

An Introduction to **Child Development**

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An Introduction to **Child Development**

Thomas Keenan, Subhadra Evans & Kevin Crowley

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Edition



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The Biological Foundations of Development I: Physical Growth, Motor Development and Genetics

4

Chapter Outline

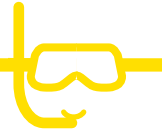
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LEARNING AIMS

At the end of this chapter you should:

- be aware of prenatal development, including the influence of teratogens, labour and birth, and potential birth complications
- be able to describe the developmental course of physical growth and articulate the principles which growth follows
- understand the factors which can influence physical growth and sexual maturation in adolescence
- be able to describe the course of motor development and recognize the difference between *gross* and *fine motor* development
- be able to explain the logic of behaviour genetics, twin designs, and associated concepts such as *heritability*, *niche picking*, and *range of reaction*
- be able to articulate the notion of *epigenetics*



Introduction

Biological influences in development touch on a number of important areas, which is why we have two chapters, 4 and 5, devoted to biological development. In this chapter, we will summarize prenatal development, and examine physical growth across childhood and adolescence, including motor skills in childhood and sexual maturation in adolescence.

The Course of Physical Growth

In comparison to other species, the course of physical growth in human beings is a long, drawn out process. Evolutionary theorists have suggested that our lengthy period of physical immaturity provides us with added time to acquire the skills and the knowledge which are required in a complex social world (Bjorklund, 1997). This suggestion emphasizes the fact that physical growth is not simply a set of maturational processes that operate independent of input from the environment; rather, physical growth occurs within an environmental context. Environments, including factors such as cultural practices, nutrition and opportunities for experience, play an important role in physical development.

Prenatal development

Prenatal development occurs during the nine months or so between conception – the point at which an egg has been fertilized – and birth. As we will explore, our time in the womb can have a considerable impact on our later wellbeing. The nine months of prenatal development can be characterized as involving three periods: (1) the *zygote*, which encompasses the first two weeks of life; (2) the *embryo*, from the beginning of the third week of gestation until the end of the second month; and (3) the *foetus*, the term used to describe the organism from the third month of gestation until birth. The central nervous system undergoes rapid changes during this period, and brain growth is at its peak. The foetus’s body parts have developed by the end of the third month, reflexes such as swallowing are present by the fifth month, and it can open and close the eyes by the sixth month. The period between 22 and 26 weeks is called the *age of viability*, as the foetus’s systems are sufficiently developed at this point that, if born prematurely, the baby has a good chance of surviving.

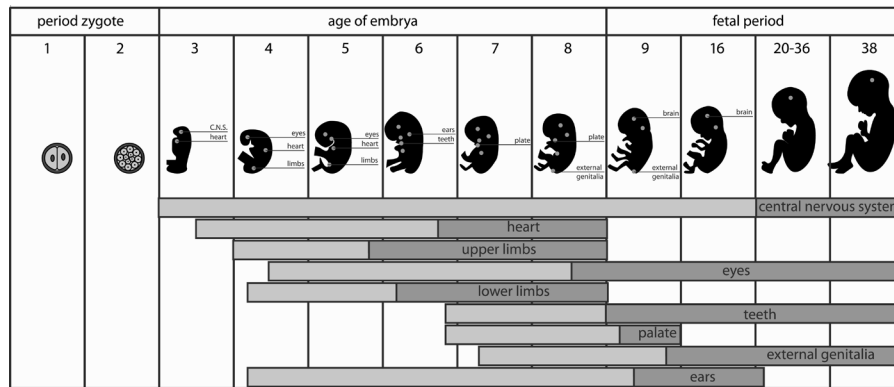


Image 4A Growth of the human fetus in weeks

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There are a number of environmental risks to the unborn baby, known as *teratogens*. These teratogens can severely damage a foetus and include a range of agents, from prescription and illegal drugs to the mother’s health and stress. The effects of teratogens are dependent on a number of factors, including: *dose response* (longer and more intense exposure leads to more damage); *age* (certain growth periods in the foetus are more critical or sensitive to risk); *biology* (the genetic makeup of the mother and her child play a role; some individuals remain immune to harm); and *combinations* (the presence of many risk factors, such as poverty and poor maternal nutrition, can intensify a teratogen’s effect).

Teratogens commonly affect the unborn child’s physical health and may cause visible abnormalities, such as a missing limb. Damage can also be delayed or more subtle. For example,

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high birth weight in baby girls can result in increased risk of breast cancer in later adult life (Vatten, Mæhle, Nilsen, Tretli, Hsieh, Trichopoulos, & Stuver, 2002). It is thought the teratogenic mechanism may be an overweight expectant mother, who releases excess estrogens which promote large foetal size and changes in breast tissue, which may make the baby, when she grows up, more susceptible to breast cancer (Vatten et al., 2002). Moreover, a teratogen can have psychological and *bidirectional* consequences. For example, babies of mothers using cocaine are often born experiencing drug withdrawal, which makes them irritable and less inclined to be cuddled by their mothers. This extra stress can then impact on the mother–child bond, increasing the odds that the child will develop long-term behaviour problems (Ostrea, & Simpson, 1997).

Now you know what teratogens are, let's explore more about what these teratogens look like. Following is a list, by no means exhaustive, of some teratogens.

Legal and Illegal Drugs: In many cases, women take drugs during pregnancy because they do not realize yet they are pregnant, or because they are not aware of the drug's risks. You may be surprised to learn that heavy ingestion of caffeine, including tea and coffee, by expectant mothers has been associated with low birthweight and even withdrawal symptoms in newborns (Klebanoff, Levine, Clemens, & Wilkins, 2002). Heavy use of aspirin in mothers can also lead to low birth weight, lower IQ and poor motor control (Barr, Steissguth, Darby, & Sampson, 1990). These days the general public are more aware of other links, such as alcohol consumption and use of tobacco and cocaine, in pregnancy and foetal problems. The effects of drugs such as marijuana are still being studied, and although the long-term effects are unclear, researchers have noted reduced weight and size and sleep problems in babies and even later attention and memory difficulties in childhood (Fried, Watkinson, & Gray, 2003).

Well-known prescription teratogenic drugs include diethylstilbestrol (DES), which was meant to help prevent pregnant women miscarrying, and thalidomide, an antianxiety and antinausea drug. Both of these prescription drugs resulted in a range of severe foetal abnormalities and are no longer prescribed to pregnant women (Moore & Persaud, 2003). The effects of drugs are often difficult to predict. Such drugs may have severe effects in some children and less of an impact on others. The best policy for pregnant women regarding drugs, whether they are prescription, legal or illegal, is avoidance.



Can you think of some reasons why establishing the effects of specific drugs on prenatal development might be difficult?

Maternal Factors: There are certain characteristics of the mother herself that can result in risk to the child. These include maternal *age* (teenage mothers tend to live in risky environments and neglect their health, while older women may be at greater risk of bearing a Down syndrome child); *diet* (malnourishment caused by famine, poverty or dieting is perhaps one of the biggest threats to foetal development; insufficient nutrition can result in prematurity, physical and neural defects and stillbirth); *disease* (a range of diseases including mumps, rubella, diabetes and STDs

can all impact negatively on the foetus); and *stress* (anxiety may lead to miscarriage, a difficult labour and greater need for childbirth anaesthesia – which itself can result in risk). The mother’s emotional state is thought to affect a foetus and newborn in a number of ways. Research has shown that a pregnant woman’s emotional state can cause biochemical changes that affect the foetus such that foetal levels of stress hormones mirror those of the mother (DiPietro, 2004). The research highlighted in Research Example 4.1 also demonstrates how a mother’s behaviour in the form of alcohol consumption can affect childhood depression.

Research Example 4.1

Prenatal Alcohol Exposure and Child Depression

A recent study explored the relationship between a common teratogen – alcohol consumption – and children’s mental health (O’Connor & Paley, 2006). We know that maternal alcohol intake is associated with a range of cognitive problems in children, including developmental delays, slowed learning and faulty memory. Physical abnormalities – usually in the head and face region – can also result. Such babies may be diagnosed as having *fetal alcohol syndrome*, a tragic condition caused by drinking during pregnancy. While the cognitive and physical effects of mothers’ drinking are well documented, less is known about its psychosocial and emotional effects on children. The authors of this study therefore examined the depressive symptoms of 42 children aged 4 to 5 years-old and their mothers’ reported alcohol consumption during pregnancy. Mother–child interactions were also assessed.

