Where parent–child relationships are good before adolescence, relationships generally continue to be good through adolescence as well, and parents continue to have a major influence on their children.

In support of the notion that early adolescence may be a time of adjustment in family relationships, studies of pubertal development and family relationships indicate that, at least in families with both biological parents present, there is increased family conflict when children are in the early and transitional phases of puberty. In his early work, Steinberg (1981; Steinberg & Hill, 1978) documented an increase in conflict between mothers and sons in the early and middle stages of puberty and a subsiding of that conflict after the pubertal apex. More recently, his cross-sectional and longitudinal studies of communication, autonomy, and authoritarian versus permissive parenting support increased distance between children (age 10 to 15 years) and parents (especially mothers) with pubertal maturation (Steinberg, 1987a, 1988, 1989). Inoff-Germain et al. (1988) observed that 9–14-year-old boys were more likely to show anger toward family members when provoked, the more pubertally advanced they were. Others have also found heightened conflict between intact-family parents and children when those children are in the transitional stages of puberty (Anderson, Hetherington, & Clingempeel, 1989; Hill, Holmbeck, Marlow, Green, & Lynch, 1985a, 1985b; Papini & Savage, 1987; Papini & Sebby, 1987, 1988). Similarly, there is evidence that parent–daughter relationships are more conflictual just after menarche (Garwood & Allen, 1979; Hill, 1988; Hill & Holmbeck, 1987; Hill et al., 1985a).

Timing of puberty seems to be important as well. For girls, early timing of development poses the most difficulty for families (Hill et al., 1985a; Savin-Williams & Small, 1986). Savin-Williams and Small found early-maturing girls to report more conflict with parents than other girls, and although the results of parents' reports did not reach significance, they went in the same direction. Hill et al. (1985a) present evidence that temporary perturbations in mother–daughter relationships may not be so temporary when development is early. Problems between mothers and seventh-grade daughters occurred when girls were either less than 6 months postmenarche or more than 12 months postmenarche. Because seventh-grade girls who are 12 or more months postmenarche are likely to be very early developers, the authors interpret the curvilinear relationship as evidence that relational problems in the family are more long-lasting for early developers. This intriguing hypothesis needs to be tested with longitudinal data and for older children, to see how long lasting the perturbations might be. For example, although Simmons and Blyth (1987) found that early-maturing sixth- and seventh-grade girls were more independent from their parents than their later maturing peers, this effect of puberty was not found when these same girls had reached high school. These results suggest that pubertal development has its greatest influence on parent–daughter relationships (or the rules parents have for their children) during the early-adolescent period. In early adolescence, puberty is one of the first (and perhaps only) signs of entry into adolescence; by high school, several adolescent transitions are likely to have occurred (e.g., the moves to junior high and high school and into adolescent activities)—the effects of which could overshadow the impact of pubertal changes on parent–child relationships.

For boys, the relation of pubertal timing to family conflict is not clear. In one study, early development predicted conflict between mothers and 10–15-year-old sons (Steinberg, 1987a). In another, parents reported less conflict with early-developing boys than on-time or late maturers, although the boys themselves did not report such differences, and the effects of pubertal timing were the same across the entire 10–17-year age range (Savin-Williams & Small, 1986).

In summary, as children enter early adolescence, defined by either age or pubertal development, family conflict may increase. As with several of the moods and behaviors reviewed, however, this conflict is not dramatic or long lasting for most children and is more likely to occur when problems have been exhibited in childhood. The majority of adolescents speak favorably of their parents and place importance on relationships with their parents. Conflict that occurs is not normally related to important family values. Early maturers, however—especially girls—may present special challenges to family dynamics, and the conflicts that arise in these families may be more severe or long lasting. This may be especially true for girls for several reasons. First, because their development begins earlier than that of boys, families may be less prepared for the changes. In addition, parents may be more concerned with the potential risks of adolescence to girls than to boys. Finally, because early-maturing girls may display behavior problems, these could be a cause (as well as a consequence) of adjustment difficulties in the family.

