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Not all adolescents experience identity crises, rebel against their parents, or fall madly in love, but virtually all go through puberty, the biological changes that change our appearance and ultimately make us capable of sexual reproduction.

Physical development is influenced by a host of environmental factors, and the timing and rate of pubertal growth vary across regions of the world, socioeconomic classes, ethnic groups, and historical eras. Today, in contemporary America, the average girl has her first period at about age 12. At the turn of the 20th century, she was around 14½.

Physical and sexual maturation profoundly affect the ways in which adolescents view themselves and are viewed and treated by others. But the social environment exerts a tremendous impact on the psychological and social consequences of going through puberty (Worthman et al., 2019). In some traditional societies, pubertal maturation brings with it a series of public initiation rites that mark the passage of the young person into adulthood, socially as well as physically.

In other societies, recognition of the physical transformation from child into adult takes more subtle forms. Parents may merely remark, "Our little boy has become a man," when they discover that he needs to shave, or "Our little girl has grown up," when they learn that she has gotten her first period. Early or late maturation may be cause for celebration or cause for concern, depending on what is admired or made fun of in a given peer group at a given point in time. The fifth-grader who is developing breasts might be embarrassed, but the ninth-grader who has not developed breasts might be equally self-conscious.

In sum, even the most universal aspect of adolescence—puberty—is hardly universal in its impact on the young person. In this chapter, we examine just how and why the environment in which adolescents develop exerts its influence even on something as fundamental as puberty. As you will learn, the adolescent's social environment even affects the age at which puberty begins.



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Obesity and Eating Disorders

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Puberty: An Overview

Technically, puberty refers to the period during which an individual becomes capable of sexual reproduction. More broadly, however, puberty encompasses all the physical changes that occur in adolescents as they pass from childhood into adulthood (Worthman et al., 2019).

Puberty has four chief physical manifestations:

1. A rapid acceleration in growth, resulting in dramatic increases in height and weight.
2. The development of primary sex characteristics, including the further development of the gonads (sex glands), which results in a series of hormonal changes.
3. The development of secondary sex characteristics, including changes in the genitals and breasts, and the growth of pubic, facial, and body hair.
4. Changes in the brain's anatomy and activity as a result of hormonal influences.


Each of these sets of changes is the result of developments in the endocrine and central nervous systems, many of which begin years before the signs of puberty are evident—some actually occur at conception (Dorn et al., 2019). No new hormones are produced at puberty. Rather, the levels of some hormones that have been present since before birth increase, whereas others decline.

The Endocrine System

The endocrine system produces, circulates, and regulates levels of hormones. Hormones are highly specialized substances that are secreted by one or more endocrine glands and then enter the bloodstream and travel throughout the body. Glands are organs that stimulate particular parts of the body to respond in specific ways. Many of the hormones that play important roles at puberty carry their instructions by activating certain brain cells, called gonadotropin-releasing hormone (GnRH) neurons (Sisk & Romeo, 2019).

The Hormonal Feedback Loop

The endocrine system receives its instructions to increase or decrease circulating levels of particular hormones from the central nervous system, mainly through the firing of GnRH neurons (Aylwin et al., 2019). The system works like a thermostat. Hormonal levels are “set” at a certain point, which may differ depending on the stage of development, just as you might set a thermostat at a certain temperature (and use different settings during different seasons or different times of the day). By setting your room’s heating thermostat at 60°F, you are instructing your heating system to go into action when the room becomes colder than that. Similarly, when a particular hormonal level in your body drops below the endocrine system’s set point for that hormone, secretion of the hormone increases; when the level reaches the set point, secretion temporarily stops. And, as is the case with a thermostat, the setting level, or set point, for a particular hormone can be adjusted up or down, depending on environmental or internal bodily conditions.