The results showed:

- The higher the mother’s alcohol consumption, the more depressive symptoms in children and the smaller the child’s head circumferences (consistent with fetal alcohol syndrome)
- Child negative affect was associated with less maternal emotional connection
- The results held even when considering the mother’s current drinking patterns and current depressive symptoms

The authors concluded that moderate to heavy alcohol exposure is a risk factor for children’s later depression, and some of this effect may occur through the impact of a negative mother–child relationship.

While the results are quite compelling, you may want to note that the study involved a correlational design, which limits what we can say about the cause and effect of alcohol consumption. What must the authors do to ensure they can make valid conclusions about the causal relationship between mothers’ alcohol intake and children’s mental health? (Hint: you may want to turn to Chapter 3.)

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Environmental Agents: Radiation has long been known to cause problems in foetal development, which is why pregnant women are no longer given x-rays. Other environmental toxins include lead, mercury, herbicides, pesticides, and even some decongestants (Werler, 2006). A father's exposure to toxins such as radiation, anaesthetic gases or lead can cause harm to the developing foetus. Occupations that involve such exposure can result in men developing chromosomal abnormalities that can lead to their partners miscarrying or giving birth to infants with birth defects (Friedler, 1996). These findings indicate that both parents must evaluate their exposure to teratogens to ensure their baby's safety.

Fetal learning

Research on teratogens clearly shows that the fetus is sensitive to influences in the womb. The fetus is also capable of learning, especially during the last trimester of pregnancy. Research into the early stages of how we start responding to information from our environments is called *fetal origins*. Exciting studies in this field have demonstrated that far from being an inert lump, the developing fetus is an active and dynamic creature responding to and learning from the rich sources of information that filter in through the amniotic fluid and placenta. Such research has demonstrated that developing babies can hear, are sensitive to human voices, and are attracted to the voice of their mother while still in utero. A recent collaborative study between Canadian and Chinese researchers tested 60 women in the final stages of their pregnancy. Mothers were videotaped as they read aloud a poem: half the foetuses heard the recording of their mother, the other half heard recordings of a mother, but not their own mother. The heart rate of foetuses listening to their mothers accelerated, while the heart rates of foetuses listening to a stranger decelerated, indicating they were paying close attention. In other words, the developing babies were trying to figure out who was speaking when they heard the stranger speaking (Kisilevsky et al., 2003). The findings indicate that even before birth we have capacity for attention, memory and sensitivity to language.

Other senses are also being primed for learning. Tastes and smells develop while in the uterus. One study demonstrated that if mothers ate anise flavour while pregnant, their newborns (at days 1 and 4) showed more attraction to an anise-scented cotton swab presented under their noses than infants whose mothers did not consume anise. Obviously the researchers couldn't simply ask the babies and had to rely on behavioural signals, including whether infants moved their heads towards or away from the scent and facial expressions using a well-validated facial configuration measure (which included nose wrinkling, just like in adults) (Schaal, Marlier, & Soussignan, 2000). It is also known that if a mother eats garlic while she is pregnant, the baby will show less aversion to garlic after they are born.

Birth

Labour and delivery represent a significant milestone in the lives of parents and infants. Once babies enter the world, they are exposed to all kinds of stimuli, learning experiences and relationships. However, the process of labour and delivery is an arduous one. Millions of women deliver healthy infants, but birth can be associated with a number of complications. Since the 1970s, when having a baby in a sterile hospital environment was the norm, natural and

alternative childbirths have become increasingly popular (Eberhard & Geissbühler, 2000). The father's role in delivery and childrearing has also changed, with many more men today being present at their child's delivery. Research suggests that having a supporter makes the experience of childbirth more positive for women (Mackey, 1995). A study conducted in Greece has shown that a father's attendance at the birth is associated with an increased bond with the infant (Dragonas, 1992).

Despite many women's preference for a home or home-like birth, complications can occur. These include anoxia (a lack of oxygen to the foetus's brain), which can lead to brain damage and even death, and incorrect positioning of the foetus which precludes natural delivery. Male babies are more likely to experience complications, perhaps due to their larger size and the greater pressure on their heads during birth (Berk, 2006). When complications occur, medical intervention is often required. Caesarean deliveries (C-sections), in which the baby is removed through an incision in the mother's abdomen, can be used electively, but are often reserved for deliveries with complications. For normal deliveries, Caesarean births may double both the mother's and infant's complications, including the risk of infection and extended hospitalization, and babies being at risk of breathing problems and reduced short-term responsiveness (Villar, Carroli, Zavaleta, Donner, Wojdyla et al., 2007).

How do we assess the wellbeing of newborns? The most common method for determining how an infant is faring is the *Apgar scoring system* (Apgar, 1953). Medical staff assess the infant's heart rate, respiratory rate, muscle tone, reflexes and skin tone both one and then five minutes after birth. A score of 0, 1 or 2 is given to each of the five signs with a total score yielded. A total score of 7 to 10 indicates a favourable condition, while a score of 4 or less tells medical staff that the infant needs emergency intervention.

Prematurity

The term *premature* is used when a baby is born before the full-term gestational period of 38 weeks. These babies typically have a low birth-weight, often weighing less than 5lbs (compared to a full-term baby, which often weighs 7lbs or more). Premature babies may have to remain in hospital for extended periods as they often cannot survive without assistance. Premature babies may also lag on physical and cognitive development milestones. Although most catch up by the time they are 4 years-old, babies who were born with very low birth weights commonly continue to show deficits (Goldberg & DiVitto, 2002). One study conducted in Norway found that babies born during 28–30 weeks gestation are at particular risk of long-term problems, including a forty-six-fold higher risk of cerebral palsy (a group of disorders that involve various nervous system functions, including perception, cognition and movement), a seven-fold higher risk of autism (see Chapter 13) and a four-fold risk of mental retardation (Mostert, Lie, & Markestad, 2008). The later the gestational age, the fewer the risks compared to full-term babies, but even babies born at 37 weeks have comparatively elevated health and cognitive risks. However, the long-term outcomes for premature infants can also be affected by the psychosocial environment in which they are raised, and there is evidence that if they are raised in a stimulating and positive home environment and the parents receive appropriate support from health, education

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and social services, this can facilitate developmental recovery. Typically, infants raised in such environments have better outcomes in terms of cognitive and motor skills and fewer behavioural problems compared to preterm infants raised in unstable and socioeconomically disadvantaged homes (see for example, Jefferis, Power, & Hertzman, 2002; Robert et al., 1994). Although many preterm births are spontaneous (and these rates are climbing, with limited evidence of why), some are preventable and involve medically inducing labour. Close to 10% of medically induced births before 37 weeks are done in the USA without strong medical reasons, such as complications with a prior pregnancy (Engle & Kominiarek, 2008). This is a critical area that needs addressing in the maternal–child health field.

Patterns of growth

Physical growth does not proceed randomly; instead, it follows orderly patterns known as **cephalocaudal** and **proximodistal development**. The cephalocaudal pattern of development refers to the fact that growth occurs in a head-to-toe direction. For example, two months after conception the human infant's head is very large in contrast to its total height, and by birth this ratio is much smaller as the rate of growth in the rest of the body begins to catch up. Within the head itself the eyes and the brain grow faster than the jaw. These examples illustrate the head-to-toe direction of physical growth. The proximodistal pattern of development refers to the fact that development occurs outwards from the centre of the body. For example, a baby will acquire control over the muscles of the neck and trunk before it acquires control over the fingers and toes.

Body size

Changes in body size are the most obvious manifestation of physical growth. During infancy, the changes in growth are extremely rapid. An example which readily comes to mind is the dramatic changes in height. By 1 year of age infants average a growth of approximately 11 inches (approximately 32.5 cm) over their size at birth (Malina, 1975). Similarly impressive gains are noted in weight. At 2 years of age an infant's weight will have quadrupled since birth. In general, physical developments in height and weight tend to occur very rapidly in infancy, continue at a relatively steady pace throughout childhood, and then slow down towards puberty.