To what extent might the temporary perturbations among family members during early adolescence be due to hormone changes? The hormones most consistently tied to conflict behaviors (i.e., impulsiveness and aggression) are the sex steroids and adrenal androgens. Because relations between these behaviors and family conflict are tempered or exacerbated by physical stature, pubertal development, and environmental circumstances, however, it is necessary to obtain data that directly examine hormones and confrontational, conflictual behavior in the family during adolescence. As reported earlier, hormone concentrations (adrenal androgens, LH, and estradiol) were positively related to angry and aggressive interactions between children and their parents (Inoff-Germain et al., 1988). In another study, of 11–16-year-olds, Steinberg (1987b) found that higher testosterone was related to more parent–child arguments and emotional autonomy, lower cohesion with father, and lower frequency of calm discussion in the family. These relations held only for boys and were not significantly diminished by controlling for pubertal stage. Thus, there is some evidence that hormonal changes are related to changes in family interaction at adolescence, but because the necessary intermediary measures have not been collected systematically, the mediational hypotheses cannot be assessed. Steinberg (1987b, 1989) has also proposed and provided some support for the hypothesis that family conflict may lead to changes in hormone levels rather than, or in addition to, the reverse effect.

Summary of data on behaviors related to affective states. The several studies on aggression and behavior problems suggest that developmental changes and hormone–behavior relations are modified by environmental and personality factors and that effects may be mediated by changes in affect (e.g., tolerance for frustration). Future research might benefit by looking more closely at moods and affective states as mediators of the hor-

mone–aggression associations. The hypothesis that hormones influence aggressive moods and behaviors primarily in the earlier stages of hormonal change (i.e., the adjustment hypothesis) also seems worthy of further exploration.

Data on developmental changes in family relationships are also plentiful, but data on their associations with hormonal change are not. Again, research in this area would benefit from looking at moods and affective states as potential mediators of hormone–family relationship associations and from taking other aspects of the environment into account (e.g., actual levels of parental control, aspects of family structure). Hormone–behavior relations are likely to be stronger in some circumstances than in others.

Self-Related Perceptions and Beliefs

Cognitive developmentalists (e.g., Elkind, 1967), social role theorists (e.g., Eccles, 1987; Higgins & Eccles-Parsons, 1983), interactionists–contextualists (e.g., Eccles, 1987; Eccles & Midgley, 1988; R. Lerner, Lerner, & Tubman, 1989; Petersen, Schulenberg, Abramowitz, Offer, & Jarcho, 1984), and psychoanalytic theorists (e.g., A. Freud, 1966; Jacobson, 1961; Kestenberg, 1967b; Spiegel, 1961) all suggest that early adolescence may be a period of heightened self-consciousness, self-focus, and worry about one's competence. Several of these theorists also suggest that early adolescence may be a period of redefinition of the self leading to changes in self-image. In this section, we review evidence for these types of changes and for any association between changes in these domains and hormones.

Self-consciousness. Biological, morphological, cognitive, and social role changes all ought to lead to increased self-consciousness during early and middle adolescence. In support of this prediction, Rutter et al. (1976) found that about one quarter of his normal 14-year-olds experienced feelings of being looked at, laughed at, or talked about. In Japan, Abe and Suzuki (1986) found that fear of blushing and fear of being looked at were highest among 11–19-year-olds, with a peak at age 16, and that the belief that one is being talked about by others was highest among 9–13-year olds. Similarly, in the United States, adolescents (aged 12 years and older) expressed more self-consciousness than 8–11-year-olds (Simmons & Blyth, 1987; Simmons et al., 1973). The steepest increase occurred between ages 10 and 13 years, especially among girls who moved into junior high schools at age 12.

In contrast, other studies have reported either no difference in self-consciousness by age or a decrease at adolescence. According to parents, young children were the most shy and timid, and self-consciousness was at its highest, in the middle-childhood years rather than during adolescence (Achenbach & Edelbrock, 1981). Similarly, among girls in Grade 7 through 12, self-consciousness decreased with grade level (Brooks-Gunn et al., 1989). How do these studies differ from the ones that documented increased self-consciousness at adolescence? Achenbach and Edelbrock (1981) used parent reports of self-conscious behaviors; the rest of the studies cited used self-report. Perhaps as with depression, parents are less aware of adolescents' feelings of self-consciousness than are adolescents themselves. Brooks-Gunn et al. (1989) used self-report, however, and still found a decline in self-consciousness with age. Perhaps their youngest girls (7th graders) were at a peak of self-consciousness (given that this is the time of transition to junior high school for most children). In summary, the limited evidence on age and self-consciousness indicates that self-consciousness may peak in early adolescence and may be compounded by transitions associated with adolescence (such as the transition into a new school).