Such a feedback loop—the HPG axis (for hypothalamus, pituitary, gonads)—becomes increasingly important at the onset of puberty. Page 15
Long before adolescence—in fact, before birth—the HPG axis develops involving three structures: the pituitary gland (which controls hormone levels in general), the hypothalamus (the part of the brain that controls the pituitary gland and where there is a concentration of GnRH neurons), and the gonads (in males, the testes; in females, the ovaries), which release the “sex” hormones—androgens and estrogens (see  Figure 1.1).

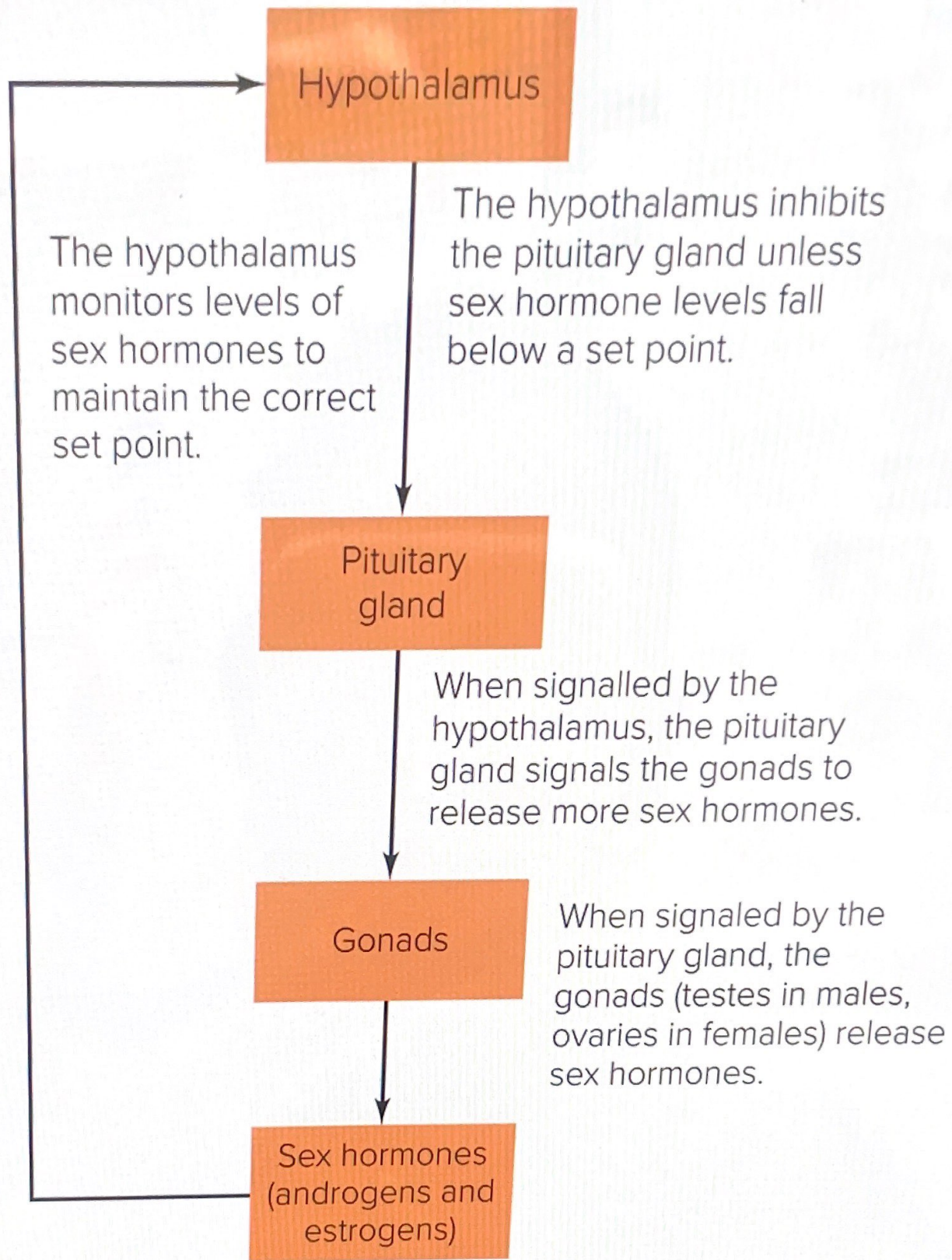


Figure 1.1 Levels of sex hormones are regulated by a feedback system (the HPG axis) composed of the hypothalamus, pituitary gland, and gonads.