At puberty, there is a marked *growth spurt*, that is, a very rapid increase in size and weight. The pubertal growth spurt varies from person to person in terms of its intensity, its duration and its age of onset. The pubertal growth spurt tends to last around four and a half years, with girls usually showing their pubertal growth spurt around age 11, and in boys the same process beginning at approximately age 13. According to Tanner (1990), girls finish pubertal growth by about age 16 whereas boys continue to grow until approximately 18 years of age; however, in both sexes growth may still take place after the completion of the pubertal growth spurt.

A number of studies have provided evidence that hereditary factors play a strong role in physical growth. Work by Wilson (1986) examining correlations in a variety of physical indices showed that the correlation in height between identical twins was approximately .94 at 4 years

of age, and this correlation remained stable after this time. For fraternal twins, the correlation for height was relatively high at birth but became increasingly smaller over time, moving from .77 at birth to .49 at 9 years of age (at which point it became stable). The large and stable correlations observed in identical twins and the smaller correlations observed for fraternal twins suggest that genetic factors play an important role in determining height. Similar patterns are observed for weight as well as for the timing of growth spurts (Wilson, 1986).

Environmental factors in physical growth: nutrition

Of course, genetic factors are unlikely to tell the entire story of physical growth. Growth is highly dependent on our nutritional intake, that is, what kinds of food we eat and how much of them we eat. Height and weight are clearly affected by nutritional intake.

Babies need sufficient food to grow properly, but they also need the correct kind of food. *Breastfeeding* meets a baby's quality of nutritional needs. Although bottled formula attempts to imitate the nutrients in breast milk, research indicates that nothing beats nature's formula. Breast milk provides the ideal balance of fat and proteins, helps ensure healthy growth, provides antibodies that protect against disease, protects against tooth decay (in comparison to babies who fall asleep with a bottle of sweet solution in their mouths), and helps with digestion (Fulhan, Collier, & Duggan, 2003). The benefits of breastfeeding aren't limited to physical growth and health. A recent randomized controlled trial of breastmilk versus formula indicates that breastfed babies are more likely to have higher IQs, better reading comprehension, and general increased cognitive development later in life (Kramer, Aboud, Mironova, Vanilovich, Platt, Matush et al., 2008). Guidelines from health agencies advise exclusive breastfeeding for the first six months and that breast milk is included in a baby's diet for at least one year (Satcher, 2001).

The importance of nutrition is not limited to babies. Eating enough quality food is vital for children of all ages. Studies during World War II showed that the restrictive diets imposed by wartime conditions in Europe led to a general decline in average height, reversing a trend towards increasing height which had been apparent since the end of World War I (Tanner, 1990). However, more than just our height and weight can be affected by nutritional intake: research also indicated that dietary restrictions during the war had an effect on the timing of puberty. Studies of French women showed that **menarche**, the onset of menstruation, was delayed by up to three years (Tanner, 1990).

Cognitive development has also been related to nutrition. For example, *anaemia*, the condition where a person suffers from low levels of iron in the bloodstream, has been associated with a slowing of intellectual development (Pollitt, 1994). A striking example of nutritional effects on cognitive development comes to us from the examination of intestinal worms. Intestinal worms sit in our digestive track and rob us of valuable nutrients which fuel our growth. Watkins and Pollitt (1997) showed that children who have high levels of intestinal worms have reduced performance on psychometric tests of cognitive ability. In some cases, studies have shown that these effects can be quite severe.

Healthy physical growth is not just a product of nutrition. **Psychosocial dwarfism** results from extreme emotional deprivation. Symptoms relate to physical appearance, including short stature

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and immature skeletal age as well as cognitive and emotional impairments, which are used to differentiate the condition from normal short stature (Voss, Mulligan, & Betts, 1998). Typically, psychosocial dwarfism results when extreme abuse and neglect interfere with the production of growth hormones. When children are removed from the abusive environment, their levels of growth hormone and stature quickly increase.

Recently, a new problem of nutrition has affected industrialized nations. Over-nutrition or childhood *obesity* (a condition in which weight is 30% or more in excess of the average weight) is a growing concern in places like North America, the UK and Australia. It is estimated that nearly 25% of American children are obese (Cowley, 2001). It is likely that weight problems are at least in part due to genetics. The weight of adopted children more closely mirrors their biological than adoptive parents (Stunkard et al., 1986). Environmental factors such as education and family income also play a role; higher education and income are associated with fewer weight problems. This may seem odd given that millions of people in developing countries are starving due to poverty. However, in wealthier counties, the association between income and thinness may be due to luxuries such as health club membership and fat-reduced food. There is also evidence of modelling, with obese children modelling the unhealthy eating of their often overweight parents. Overweight children learn consumption patterns. What parents place in front of children has an enormous impact on children's eating habits. Parents play a role in teaching children what, when and how much to eat (Rozin, 1996). Even by the age of 5, children will eat more when they are given larger portions (Rolls, Engell, & Birch, 2000). The good news is that children can also unlearn eating patterns. If children see their parents eat healthy food and are taught about nutrition, they tend to change their food choices. But such changes must occur early on to be effective. Being overweight is a life-span trend: 80% of children who are overweight will grow up to be overweight adults.

Ironically, the quest for thinness is growing in direct proportion to weight increases in children. Increasingly younger girls and boys have become preoccupied with their appearance. A recent Australian study found that among 5 to 8 year-old children, 60% of girls and 35% of boys wanted to be thinner (Lowes & Tiggemann, 2003). By the time they are 15 years-old, 70 to 80% of girls in the USA have been on at least one diet (Cowley, 2001). This struggle to be thin in the face of so much over-nutrition is associated with eating disorders, including bulimia and anorexia. A thorough discussion of these issues is outside the scope of this text, but eating disorders are affecting ever-growing numbers of young people and represent an important area of study. Girls undergoing puberty appear to be at particular risk.

Hormonal influences

In large part, the physical changes observed at puberty are controlled by **hormones**, a set of chemical substances manufactured by glands and which are received by various cells throughout the body to trigger other chemical changes. The most important of these glands is the **pituitary gland** located near the base of the brain. The pituitary gland triggers changes both directly, via the hormones it secretes into the bloodstream, which act on various tissues to produce growth, and indirectly, by triggering other glands to release different hormones.

The physical changes associated with puberty, specifically **primary sexual characteristics** (growth involving the reproductive organs: the penis, scrotum and testes in males and the vagina, uterus and ovaries in females) and the **secondary sexual characteristics** (visible changes which are associated with sexual maturation, such as the development of breasts in females, facial hair in males, and pubic hair for both males and females) are also controlled through the pituitary gland, which stimulates the release of the sex hormones. In boys, **testosterone** is released in large quantities, leading to the growth of male sexual characteristics, while in females **estrogens** are associated with female sexual maturation. Both types of hormone are actually present in both sexes although in quite different amounts.

Sexual maturation

In terms of sexual maturity, the most important changes to result are **menarche** and **spermarche**, that is, the first menstruation in females and the first ejaculation in males. These two milestones are commonly believed to indicate a readiness to reproduce, although in actuality there is often a short period of sterility which can last about one year in both females and males in which menstruation and ejaculations occur but no eggs or sperm are released (Tanner, 1990).

The factors which determine the timing of puberty are multiple and complex, ranging from genetic determination to the nature and quality of family relationships. Genetic factors are certainly involved in determining when the pituitary gland begins releasing the hormonal signals which begin the physical transformations, but interestingly these are not the sole cause of when pubertal timing occurs for an individual. In young women physical exercise can delay the onset of the physical changes associated with puberty. For example, Brooks-Gunn (1988) found that very few ballet dancers actually had their first menstruation at the 'normal' time. Family factors can also play an important role in pubertal timing. Moffitt, Caspi, Belsky and Silva (1992) found that family conflict and the absence of fathers predicted an earlier onset of menarche. Steinberg (1987) found that an increased psychological distancing between girls and their fathers also predicted an earlier menarche. Ellis and colleagues (1999) showed that the quality of fathers' investment in their daughters was positively associated with the timing of puberty: when fathers had good-quality relationships with their daughters, the onset of pubertal maturation in their daughters came later. Income and nutrition also have an effect on sexual maturation. In poor regions, menarche is generally delayed, while girls from higher-income families in these regions reach menarche up to three years earlier (Allsworth, Weitzen, & Boardman, 2005). Together, these studies highlight the importance of environmental factors in sexual maturation, demonstrating the necessity of examining interactions between genetic and environmental causes in studying development.