There is no indication in the few relevant studies that self-consciousness varies by pubertal status. Simmons and her colleagues (Blyth et al., 1981; Simmons & Blyth, 1987; Simmons et al., 1983) found no differences in self-consciousness by either pubertal status or timing. In an example of how the effects of physical development may depend on other life circumstances, Ruble and Brooks-Gunn (1982) found that among postmenarcheal seventh and eighth graders, girls who felt unprepared for menarche reported higher levels of self-consciousness than girls who felt prepared for this event. These researchers did not report, however, whether postmenarcheal girls were more self-conscious than premenarcheal girls.

Although one might predict that heightened self-consciousness in early adolescence is, in part, related to early hormone increases of that time, the association has simply not been tested.

Self-esteem and perceived competence. To the extent that better moods or heightened energy or activity levels stimulated by androgens and estrogen lead to more positive feelings and general well-being, adolescents with higher concentrations of androgens or estrogen would be expected to exhibit better perceptions of self. If, on the other hand, hormone activity is a negative or distracting event, adolescents with higher concentrations of hormones would show lower self-concepts. Alternatively, if hormones increase general reactivity, hormone concentrations should interact with the positivity or negativity of the environment in affecting self-esteem. In addition, to the extent that hormone concentrations might covary with body type and with changes in body structure, hormones might indirectly affect self-perceptions through their association with more or less valued body types. Finally, all of these processes might contribute to within-person variations in self-esteem across time.

Many scholars have suggested that self-esteem should be lower and more volatile at early adolescence than in the preceding childhood years (Rosenberg, 1979; Tobin-Richards & Kavrell, 1984), not necessarily because of hormonal change but as a result of the many changes experienced at this age, from bodily change to changes in the school environment that are often at odds with the needs of early adolescents (Eccles & Midgley, 1988). Attempts to test whether adolescence is indeed a vulnerable time for the self-concept have yielded mixed results that are as likely to directly contradict the hypothesis as to support it. Cross-sectional studies often report declining general self-esteem at early adolescence (e.g., Katz & Zigler, 1967; Nottelmann, Susman, Blue, et al., 1987; Simmons et al., 1973; Thornburg & Jones, 1982). In a closer look at perceived competence in specific domains, attitudes and expectancies regarding math—but not English—ability decreased with increasing grade across a 5th–12th-grade sample (Eccles et al., 1983; Eccles, Midgley, & Adler, 1984). In contrast to these studies, two

cross-sectional reports found no relation between age and self-image among early-adolescent girls (Brooks-Gunn et al., 1988; Nottelmann, Susman, Blue, et al. 1987).

Longitudinal studies paint a somewhat different picture. Summaries of the major work in this area (Abramowitz et al., 1984; Eccles & Midgley, 1988; Harter, 1990; McCarthy & Hoge, 1982; Simmons & Blyth, 1987) conclude that longitudinal studies provide evidence for slight increases in self-esteem from early- to mid-adolescence, with decreases only for certain subgroups of children. For example, McCarthy and Hoge (1982) studied 7th, 9th, and 11th graders at one time point and then again 1 year later. Self-esteem scores increased slightly but significantly from Year 1 to Year 2. Jessor and Jessor (1977) also found age increases in general self-esteem among persons followed from junior high school into adulthood. Studies of children in the 6th–8th-grade range suggest that changes in self-image and perceived competence vary depending on the domain of competence examined (Abramowitz et al., 1984; Eccles et al., 1989). These studies also find that changes are often more pronounced between 6th and 7th grades than they are within a school year or between 7th and 8th grades. Furthermore, Eccles et al. (1989) found that general self-esteem increased over the 7th-grade school year after dropping between the end of 6th grade and the beginning of 7th grade. These data support the notion that the junior high school transition may present particularly difficult challenges for some early adolescents. Eccles et al. (1989) also found higher stability of self-esteem in 7th grade than in 6th grade. In their longitudinal study of adolescents moving from 6th through 10th grade, Simmons and Blyth (1987) found a slight increase in general self-esteem and in perceptions of one's popularity with the opposite sex but a slight decrease in confidence in one's ability to do good schoolwork and in one's athletic ability. One group of adolescents, however, did show a decline in general self-esteem: girls who moved into a junior high school as they went from 6th to 7th grade. Thus, the consensus of more methodologically sound longitudinal studies is that young people show stable or increased self-esteem during adolescence, with, perhaps, some fluctuations in certain areas of esteem and some temporary dips that are due to school transition effects, especially for girls (Eccles & Midgley, 1988).