(Grumbach et al., 1974)

Your HPG axis is set to maintain certain levels of androgens and estrogens. When these hormone levels fall below their set points, the hypothalamus stops inhibiting the pituitary, permitting it to stimulate the release of sex hormones by the gonads. When hormone levels reach the set point, the hypothalamus responds by once again inhibiting the pituitary gland. Just as you might change the setting on your heating thermostat automatically every November 1, or when your utility bill has become too expensive, your brain is constantly monitoring a variety of signals and adjusting your hormonal set points in response. Puberty begins when several different signals—genetic as well as environmental—instruct the brain to change the set point (Sisk & Romeo, 2019).

Adrenarche

Do you remember the first time you felt sexually attracted to someone? Most people report that their first sexual attraction took place *before* they went through puberty. These early sexual feelings may be stimulated by maturation of the adrenal glands, called **adrenarche** (Herdt & McClintock, 2000), which also contributes to the development of body odor, which is a way of signaling the beginning of sexual maturation to others (Campbell, 2011).

Changes at puberty in the brain system that regulates the adrenal gland are also important because this is the brain system that controls how we respond to stress (Kircanski et al., 2019; Lucas-Thompson et al., 2018). One reason adolescence is a period of great vulnerability for the onset of many serious mental disorders is that the hormonal changes of puberty make us more responsive to stress (Burke et al., 2017; Monahan et al., 2016; Sisk & Romeo, 2019). This leads to excessive secretion of the stress hormone **cortisol**, a substance that at high and chronic levels can cause brain cells to die (Carrion & Wong, 2012). Keep in mind, though, that there is a difference between saying that adolescence is an inherently stressful time (which it is not) and saying that adolescence is a time of heightened vulnerability to stress (which it is).

What Triggers Puberty?

Although the HPG axis is active before birth, it is relatively quiet during childhood. During middle childhood, the HPG axis is reawakened and signals that the body is ready for puberty. Some of this is caused by an internal clock whose “puberty alarm” is set very early in life by information coded in our genes (the age at which someone goes through puberty is largely inherited). But some of the reawakening of the HPG axis at puberty is due to multiple signals that tell the brain it is time to start preparing for childbearing. These signals indicate whether there are sexually mature mating partners in the environment, whether there are sufficient nutritional resources to support a pregnancy, and whether the individual is physically mature and healthy enough to begin reproducing.

The onset of puberty is stimulated by an increase in a brain chemical called kisspeptin (Aylwin et al., 2019) (so named because it was discovered in Hershey, Pennsylvania, the birthplace of chocolate kisses). The production of kisspeptin in the brain is affected by other chemicals, most importantly leptin, which stimulates it, and melatonin, which suppresses it. Leptin is a protein produced by fat cells and exists in our body in levels proportionate to our amount of body fat. It plays a critical role in the regulation of hunger and appetite by suppressing our desire to eat when we're full. In some senses, leptin serves to signal the brain not just that we are full enough but that we are “fat enough.” Melatonin is a hormone whose levels rise and fall as a function of how light or dark it is, which helps regulate the sleep cycle (we'll discuss this later in this chapter). Our melatonin levels are lower when it is light and higher when it is dark.