Besides examining the questions of when and why adolescents enter puberty earlier or later than their peers, we can ask what effects early or late maturation has on individuals. A classic study by Jones and Bayley (1950; see also Jones, 1965) suggested that early maturation carries distinct advantages for boys but not for females. Jones and Bayley tracked 16 early-maturing and 16 late-maturing boys for a six-year period. Late-maturing boys were characterized as lower in physical attractiveness and masculinity, and were rated as more childish, eager and

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attention-seeking than early-maturing boys. In contrast, early-maturing boys were characterized as independent, self-confident, and as making better leaders and athletes. Jones showed that for women (Jones & Mussen, 1958) early-maturing girls were more likely to show social difficulties than late-maturing girls. They were also less popular, less self-confident, held fewer leadership positions, and were more withdrawn than late-maturing girls. More recent research has confirmed and extended these findings. Early-maturing girls tend to have a poorer body image than normally-maturing or late-maturing girls (Brooks-Gunn, 1988), at least in part because the normal weight gains which accompany pubertal maturation violate the cultural ideal for thinness. This trend is exactly the reverse for males: early-maturing boys tend to have a much more positive body image, in large part because many cultures seem to value traits like height and muscularity. Early-maturing boys clearly have a number of advantages compared to late-maturing boys, although recent research suggests there may be more to the story. Early maturing boys report more psychological stress than their later-maturing peers (Ge, Conger, & Elder, 2001) and an increased risk of risk-taking and problem behaviour since they are more likely to associate with older males (Ge, Brody, Conger, Simons, & Murray, 2002).

Behavioural problems have also been associated with early vs. late maturation, particularly in girls. The explanations for these problems seem to reduce to two types. Caspi and Moffitt (1991) argue for a *dispositional account*, believing that it is not early-maturation *per se* that creates problems for girls, but rather, early maturation on top of a previous history of behaviour problems. Their argument is that when stressful events such as early maturation occur, they may highlight dispositional factors (tendencies to behave in a particular fashion, possibly due to genetic factors or previously acquired habits). It is these dispositions which Caspi and Moffitt believe are ultimately responsible for the behaviour problems. In contrast, Graber, Brooks-Gunn and Warren (1995) believe that *psychosocial factors* – factors such as parental warmth, parental approval and the level of family conflict – play an important role in how girls react to early maturation. Research from Sweden has tended to support the view that psychosocial factors play a significant role in the effects of early maturation on girls (Stattin & Magnusson, 1990). These researchers found that early-maturing girls tended to have smaller networks of friends, to associate with older friends who often engaged in deviant behaviours, and were more likely to engage in risky behaviours such as smoking, drinking alcohol and sexual intercourse. While the findings to date do suggest a risk to early-maturing girls, it is clear that contextual and psychosocial factors play an important role: not all early-maturing girls will experience problems and some early-maturing girls may show very positive developmental outcomes (Brooks-Gunn, 1988).

Motor Development

Human infants start life with very limited motor skills, yet by about 1 year of age they are walking independently. In between birth and learning to walk a great many skills are acquired. What does the course of motor development in infancy look like? Nancy Bayley (1969) provides us with a description of the average age at which infants and toddlers acquire many of the most

common motor skills. According to Bayley, infants can hold their heads upright by 6 weeks of age; by 2 months they can roll from their sides onto their back; by 3 months of age they can grasp an object; by 7 months infants can sit alone and begin to crawl; and by 12 months they walk on their own.

Also included in Bayley’s work is a description of the age range at which 90% of children achieve a particular skill. For example, while the average infant sits upright alone by 7 months of age, 90% of infants will acquire this skill somewhere between 5 and 9 months of age. Bayley’s data highlight a significant fact regarding the variability of motor development: while the sequence of motor development is relatively uniform, progress in the acquisition of motor skills is highly variable. For example, some infants will learn to walk as early as 9 months while others will not take their first steps until 17 months. It is important to remember that individual children will not conform exactly to any description of the average age at which developmental milestones are achieved: some variability is normal and early progress or lack of the same is not a good predictor of the final level of development.

Table 4.1 Selected milestones in motor development

Age	Milestone
6 weeks	Hold head upright while in a prone position
2 months	Roll from back onto side
3 months	Directed reaching for objects
5 to 7 months	Sit without support
9 to 14 months	Stand without support
8 to 12 months	Walk with support
12 months	Use of pincer grasp when reaching
12 to 14 months	Walk alone

A principle known as **differentiation** comes into play when we try to describe the acquisition of motor skills (Bühler, 1930). Differentiation refers to the fact that initially, motor skills are rather global reactions to a particular stimulus – only with time and practice do motor behaviours become more precise and adapted to particular ends. Consider an infant’s reaction to having an unwanted blanket placed on top of them. A very young infant might twist and writhe in a random fashion which may or may not achieve the desired effect. Older infants will grasp the blanket and pull it away: they use a more specific, more precise behaviour to accomplish their goals. The principles of cephalocaudal and proximodistal development also apply to the acquisition of motor skills. For example, infants learn to hold their head upright before they learn to sit upright or pull themselves into a standing position.

Maturation vs. experience

The maturation of the neural and muscular systems determines to a large extent when children will acquire a particular skill. Early research on motor skills highlighted a maturationist viewpoint, that is, that development is under the control of inherited programmes that are genetic in origin (Gesell & Thompson, 1929; McGraw, 1935). These researchers were reacting against behaviourists like John B. Watson (see Chapter 2) who believed that motor skills like walking were simply conditioned reflexes. In contrast, maturationists like Gesell and McGraw believed that motor behaviours such as walking emerged according to a pre-programmed genetic timetable.

Gesell devised a simple design to demonstrate the effects of maturation. Using identical twins allowed Gesell to control for biological factors since identical twins share 100% of their genes. One twin would be given extra practice at a particular motor task while the control twin received no extra training. When tested after a period of training, *both* twins showed significant evidence of acquiring the motor skill, not simply the twin who had been given extra practice, as might be predicted (Gesell & Thompson, 1929). Such findings led Gesell to the conclusion that maturation and not experience was the prime factor in determining when children acquire skills.

However, as Thelen (1995) notes, the development of motor skill is not simply the outcome of genetic programming: transactions with the environment must play a crucial role in the timing of motor skill acquisition. Thus, an important aspect of when children acquire a particular motor skill is experience. In contrast to the work of Gesell, opportunities to practise particular motor skills have been shown to promote their earlier appearance (Zelazo, Zelazo, & Kolb, 1972). The acquisition of motor skills also varies across cultures in ways which are not consistent with genetic factors. Some cultures emphasize practices which encourage the earlier or later appearance of a skill. For example, Hopkins and Westra (1988) found that mothers in the West Indies have babies who walk considerably earlier than the average North American infant. West Indian mothers use a particular routine, passed down to them by other members of their culture, which encourages the early development of walking and other motor skills. As this example shows, environments can have important effects on when skills are acquired.

Gross and fine motor development

Bertenthal and Clifton (1998) note that control over one's motor behaviour ranks among the infant's greatest achievements. Psychologists who study the acquisition of motor skills find it useful to distinguish between **gross motor development**, that is, motor skills which help children to get around in their environment, such as crawling and walking, and **fine motor development**, which refers to smaller movement sequences like reaching and grasping. The development of motor skills has implications beyond simply learning how to perform new actions: motor skills can have profound effects on development. For example, researchers have shown that infants with locomotor experience were less likely to make errors while searching for hidden objects (Campos & Bertenthal, 1989; Horobin & Acredolo, 1986). The ability to initiate movement about one's environment stimulates the development of spatial encoding abilities, making hidden object tasks easier to solve. Rovee-Collier (1997) has made a similar point in regard to

memory development. She argues that the onset of independent locomotion around 9 months of age marks an important transition in memory development. Children who can move about the environment develop an understanding of locations such as 'here' and 'there'. Because infant memory is initially highly dependent on context – that is, the similarity between the situation where information is encoded and where it is recalled – infants who have experience moving about the environment and who learn to spatially encode information become less dependent on context for successful recall. These examples show that motor development has implications beyond the immediately apparent benefits of crawling or walking.