Studies relating self-image to pubertal development yield a more complex picture. One of the more consistent findings across studies is that pubertal development is, in fact, related to body image. In general, pubertal development, especially when it occurs early, is related to less positive body image among girls (Duncan et al., 1985; Gargiulo, Attie, Brooks-Gunn, & Warren, 1987; Simmons et al., 1983; Simmons & Blyth, 1987; Tobin-Richards, Boxer, & Petersen, 1983). Early pubertal development among boys seems to affect body image positively (e.g., Blyth et al., 1981; Simmons & Blyth, 1987; Tobin-Richards et al., 1983), presumably because development for boys leads to a more muscular (and societally valued) body build. In the one longitudinal study that has looked at these associations over a fairly wide age span, the effects of pubertal timing were most evident in early adolescence and often disappeared by the time the adolescents were in 10th grade (Simmons & Blyth, 1987).

The effect of pubertal development on overall self-image is less clear. Any effects of development on self-image may be mediated by its effects on body image. Consistent with the effects of development on body image, late-developing boys have been found to tell stories with more negative characteristics about self than early-maturing boys (Mussen & Jones, 1957) and to have more problems with self-image (Nottelmann, Susman, Blue, et al., 1987). In contrast, Tobin-Richards and Kavrell (1984) found that seventh- and eighth-grade boys and girls further along in puberty had lower self-images but that this effect was mediated by weight, satisfaction with weight, body image, quantity and quality of peer relationships, and athletic involvement. The specific mediators differed for girls and boys. Simmons and her colleagues also provide evidence that effects of pubertal development on self-esteem may depend on factors other than body image or bodily characteristics. Although in their most recent work (Simmons & Blyth, 1987), they found no direct effect of either pubertal development or pubertal timing on general self-esteem or specific self-concepts (other than body image), in earlier work (Simmons, Blyth, Van Cleave, & Bush, 1979), they found lower self-esteem in pubertally advanced girls if the girls had also begun to date and were making the transition to junior high school. And in the more recent sample, they found a strong negative association between the number of life transitions an adolescent experienced and general self-esteem (Simmons, Burgeson, Carlton-Ford, & Blyth, 1987). These results suggest that pubertal change is associated with self-image problems when it occurs in conjunction with other new and potentially stressful situations.

There may also be sensitive periods of time around the occurrence of menarche that make one vulnerable to lowered self-esteem. These sensitive periods could be due to hormonal factors or to the adjustment process once menarche occurs. In a study of seventh-grade girls, Garwood and Allen (1979) found postmenarcheal girls to have higher self-concepts and better overall adjustment on a clinical scale. There were no significant differences between girls of different menarcheal statuses with regard to self-concept measured by a counseling scale. The authors note, however, different patterns of self-concept by five levels of menarcheal status: premenarcheal, initial (menstruating 1–4 months), intermediate (5–8 months), middle (9–12 months), and established (over 1 year). Although the differences did not reach significance, girls in the initial and middle categories consistently scored higher than premenarcheal and intermediate girls on several scales of the counseling self-concept measure. Further research is needed that breaks menarcheal development into these more specific periods to see if such findings can be replicated and why certain periods of time are more vulnerable.

In general, adolescents may experience self-image difficulties in certain domains, under certain circumstances, or at certain, sensitive, points in development, although the research summarized certainly points out that these problems are not inevitable and are not usually very large. In light of potential environmental influences on sense of self and self-image at this time, is there reason to suspect that hormonal activity might also influence these changes?