Your genes predispose you to go through puberty around a particular age (Horvath et al., 2020), but the more fat cells you have, and the more light to which you have been exposed during childhood, the more likely it is that you will go through puberty on the early side of your inherited propensity. Someone with the same genes but who is thin and doesn't get as much light exposure will go through puberty later (Aylwin et al., 2019). This is why puberty starts earlier among overweight children and among children who grow up closer to the equator (Lee et al., 2016). Obese children have more body fat and therefore produce a lot more leptin, which stimulates kisspeptin production. Children who live near the equator are exposed to relatively more sunlight each year, and they have lower melatonin levels as a result, so their kisspeptin production is not suppressed as much as it is among children who live closer to the poles. Exposure to artificial light, especially the kind of light emitted from electronic gadgets, can also suppress melatonin levels and hasten puberty (Greenspan & Deardorff, 2014). Children who spend a lot of time in front of electronic screens may be inadvertently speeding up the onset of puberty.

The reason that body fat and light exposure affect the timing of puberty is found in our evolutionary history. Humans evolved when resources were scarce, and it was adaptive to conceive and bear as many offspring as possible since not all of them would survive. If the ultimate goal is to bear as many healthy children as possible, once someone has developed enough fat and senses that the season is right for gathering food, it is time to start maturing physically. Our genes don't know that we no longer live in a resource-scarce world and can store food in our cupboards and refrigerators so that we have plenty to eat in the dark of winter. Although conditions have changed, our brains evolve much more slowly, and the timing of puberty is still affected by how much fat we have accumulated and how much light we've been exposed to.

How Hormones Influence Adolescent Development

Most people understandably think that changes in behavior at puberty result from changes in hormones at that time. But this is only partially correct.

Long before adolescence—in fact, before birth—hormones organize the brain in ways that may not be manifested in behavior until childhood or even adolescence (Sisk & Romeo, 2019). Generally, until about eight weeks after conception, the human brain is “feminine” unless and until it is exposed to certain “masculinizing” hormones, such as testosterone. Because levels of testosterone are higher among males than females while the brain is developing, males usually end up with a more “masculinized” brain than females. This sex difference in brain organization predetermines certain patterns of behavior, many of which may not actually appear until much later (Sisk & Romeo, 2019). Studies of sex differences in aggression, for example, show that even though some of these differences may not appear until adolescence, they likely result from the impact of prenatal hormones, rather than from hormonal changes at puberty.



For instance, our dog, Benson, a male who was neutered shortly after birth and therefore didn't have testicles when he reached "adolescence" (which in dogs begins sometime between 6 months and 1 year, with smaller dogs maturing earlier than larger ones), still displayed stereotypical male "humping" behavior when he reached this age. This was likely due to the way his brain was programmed by sex hormones before he was born.

In other words, the presence or absence of certain hormones early in life "program" the brain and the central nervous system to develop in certain ways and according to a certain timetable (Sisk & Romeo, 2019). Because we may not see the resulting changes in behavior until adolescence, it is easy to mistakenly conclude that the behaviors result from hormonal changes that take place at the time of puberty. In reality, however, exposure to certain hormones before birth may set a sort of alarm clock that does not go off until adolescence. Just because the alarm clock rings at the same time that puberty begins does not mean that puberty *caused* the alarm to go off.

Many changes in behavior at adolescence do occur because of changes in hormone levels at puberty, however (Schulz & Sisk, 2016). For instance, the increase in certain hormones at puberty is thought to stimulate the development of secondary sex characteristics, such as the growth of pubic hair. There is also growing evidence that puberty affects the brain in ways that increase adolescents' emotional arousal and desire for highly rewarding, exciting activities, which may make teenagers who are especially sensitive to rewards more prone to emotional and behavioral problems (Goddings et al., 2019; Icenogle et al., 2017).

Other changes during puberty are likely caused by an interaction between prenatal and pubertal hormones. Hormones that are present prenatally may organize a certain set of behaviors (e.g., our brains may be set up to have us later engage in sexual behavior), but certain changes in those hormones at puberty may be needed to activate the pattern; that is, individuals may not become motivated to engage in sex until puberty.