Image 4B Children who can move about the environment develop an understanding of locations

Piaget (1952) argued that the development of reaching and grasping was a key aspect of cognitive development because it formed an important link between biological adaptation and intellectual adaptation. Reaching and grasping are voluntary actions under the infant's control, and as such, they open up exciting new possibilities in their ability to explore their environment. An infant who reaches for and grasps an object in order to explore it pushes their development forward as they engage in processes such as adapting their grip to the size and shape of the object. Piaget argued that these early processes of assimilation and accommodation to objects drove cognitive development in the sensorimotor period.

The development of reaching begins early in life. Newborn infants seated in an upright position will swipe and reach towards an object placed in front of them, a behaviour labelled **prereaching**. These poorly coordinated behaviours start to decline around 2 months of age (Bower, 1982) and are replaced by **directed reaching**, which begins at about 3 months of age (Thelen, Corbetta, Kamm, Spencer, Schneider, & Zernicke, 1993). At this time reaching becomes more coordinated, efficient and improves in accuracy (Bushnell, 1985). According to research conducted by Clifton, Rochat, Robin and Berthier (1994), the infant's reaching does not depend simply on the guidance of the hand and arm by the visual system, but is controlled by **proprioception**, the sensation of movement and location based on stimulation arising from bodily sources such as muscle contractions. By about 9 months of age infants can adjust their reaching to take into account a moving object. However, 9 month-olds are far from expert reachers and a good deal of skill remains to develop.

Once infants begin reaching they also begin to grasp the objects that are the target of their reaches. The **ulnar grasp** is seen when infants first engage in directed reaching. This is a primitive form of grasping in which the infant's fingers close against their palm. The fingers seem to act as a whole, requiring the use of the palm in order to hold an object. Shortly after this accomplishment, when infants can sit upright on their own, they acquire the ability to transfer objects from hand to hand. By around the end of the first year, infants have graduated to using

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the **pincer grasp** (Halverson, 1931) wherein they use their index finger and their thumb in an opposable manner, resulting in a more coordinated and finely-tuned grip. This allows for the exploration of very small objects or objects which demand specific actions for their operation, such as the knobs on a stereo system, which require turning to the left or right to adjust volume.

Motor development as a dynamic system

You may remember from Chapter 2 that dynamic systems theories stress interactions that make up a complete system. Dynamic systems have been used to understand motor development, by seeing mastery of motor skills as involving a complex system of actions. Thus, different motor skills combine in new and increasingly effective ways. We can understand the combinations that create many motor skills. For example, control of the head and chest allows infants to sit with support; kicking, rocking and reaching combine to allow the infant to crawl; and crawling, standing and stepping combine to produce the ability to walk (Thelen, 1989). Each set of developments unites a number of factors: muscle development, the child's goal and environmental support. Imagine if we lived underwater and how this might affect children's motor skills: it is likely that limbs would develop to support a swimming motion, the child's goal would be to move through water and the environment would support the motion of swimming rather than crawling or walking. A number of elements combine to produce what we call motor skills.

Babies must practise their skills and in doing so they often come up with novel ways around problems, which is why not all infants and children develop the same skills in the same set of ways. For example, some babies do not like to be on their stomachs, and will learn to sit and pull themselves to standing, thereby learning to walk before crawling. Toddlers practise learning to walk for up to six hours a day (Adolph, Vereijken, & Shrout, 2003). That's quite some homework! Through such repetition of movements, new connections in the brain develop to solidify the skill needed to walk.

Cross-cultural research provides further evidence for a dynamic system view of motor skills by showing that opportunity for movement and a supportive environment lead to motor development. For example, mothers in developing countries tend to encourage infant walking at an earlier age than mothers in North America and Britain. One thought is that parents in developing countries place value on their child's physical strength as strength is likely to equate to survival. Thus, in places such as Kenya, mothers vigorously exercise their babies and leave infants sitting alone to explore their environment, providing plenty of time to practise motor skills (Keefer, Dixon, Tronick, & Brazelton, 1991). These infants typically develop the ability to walk early on, often much before children in places such as North America. However, it has also been shown that when mothers of newborns in the United States give their babies practice in a stepping motion, even for a few minutes a day, those babies are more likely to walk early than a control group (Zelazo, Zelazo, & Kolb, 1972).

Together, this research suggests that motor development results from an interaction between nature and nurture. Consistent with a dynamic systems view, it seems that genes provide the basic blueprint for motor skills, but the exact way that motor skills are acquired results from a complex interplay of the brain, body movement and environmental supports.

The development of motor skills beyond infancy

Beyond infancy, not a great deal is known about the development of motor skills. Gallahue (1989) suggests that, beyond infancy, three fundamental sets of motor skills emerge in the child's repertoire. These are *locomotor movements*, which include walking, running, jumping, hopping, skipping and climbing; *manipulative movements*, including throwing, catching and kicking; and *stability movements* (centred on controlling one's body), including bending, stretching, rolling, balancing and walking on one's hands.

The development of motor skills progresses through three stages (Gallahue, 1989). Consider an example such as learning to swing a tennis racquet. Initially, a child tries to execute the motor skill; however, they fail to follow through with the movement. They also fail to engage in any sort of anticipatory movements which prepare them to execute the action. A young child's stroke often looks more like a swipe, barely resembling the straight-armed, locked-wrist style that mature players use. By the second stage, what we might think of as a transitional stage in the development of the skill, children can execute the individual components of the swing more competently; however, they fail to organize the components into a smoothly sequenced whole. At this stage children may adopt a straight arm, start with their racquet well behind their body and follow through, but on any given swing they are unlikely to execute all three of these aspects of an accomplished stroke together. Finally, by the third stage all components of the behaviour are integrated into a coordinated whole. Motor skills continue to improve as related developments in the sensory and perceptual skills, as well as the maturation of the nervous system, take place. However, increased practice will speed children's acquisition of a skilled behaviour.

Genetics

Consider your own siblings or a friend you know who has brothers or sisters: are you or your friend exactly the same as your or their brother or sister? The answer (even if you have an identical twin) is probably 'no'. Siblings share half their genes with each other; that is, half of your genetic material is the same as your brother's or sister's, but these shared genes are not enough to ensure a high degree of similarity. This is because genes interact with the environment to produce observable characteristics such as eye colour, and height or behaviours such as personality and intelligence. When we speak of an individual's **genotype**, we refer to their genetic makeup, that is, the particular set of genes they have inherited from their parents. As a result of development, environments act on individuals to produce their **phenotype**, that is, their observable characteristics.

In our discussion of genetics and human development, we will take for granted that by this point in your career you have acquired an understanding of sexual reproduction and instead will focus on the key genetic aspects of the process. At conception, a single sperm from males unites with the **ovum** or egg from the female to create a fertilized egg called a **zygote**. Sperm and egg are unique cells in that they are the only cells in the human body to carry 23 **chromosomes** (all other cells carry 46 chromosomes). These special cells are known as **gametes**. Chromosomes are a very special chemical structure made up of a series of proteins known as deoxyribonucleic acid

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or **DNA**. They have a thread-like appearance and are found in the nucleus of a cell. Chromosomes come in 23 pairs; half of these come from the mother and half from the father. The chromosomes carry the **genes** which are the units of hereditary transmission. Genes are sequences of proteins, a part of the DNA molecule. They work by triggering the production of proteins when instructed to do so by environmental signals or by other genes.