Nottelmann and colleagues (Nottelmann, Susman, Blue, et al., 1987; Nottelmann, Susman, Inoff-Germain, et al., 1987;

Nottelmann, Inoff-Germain, Susman, & Chrousos, 1990) found that among boys, low sex steroids and high adrenal androgens were associated with less positive self-images, particularly in the domains of social relationships and coping. When age and pubertal status were controlled, the results for overall self-image and for social self-image remained the same, but only high adrenal androgens continued to predict more coping problems. For girls, high gonadotropin (FSH and LH) concentrations were associated with lower self-image in several domains; all but the association between LH and social self-image disappeared when age and pubertal status were controlled. The same general pattern emerged when the outcome variable was perceived competence (Nottelmann et al., 1985; Nottelmann, Cutler, & Chrousos, 1986). Although there was some variation by domain of perceived competence (cognitive, social, or physical), boys had generally higher perceptions of competence when androstenedione was low and testosterone was high. Again, these relations held when age and pubertal status were controlled. For girls, perceived competence was higher when gonadotropins were lower.

Nottelmann et al. (1986) also examined the rate of change in hormones over a 1-year period. In general, higher rates of change (both increases and decreases) were associated with better self-image scores at the end of the year. Why this would be is not clear. On the basis of an adjustment hypothesis, one would have expected higher rates of change to be associated with worse outcomes. Perhaps the effect of change in this age group was to heighten sex-steroid concentrations and decrease concentrations of adrenal androgens and gonadotropins. If this were the case, one would expect better outcomes over a year because of the association of high adrenal androgens/gonadotropins with negative outcomes and the association of higher sex steroids with more positive outcomes.

Clearly, the exploration of self-esteem in adolescence is a complicated task. Self-esteem is multidimensional and under a myriad of influences. That Nottelmann and her colleagues have documented any direct relations between hormones and self-esteem seems remarkable. Their results fit into a picture in which adrenal androgens (for boys) and gonadotropins (for girls) are related to negative moods and behaviors among early adolescents. These hormonal characteristics may be signs that the entire hormonal system is being turned on and that the activation of this system can be disruptive emotionally and behaviorally. It is imperative, however, for future studies of hormones and behavior—particularly when using constructs as complex as self-esteem—to consider how hormones interact with aspects of the individual or the environment, to understand under what circumstances hormones are related to behavior.

Summary of data on self-related perceptions and beliefs. Further data on self-consciousness are needed. In examining this construct, it is important to take into account other important early-adolescent transitions, such as school transitions and the morphological changes of puberty, that can influence the level of self-consciousness. The role of hormones should also be examined. Self-esteem is a complicated, multidimensional, construct. Yet, amazingly, hormone relations to perceived competence have been documented. Further research is needed to see if the findings can be replicated and how these effects are mediated.

Summary and Conclusions

Many of the studies we have reviewed confirm current thinking that adolescence does not inevitably spell trouble. This conclusion is, however, based on very little research in some domains. In addition, there may be affective or behavioral changes that are not dramatic or particularly troublesome but that happen fairly consistently. The historical conceptual focus on marked or extreme changes, coupled with a societal need to understand behaviors that are most deviant, seems to have limited research inquiry to the more deviant behaviors such as depression or aggression. Thus, whether there are systematic changes in affect or behavior during the adolescent period that might in turn be linked to hormones is, to a large extent, still an open question.

The research available offers some support for each of the types of hormonal influence described (activation, adjustment, and irregularity) and for hormone–mood and behavior relations that are sometimes distinct from the relations of age or pubertal status to the same outcome. In some cases, the effects are only evident at particular ages or stages. The studies, however, point to a number of complexities relevant for further research. In what follows, we summarize the themes that have emerged in this review, identify potentially fruitful avenues for further exploration of hormone–behavior relations, and emphasize theoretically related methodological considerations that are not only important if we are to elucidate the nature of hormone–behavior relations at adolescence but are necessary for obtaining meaningful data (also see Brooks-Gunn, 1988; Paikoff & Brooks-Gunn, 1990a, 1990b).

There is evidence that adolescents' moods and behavior differ from those of younger children and adults in some general ways. Although more research is needed to confirm these trends, adolescents may experience more swings in mood, more intense moods, lower or more variable energy levels, and more restlessness than people at other points in development. Anxiety and self-consciousness may be heightened during adolescence as well. Also, there is a fairly consistent relation between initial pubertal development (and early timing of puberty) and increased family conflict. All of these characteristics, if in fact they do pertain in a unique way to adolescents, undoubtedly have roots in the social, cognitive, and environmental changes associated with adolescence. This fact, however, does not rule out possible hormonal influences on these moods and behaviors. In addition, as Offer and Offer (1975) suggested more than a decade ago, early adolescence may be a time of adjustment and vulnerability. We see evidence for mood and behavioral adjustments during the early adolescent–early pubertal years in the areas of self-consciousness and family relationships. Of course, many changes take place in early adolescence—including school changes and external bodily changes, as well as increased concentrations of and fluctuation in hormones. It seems potentially fruitful to consider if and when hormonal events may play a significant part in the transition into adolescence.