Remember that chromosomes come in pairs, one from the father and one from the mother. Thus, a gene on one chromosome has a partner or an alternate form on the other chromosome. This alternate form of the gene is called an **allele**. To further complicate matters, the alleles of a gene from both parents can be similar or dissimilar in their genotype. If the alleles are alike, the child is said to be **homozygous** for the trait coded for by the gene; if the genes are dissimilar, the child is **heterozygous**. Homozygous children will display the trait which is coded for by the genes whereas the relationships between the two alleles will determine how the trait is expressed for heterozygous children. Consider eye colour as an example. The genes which code for eye colour can have different forms, an allele which specifies blue eyes and an allele which specifies brown eyes. If the child's parents both carry the blue-eyed allele, the child will have blue eyes.

The relationships between alleles are described in terms of **dominant** and **recessive** alleles. In some cases, one allele is more powerful or dominant than another and will always express its effects over those of another allele. This is the case for hair colour. The brown hair allele is dominant over the red hair allele. Thus a child who inherits a red hair allele from one parent and a brown hair allele from the other will always develop brown hair. If we represent a dominant allele by **A** and a recessive allele by **a**, then you should recognize that a person could have the following combinations of alleles: **AA**, **Aa**, **aA** and **aa**. These reduce to three patterns: **AA** is homozygous and represents two dominant genes; **Aa** and **aA** are heterozygous and represent combinations where the dominant gene will be expressed; the combination **aa** is again homozygous and represents a person with two recessive genes. In our example of hair colour, this is the *only* combination of genes which would result in a red-haired child. There is yet another possibility which can occur, called **codominance**. Codominance occurs when heterozygous alleles both express their traits with equal force. For example, the blood types A and B are codominant alleles such that a person who inherits the A allele from one parent and the B allele from the other will have the blood type AB.

Many harmful traits coded for by genes are recessive, a fact which has the happy effect of greatly reducing their occurrence in the population. An example of this is the allele for **phenylketonuria** or **PKU**. This is a genetic disorder in which the child is unable to metabolize a protein called phenylalanine, a problem which can lead to brain damage and profound mental retardation. The allele which codes for the normal metabolizing of phenylalanine is dominant while the gene which leads to PKU is recessive. When both parents carry the recessive allele for PKU there is a one in four chance that their offspring will have the disorder (as we described above).

Genes and environments

In contemporary developmental psychology, rarely will one find a psychologist taking up a position that emphasizes either genes or environments as the sole cause of behaviour. Instead, modern psychologists recognize that genes and environments *interact* to shape the course of development.

Physical Growth, Motor Development and Genetics

Research has shown clearly how genetic factors serve to restrict the range of possible courses that development can take, while at the same time we have gained an ever more sophisticated understanding of how environments exert a tremendous influence on development, both supporting and restricting it.

We also know that genes can shape environments. This may strike you as an odd idea, one which violates your intuitive notions of the direction in which biological effects should go. According to the work of Sandra Scarr (1992, 1996; Scarr & McCartney, 1983), genes can have effects on the environment in at least three ways. First, genes can have what Scarr referred to as *passive* effects. Children's environments are most often dictated by parents. Because parents and children share some of their genes, it is not surprising that parents will create a home environment which is supportive of the child's genotype. Consider musical talent. Musical parents will likely have musical children. As a result of their own predisposition, musical parents will create a musical environment for their children. Thus, the parent's efforts provide an ideal environment for the child's genes which code for musical talent to be expressed. Second, genes may have an *evocative* relationship with the environment. This occurs when some trait in the child causes others to react in a certain way which has the effect of strengthening the trait. For example, temperamentally 'easy' babies who smile and act sociably will elicit positive social reactions from others which reinforces the baby's behaviours and ultimately strengthens their genetic predisposition. Finally, genes can affect the environment in an *active* way. This occurs when children seek out environments that are compatible with their genetic makeup. For example, athletically talented children will eventually move towards participation in school sports while musically talented children will join the band. This process, which Scarr (1996) calls **niche picking**, is an active process based on one's genetic predisposition. As Scarr notes, niche picking increases in importance as people move towards adulthood and begin to take increasing control over their own environments. This process may also play a role in explaining why correlations for traits such as cognitive ability show increasing concordance over time.

Can you think of any examples from your own life that might be examples of niche picking? Consider aspects such as your hobbies, sporting activities, school performance or career choice.



As suggested earlier, environments also have profound effects on genetic factors. One way in which this relationship has been conceptualized is through the concept of **range of reaction** (Gottesman, 1963). According to the range of reaction concept, genes do not fix behaviour in a rigid fashion but establish a range of possibilities which depend heavily on environmental circumstances. In a sense, you can think of a person's genotype as placing boundaries on their ability which differ depending on environmental circumstances. For example, if a child is born into an impoverished environment, their genotype may place specific limits on how far their cognitive abilities may develop. This child may show very low ability under impoverished environments and only slightly higher levels of achievement under more enriched environments. In this case, we would say the child has a small range of reaction. In contrast, another child with a different genotype may perform slightly better in impoverished environments but extremely well under an enriched environment. This child would show a much larger range of reaction.

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The reaction range concept has been criticized by Gilbert Gottlieb (1991; Gottlieb, Wahlsten, & Lickliter, 1998). Gottlieb suggests that genes play a much less deterministic role than is suggested by the range of reaction concept, which emphasizes the limit-setting effect of genes. He argues that genes and environments engage in a process of *coaction* wherein the relationships between genes, environments and other levels of behaviour, such as neural activity, all mutually influence one another. The influences between any levels are bidirectional, that is, they go both ways. Thus, genes are simply part of a system which are affected by events at other levels of the system.

Behaviour genetics

Thus far we have covered cases of genetic transmission that conform to a simple model where a gene is causally related to a particular trait, such as eye colour. However, most behaviours that are inherited are multifactorial, that is, they have more than one cause. When some trait is affected by more than one gene, geneticists speak of **polygenetic inheritance**. Given the state of genetic research, it is very difficult at this point in time to specify exactly which genes contribute to some trait, but researchers are beginning to make some progress in this regard. More often than not, researchers are only able to specify how important genetic factors are relative to environmental factors in the cause of some particular trait, that is, how much of the variance in a given trait is caused by genetic factors and how much is caused by environmental factors. This area of inquiry, examining the relationship between genetic and environmental factors, is known as **behaviour genetics**.

We know genetic factors play a critical role in human development. For example, researchers have identified a form of a gene which, if present in an individual, increases the risk of developing Alzheimer's disease by a factor of four over the normal population (Plomin, DeFries, McClearn, & Rutter, 1997). Beyond such high-profile cases as a genetic cause for Alzheimer's, behaviour geneticists have shown that genetics play important roles in the development of psychological traits, such cognitive abilities, school achievement, personality, self-esteem and drug use. In the following section we will examine some of the findings from behaviour genetic research.

Heritability

Behaviour geneticists employ a concept known as **heritability** to measure the effects of genetic factors on a trait. Essentially, heritability is an estimate of the relative influence of genetic versus environmental factors. According to Plomin et al. (1997: 79), heritability can be defined as 'the proportion of phenotypic variance that can be accounted for by genetic differences among individuals'. It is estimated by examining the correlations for some trait among relatives and is generally expressed as an *intraclass correlation*, that is, a correlation which can be straightforwardly interpreted as a percentage. In other words, an intraclass correlation of .80 between identical twins for IQ would suggest that 80% of the variance in IQ scores between the twins was due to genetic factors.

Heritability has been criticized as a concept by many authors. Bronfenbrenner (1972) demonstrated that heritability cannot be straightforwardly interpreted as simply an index of genetic causation. In his analyses, Bronfenbrenner shows how environmental factors have

a clear impact on the calculation of heritability. While not at all refuting the importance of genetic factors in development, Bronfenbrenner's argument is that heritability should be interpreted as reflecting the capacity of the environment to invoke and nurture the development of a trait. In his critique of research on racial differences in intelligence, Block (1995) questions the common assumption that heritability is simply an index of genetic causation. Block points out that heritability is calculated as a ratio of *genetically caused* variation to *total variation* in some trait. Again, while not refuting the importance of genetic factors in human development, Block's argument is that a characteristic can be highly heritable even if it is not caused by genetic factors. Take a trait such as long hair. Block would argue that in 1950 long hair was caused genetically. That is, in western cultures only women wore long hair, and since women are genetically different from men, the cause of wearing long hair could be construed as genetic. The ratio of genetic variation (sex: men or women) to total variation (women: only women wore long hair) was close to one, indicating high heritability. However, now that variability in who wears their hair long (as both men and women commonly do these days) has increased, the heritability of long hair has decreased. However, neither in 1950 or today is wearing long hair genetically determined in the normal sense. Men did not usually wear long hair in the 1950 due to strong social pressures to conform (i.e. environmental reasons): when the environmental reasons change, so to does the heritability of the trait. While this example may seem frivolous, the point it makes is very important to how we interpret heritability. The student of developmental psychology needs to remember that heritability does not necessarily imply genetic causation.

Epigenetics

Research uncovering the intricate relationship between genes and environment has taken a new, exciting turn of late. While traditional geneticists have examined the interactions of genes and environment upon behaviour, and even the impact of DNA on the individual's environment (such as through niche picking, discussed above), an exciting new question asks whether the environment can actually change a person's genes. It seems the answer is yes, and this emerging field is referred to as the study of *epigenetics*.

How can one's experiences cause permanent genetic changes? In response to certain signals, epigenetic modifications can essentially turn off a region of DNA. This occurs through chemical changes that affect the shape of the particular piece of DNA so that the protein encoded by that gene cannot be made. Furthermore, when cell division occurs and the DNA is copied, the epigenetic changes are copied as well so that all future versions of the cell contain the epigenetic change – thus, permanently changing the genetic makeup. Recent work has revealed that even transient environmental influences can cause long-lasting changes to DNA under this process. Epigenetic influences also explain why identical twins do not always look exactly the same, despite sharing identical DNA.

At this stage, most of the epigenetics research has been done using animal models and we have yet to understand the full range of epigenetic influences on human DNA. Nonetheless, this

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early research has had profound implications for understanding how impoverished or enriched environments can permanently alter not just the genetic course of the affected individual, but that of their descendants also.

Some of the more interesting findings using animal models examine how when epigenetic modifications occur in sperm or eggs, they impact on future generations. Female mice that spent two weeks of their youth in an enriched environment that included access to a variety of stimulating rat puzzles and toys displayed superior learning skills as adults than rats reared in a regular laboratory environment. Moreover, their pups did too. The pups of the enriched environment rats even showed this advantage when they were raised by a foster mother and did not receive any enriching environmental experiences themselves. It seems the pups were smarter as a result of their mother's rich – albeit briefly so – environment, which was then passed down through epigenetic processes in her DNA (Arai, Li, Hartley, & Feig, 2009). A further landmark epigenetic study is discussed in Research Example 4.2.

It is likely that similar epigenetic mechanisms are at play in the developing human. We know that child maltreatment is associated with a host of problems in adulthood, including anxiety and depression. The association in both rats and humans between persistent behaviours and early life experience suggests that there is some kind of chemical process that serves as a memory of these early life experiences in animals across species (Suderman et al., 2012). There is evidence that through epigenetic processes, early life experiences can alter rat and human DNA as it relates to the stress response (McGowan et al., 2009). Similar to the processes described in Research Example 4.2, early life stress leaves a permanent mark on our genetic makeup, essentially turning on markers of reactivity and increasing an individual's sensitivity to future stress (Labonté et al., 2012). That's not to say the news is all bad. We know from our previous discussion that environments and genes play out in a complex back and forth manner, and just because stress may turn on a stress reactive gene process, this doesn't mean we can't learn coping techniques and ways to adapt later in life. Environments can change our genes, but we also know that genetic information doesn't set our future behaviour in stone.

An additional implication of our DNA's sensitivity to early environmental threat involves seeing the process as an adaptive function. Perhaps we have been shaped to respond to subtle variations in parental behaviour as a forecast of things to come; that is, perhaps in some instances having a reactive stress system 'turned on' from early stress sets up the individual to recognize and survive in a stressful environment (Meaney, 2001). It may be easy to see this in terms of rat survival, such that pups born into stressed, low grooming families grow up to be reactive to stress, vigilant of their surroundings, and perhaps better able to cope and survive in a realistic rat world (one that isn't a safe laboratory) filled with threat and danger and limited food. However, the situation may seem more unfortunate when considering human requirements. Arguably, most of us live in a safe (in relative rat terms) world, one that requires some vigilance for a threat to our survival, but where high reactivity and hypervigilance are associated with unfortunate outcomes, including poor mental and physical health.

We are inclined to think of inheritance as concerning fixed, stable traits written down in the genetic code passed down to us through eggs and sperm at the time of conception. However,

these landmark epigenetic studies show us that a mother rat can write information into her pups' DNA in a way that has nothing to do with the traditional way of creating DNA, through eggs and sperm. The mother rat's behaviour actually programmes her pups' genetic material so that they are more likely to succeed in the world they are born into. The epigenetic code provides a level of flexibility in the genome that brings a complex and fascinating level to the field of genetics.

Research Example 4.2

A Mother's Lick

A fascinating study from a group of Canadian scientists has demonstrated the epigenetics of stress (Weaver et al., 2004). This study involved examination of the rates that mother rats licked their pups (the equivalent of human mothers cuddling, stroking or holding their babies). Some rat mothers extensively lick and groom their pups, while others ignore their offspring. Pups that receive attention during the first week of life tend to display calm, non-reactive behaviours, while those that were ignored grow up to be anxious and more prone to disease. The relationship seems straightforward enough, but the mechanics of how this occurs are fascinating. The differences in behaviour reflect different genetic processes at play in the two groups of mother–infant rat pairs. At birth, one of the genes responsible for the body's stress response, known as the glucocorticoid receptor (GR) gene, is highly inactive – or, in scientific speak, it is *methylated*. In the group of sensitive rat mothers, the authors were able to demonstrate that the pups' GR gene demethylated, making the gene more active, and resulting in the pups becoming more relaxed. The opposite was true for the ungroomed pups: these babies did not express the GR gene, and consequently responded poorly to stress. Such tendencies, if left unchecked, persisted, and the pups were more or less anxious as adults depending on whether their mother was a high or low licker.

To directly examine the cause–effect relationship between maternal behaviour and DNA methylation, the scientists performed an adoption study, cross-fostering the rat pups. Biological offspring of low-nurturing mothers were reared by high-nurturing mothers and the results showed they ended up having a similar genetic expression as the normal offspring of high-nurturing mothers, while the converse was true; biological offspring of high-nurturing mothers reared by non-licking mothers resembled the biological babies of the non-licking mothers. The researchers had demonstrated that an environmental condition – maternal care – directly altered the genetic material of an individual.

It may be tempting to think of the high-grooming rats as 'good mothers'. However, as discussed above, this rules out the possibility that early environmental factors provide a forecast for the survival skills babies will need. In fact, both groups of mothers are matching their pups' adult behaviour to likely future conditions. In effect, both the high- and low-licking mothers are preparing their babies for conditions to come.

Research designs in behaviour genetics

Most commonly, heritability is estimated using *twin studies*. In one common twin study design, the correlation on some trait (for example, intelligence) is measured between pairs of **monozygotic twins** and **dizygotic twins**. Monozygotic twins are born of the same fertilized egg, a zygote which has split in half, and thus they share 100% of their genes. Dizygotic or fraternal twins develop in the womb at the same time but are of two different fertilized eggs, and as a consequence they share only 50% of their genes. If one makes the assumption that the environments of identical twins are no different from the environments of fraternal twins, then higher correlations for the trait between identical twins are thought to be the result of their genetic similarity. It is important to note that this conclusion is based on an assumption of equal environments between identical and fraternal twins. Bronfenbrenner (1972) highlighted the reasons why this assumption is problematic. Think for yourself about this issue. Do you think identical twins might be treated differently from fraternal twins in some way? If you bring to mind issues such as parents dressing twins exactly alike or friends and relatives confusing identical twins, then you have identified some of the factors that Bronfenbrenner felt might be problematic for the twin design and which violate the equal environments assumption. Again, while such problems pose issues for how exactly we interpret the findings from behaviour genetic research, they by no means suggest that genetic factors are unimportant determinants of human development.