What, then, can be said about the role of hormones in adolescent behavior? First, it is evident that many nonhormonal factors, besides being important in and of themselves, moderate the effects of hormone activity. The most obvious of these are characteristics such as sex, age, pubertal status or pubertal timing, and genetic variation in temperament and reactivity. Relations between hormones and mood or behavior are often documented for one sex and not the other or are found to involve different hormones depending on the sex being considered. For example, data from Susman, Nottelmann, and colleagues (e.g., Susman et al., 1985; Susman, Nottelmann, et al., 1987) point to more frequent and stronger relations for boys than for girls. As discussed earlier, this may be due to the prenatal exposure to androgens in boys, to greater socialization pressures for girls that overshadow biological effects (see Inoff-Germain et al., 1988), to differences in thresholds for hormonal response in boys and girls (Paikoff & Brooks-Gunn, 1990a), or to differences in how girls and boys report aggression.

Age and pubertal status also appear to moderate hormone–mood relations. Effects early in adolescence, before the body has had time to adjust to the changes and when hormone cycles may be erratic, may differ from effects later on when concentrations are higher and probably more stable. In some studies, the relations appear stronger in the early-adolescent years (e.g., Brooks-Gunn & Warren, 1989; Nottelmann, Susman, Blue, et al., 1987; Nottelmann, Susman, Inoff-Germain, et al., 1987; Warren & Brooks-Gunn, 1989). Alternatively, it may take prolonged exposure to a hormone to see any effects, as Nottelmann, Susman, Blue, et al. (1987) suggest in explaining the lack of relations involving testosterone among early- and middle-adolescent boys.

We see the importance of pubertal timing more generally in studies of pubertal development and behavior. For example, in the areas of depression, anxiety, and problem behavior, pubertal timing seems to be as, or more, important than the simple progression of puberty or age alone. Such findings have been interpreted to suggest that synchrony of development with peers is important. Perhaps they also reflect the importance of the timing of hormonal activity. The timing of various pubertal changes with regard to each other may also be important (e.g., Nottelmann et al., 1990).

Other potential moderators of hormone activity include the temperament of the person and aspects of the environment in which she or he lives. There is evidence across several domains of functioning (depression, problem behavior, family conflict) that adolescence is a time of trouble and vulnerability for children who are predisposed to problems either temperamentally (e.g., a tendency toward depression or aggressive behavior) or environmentally (e.g., living in a particularly negative, or provocative, family situation). And findings among both adolescents (Mattsson et al., 1980) and adult men (Rubin et al., 1981) indicate that testosterone concentrations are more likely to differentiate between more and less aggressive delinquents–criminals than they are to differentiate between criminals and noncriminals. In Olweus et al. (1980, 1988), boys with higher testosterone concentrations had a lower tolerance for frustration and were more likely to respond aggressively when provoked. One might hypothesize that even though two boys have equally high testosterone concentrations, one might never exhibit aggression (he is never or hardly ever provoked) and one might exhibit a great deal of aggression (he is provoked, perhaps repeatedly, in some way by his environment).

Although this review purposely has not focused on sexual behavior, an excellent example of how hormonal effects on behavior may be moderated by characteristics of the environment comes from the work of Udry and his colleagues on hormones and sexual behavior. Udry (1988) reported that although testosterone generally was a strong predictor of sexual involvement among 12–16-year-old girls, its effect was reduced or eliminated by sports participation or by having a father in the home. These environmental variables may reduce opportunities for sexual involvement, thus overriding any hormonal effects on behavior. There are many environmental variables that could be important in understanding the effects of hormones on behavior yet have not been studied in this light: variables such as preexisting family conflict, personal and parental expectations for adolescence, strength of peer relationships, range of models exposed to, and life events such as school changes, parental divorce or remarriage, or death or illness of a family member. Similarly, despite the recurring hypothesis that hormones evoke behaviors especially, or only, in people who have a tendency toward those behaviors (see A. Freud, 1966; Kopera, 1973; Paikoff & Brooks-Gunn, 1990a), research in the area of hormones and behavior at adolescence has yet to account for this methodologically or analytically.

The existing research also points to many important considerations within the biological domain alone. Hormones do not work in isolation from each other; effects likely depend on combinations of hormones (Nottelmann, Susman, Blue, et al., 1987; Nottelmann, Susman, Inoff-Germain, et al., 1987; Susman, Inoff-Germain, et al., 1987). Some of the different effects of hormones at different ages or pubertal stages may result from the different combinations of hormones at various times. Furthermore, many aspects of hormone activity are potentially important. The understanding of hormonal effects can be expanded by measuring not only concentrations of hormones but also frequency of episodic activity, amplitude of episodes, rates of increases and decreases, the regularity of increases and decreases, and the rate of response of the hormonal system to either internal or external changes. We know very little about how these various indicators of hormonal activity change with age and about how such changes may be related to changes in affect and behavior, but we have good reason to believe they are important.

The critical issue of how long it takes for hormones to influence behavior has not been adequately considered. Are hormonal effects immediate, or do they take some time to occur? If they take time, how much? A day? A week? A month? Longer? In the majority of studies on adolescent hormones and behavior, behavioral and hormonal data were either assessed concurrently or separated in time by approximately a month. Thus, short-term lagged effects are not picked up, and what seem to be concurrent effects may be invalid if the behaviors actually reflect hormones at some previous point in time. Even where measures are separated in time, conceptual reasons for expecting an effect with this time lag are not typically discussed. Most

of the existing research adopts a "traitlike" approach, in which it is assumed that measures of hormones at one point in time are indicators of stable individual differences in average concentrations and that the key research question is the association of individual differences in hormone concentrations and individual differences in other personality–behavioral–affective traits. Although this may be a valid conceptualization of hormonal activity, what we know about the changing, unstable nature of hormones at adolescence suggests several interesting alternative approaches, all of which necessitate more careful consideration of the appropriate time lag between hormonal assays and behavioral–affective assessments.

The traitlike approach has also limited the range of hypotheses regarding hormone–affect and behavior links. Because this point of view assumes stability in hormone concentrations, it has tended to focus attention on average concentrations and on between-subjects analyses rather than on other types of indicators of hormone activity such as within-subject variability over time and within-subject analyses. Eccles et al. (1988), however, suggested that the most interesting relations will exist at the level of the individual and that multiple measures over time in both hormones and behavioral–affective indicators are needed to assess the relations between intraindividual hormone changes and intraindividual behavior–affect changes. Their findings that the direction of hormone–mood relations vary across people suggest that the between-subjects approach can hide tremendous variability. Individual differences in the speed of response of the various hormonal systems to changes in other hormone concentrations or to changes in environmental stressors may be a critical set of variables for understanding individual differences in behavior and affect (Dorn, 1990; Nottelmann et al., 1990; Susman & Chrousos, 1988).

Indicators of within-subject variability are also potentially interesting as indicators of stable between-individuals differences on some as yet undefined hormonal traits, as well as indicators of within-individual state changes. For example, differences in the variability of hormone concentrations across time may account for between-individuals differences in affect, and developmental changes in this variability might be a critical factor in explaining developmental changes in affective states.

There is obviously still a need for systematic study of changes in hormonal and psychosocial events with normal adolescent subjects. This review points to several theoretically driven methodological considerations for future research. First, repeated measures of hormones and behavior in the same persons are necessary not only to examine different time lags but also to examine hormonal effects within individuals rather than between individuals. Within-subject designs could do much to increase our understanding of hormonal effects on moods and behavior that are not extreme enough to override personality or environmental variables that vary across persons. Repeated hormone measures are also necessary to accurately describe hormonal activity during adolescence. It is a challenge to get reliable hormone assessments in a population in which concentrations are expected to be both rising and fluctuating. Repeated measures, taken at different points in the day, are necessary to our understanding of the effects of hormones in an adolescent's body.

Second, more attention needs to be paid to the time of day when hormones are measured. Much of the current research has sampled hormones in the afternoon or evening, yet we know that early in adolescence, daytime concentrations of hormones may be extremely low but nighttime concentrations are rising. Thus, daytime measures probably do not accurately reflect early hormonal changes.

Third, the medium of hormone measurement must be considered. Blood measurements have been regarded as most precise, and current technology is such that hormones in blood can often be more reliably assayed than hormones in saliva (Udry & Halpern, 1990). On the other hand, hormone concentrations in saliva may more accurately reflect the hormones that actually reach the brain because in both cases there must be exchange between the serum and extracellular or salivary pools. A recent report suggests that reliability of salivary testosterone assays taken from college students is adequate (Dabbs, 1990). In addition, hormones in urine may be a better, more integrated, measure of hormone activity over time than hormones measured in serum at one time point (e.g., Wetterberg, 1978). Finally, it is difficult to obtain invasive blood measurement for large, representative samples of adolescents. Although there is no clear "best medium" in which to assess hormones, investigators must be aware of the problems and benefits of each.

Fourth, multiple and repeated measures of behavior are also important. Use of self-report measures at one point in time may reflect a current state that does not necessarily reflect behavior patterns or frequency of behavior (Rubin et al., 1981). Also, as pointed out by Susman, Nottelmann, et al. (1987) the current data on hormones and behavior show different effects depending on particular behavioral measures used. The data reviewed here support their conclusion that "examining the patterns of relations between multiple indexes of maturation and behavior may provide a more accurate assessment of the effects of timing of maturation on adjustment than examining the patterns between any one index and behavior" (p. 497). Furthermore, because it is also possible for moods and behavior to influence hormones (e.g., Christiansen, Knussmann, & Couwenbergs, 1985; Mazur, 1983; Mazur & Lamb, 1980; Rose, 1980), repeated measures of both hormones and behavior would allow a more thorough exploration of the ordering and interaction of these cause-and-effect relations.

The reality that hormone concentrations are affected by many external factors such as sleep, circadian rhythms, food ingestion, sexual activity, and moods themselves should be considered more explicitly (Petersen & Taylor, 1980). In fact, one of the primary explanations used by Nottelmann, Susman, and their colleagues to explain their consistent finding that high adrenal androgens (in particular, androstenedione) in combination with low sex steroids (in particular, testosterone) predict negative mood states has to do with the effects of stress on the hormonal system (see Nottelmann et al., 1990). Stress may simultaneously activate the hypothalamic–pituitary–adrenal axis (raising concentrations of cortisol and androstenedione) and suppress the hypothalamic–pituitary–gonadal axis (decreasing concentrations of gonadotropins and, subsequently, sex steroids). Pubertal development in boys, particularly if it is late, may be stressful and thus may produce the patterns of relation among mood adrenal androgens, sex steroids, age, and physical

development often observed in their sample. Again, studies that have within-subject, repeated-measures designs would allow more thorough exploration of cause and effect.

Last, although the primary hormones of puberty were reviewed in this article, other physiological substances are potentially important for a complete and accurate understanding of hormone–behavior relations. For example, testosterone-binding globulin (TEBG) may be important because it inactivates a portion of circulating testosterone (Susman, Nottelmann, et al., 1987). Progesterone has not been considered directly, but it may influence moods and behavior in girls who have begun to menstruate or who show hormonal cycles before the onset of menstruation; its presence or absence may also be helpful in understanding effects of estradiol. Changes in concentrations of melatonin, or in how they act on the brain, at puberty may also be associated with behavior at this time (J. B. Becker, Buchanan, Eccles, Arendt, & Klein, 1990). Additionally, changes may occur in hormones of the adrenocortical system or in their relation to moods between childhood and adolescence (Riddle & Cho, 1989).

In 1975, Beach stated that "we have only begun to comprehend the many ways in which hormones affect and are affected by human emotions and behaviors" (p. 186). Several major efforts have been made since this time to increase our understanding, and we certainly have a clearer idea of paths to pursue. Nonetheless, Beach's statement is still true, and there is much more work to be done. It is unrealistic to expect any one study to incorporate all of the considerations we have discussed. Our hope is that a variety of conceptually and methodologically rigorous studies can now be undertaken and that together these will provide a database that allows greater insight into the question of whether adolescents are, in any way, victims of raging hormones.

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