A large number of behaviour genetic studies have been conducted to examine the heritability of intelligence. A review of many of these studies by Bouchard and McGue (1981) showed that the average correlation between same-sex pairs of monozygotic twins measured for general intelligence was .86. A correlation of .62 was obtained for fraternal twins. Both of these results indicate a substantial effect for genetic factors (although keep in mind the potential interpretative problems discussed earlier). When Bouchard and McGue examined the findings for twins reared apart, the correlation dropped to .72, again, indicating a substantial role for genetic factors. Further work on the importance of genetic factors across the life span has come to the intriguing conclusion that genetic factors become more salient to explaining the correlations between the IQ scores of twins as time goes on. In other words, as age increases so does the correlation for general intelligence between twins (DeFries, Plomin, & Fulker, 1994; Plomin, Pedersen, Lichtenstein, & McClearn, 1994; Plomin et al., 1997). As many of these researchers would note, the findings described above, while indicating a substantial role for genetic factors in the development of general intelligence, also indicate the significance of environmental factors in determining intelligence.

We now briefly consider genetic effects on personality. Behaviour genetic research in the area of personality has suggested that as much as 50% of the personality differences between people are due to genetic factors (Bouchard, 1994). Loehlin (1992) reported evidence of significant genetic effects on two commonly measured aspects of personality: *neuroticism* (emotional instability) and *extraversion* (sociability). Intraclass correlations for identical twins reared together were around .50 for both traits, suggesting a strong link between genetics and personality.

Another trait known as *sensation seeking*, which is comprised of behaviours such as thrill seeking, searching out novel experiences and susceptibility to boredom, showed a correlation of .54 in a sample of identical twins reared apart. Plomin et al. (1997) suggest that there is also strong evidence that a variety of personality disorders, such as schizotypal, obsessive-compulsive and borderline personality disorder, are all at least partially heritable.

Recent research has sought to more fully understand the interactions between genes and environment. This relationship is likely to be more complex than simple formulas or percentages can account for, as shown in the work of Thomas Boyce and Bruce Ellis on stress reactivity. Stress reactivity is the tendency to physically react to psychological stressors (think of a shy person just told he must stand up in front of the class to give an impromptu speech and you get an idea of the extreme end of stress reactivity). Using an evolutionary-developmental model, Boyce and Ellis (2005) suggest that reactivity has genetic and environmental elements; however, a more useful way to look at the equation is to think about how genetic and environmental factors result in the *calibration* of a response system. That is, highly reactive phenotypes (children showing stress reactions) have a biological sensitivity to context. To illustrate, imagine a child born with the genotype to be reactive. If this child is placed in a stressful environment, the odds of the child developing into a calm, socially fearless individual are low. However, if the same child is placed in an environment that is highly protected, a similar sensitivity to stress is likely to result. Thus, for stress reactivity to be high, an individual must be predisposed to stressful environmental influences: exposure to a highly stressful or protective environment then locks in the stressed tendencies. Research has confirmed this theory. Ellis, Essex and Boyce (2005) examined the physiological stress reactions and family life of 249 children. A disproportionate number of children in stressful *and* supportive, low-stress environments displayed high autonomic reactivity (such as high heart rate and stress cortisol levels).

Summary

Perhaps the most noticeable aspect of development is physical maturation and growth. From the moment of conception, the developing baby undergoes enormous physical changes, eventually reaching the near adult size and sexual maturation of adolescence. The course of development doesn't always run smooth, however, and the foetus is at particular risk of damaging and life-threatening influences called teratogens. Genetic and environmental factors, including nutrition and stress, interact over the course of a child's life, leading to individual differences in height, weight and pubertal timing. Another aspect of children's physical development is motor skills, which progress from simple movements such as reaching and grasping in infancy and toddlerhood, to jumping, walking and the mastery of sports in childhood and adolescence. Recent developments in the field of genetics, and particularly epigenetics, sheds light on the complex interplay of DNA and experience in our physical, and also social, emotional and cognitive development.

Glossary

Allele refers to the alternate form of a gene.

Behaviour genetics is the area of inquiry examining the relationship between genetic and environmental factors in development.

Cephalocaudal development refers to the idea that physical growth occurs in a head to toe direction.

Chromosomes are very special chemical structures, found in the nucleus of a cell, which are made up of a series of proteins known as deoxyribonucleic acid or DNA.

Codominance occurs when heterozygous alleles both express their traits with equal force.

Differentiation refers to the fact that, initially, motor skills are rather global reactions to a particular stimulus and only become more precise and adapted to particular ends with time.

Directed reaching describes reaching which has become more coordinated, efficient and has improved in accuracy.

Dizygotic twins develop at the same time but from two different fertilized eggs; otherwise known as fraternal twins.

Dominant refers to the fact that one allele for a trait is more powerful than another and will always express its effects over those of another allele.

Estrogens are hormones that are associated with female sexual maturation.

Fine motor development refers to small movement sequences like reaching and grasping.

Gamete is a reproductive cell, containing only one copy of each chromosome.

Genes are the units of hereditary transmission. A gene refers to a portion of DNA located at a particular site on the chromosome.

Genotype is our genetic makeup, that is, the particular set of genes we have inherited from our parents.

Gross motor development refers to the various motor skills, such as crawling and walking, which help children move around in their environment.

Heritability is an estimated measure of the relative effect of genetic factors on a trait.

Heterozygous a child is said to be heterozygous for a trait coded for by a gene if both forms of the gene are different.

Homozygous a child is said to be homozygous for a trait coded for by a gene if both forms of the gene are alike.

Hormones are a set of chemical substances manufactured by glands that are received by specialized receptor cells throughout the body which can trigger other chemical changes.

Menarche refers to the onset of menstruation.

Physical Growth, Motor Development and Genetics

Monozygotic twins are offspring from the same fertilized egg, otherwise known as identical twins.

Niche picking is an active process whereby one's genetic predisposition leads one to arrange the environment to suit one's disposition.

Ovum is the female germ cell which unites with a male's sperm at conception.

Phenotype refers to the observable characteristics of an organism, created by the interaction of the genotype with the environment.

Phenylketonuria (PKU) is a genetic disorder in which a child is unable to metabolize a protein called phenylalanine which can lead to brain damage and mental retardation.

Pincer grasp refers to a grasp where infants use their index finger and their thumb in an opposable manner, resulting in a more coordinated and finely-tuned grip.

Pituitary gland is a gland located near the base of the brain which triggers physical growth by releasing hormones and controls other hormone-releasing glands via its chemical secretions.

Polygenetic inheritance is said to occur when a particular trait is affected by more than one gene.

Prereaching is a behaviour wherein newborn infants seated in an upright position will swipe and reach towards an object placed in front of them.

Primary sexual characteristics refer to the reproductive organs: the penis, scrotum, and testes in males, and the vagina, uterus, and ovaries in females.

Proprioception is the sensation of movement and location based on stimulation arising from bodily sources such as muscle contractions.

Proximodistal development refers to the idea that physical growth occurs outwards from the centre of the body towards the hands and feet.

Psychosocial dwarfism is the reduction in children's height and weight due to severe emotional deprivation and abuse.

Range of reaction refers to the fact that genes do not fix behaviour in a rigid fashion but establish a range of possibilities which depend heavily on the environment.

Recessive refers to the weaker of two alleles.

Secondary sexual characteristics refer to the visible changes which are associated with sexual maturation, such as the development of breasts in females, facial hair in males, and pubic hair for both sexes.

Spermarche refers to the first ejaculation in males.

Testosterone is a male hormone which is responsible for the production of sperm and for the development of primary and secondary sexual characteristics.

Ulnar grasp is a primitive form of grasping in which the infant's fingers close against their palm.

Zygote is a fertilized egg, created by the union of a sperm and an ovum, signifying the first two weeks of life.

TEST YOUR KNOWLEDGE

1. Which of the following is not a stage in prenatal development?
 - a) Zygote
 - b) Foetus
 - c) Embryo
 - d) Teratogen
2. What is the APGAR scale?
 - a) A measure of the newborn infant's condition that assesses five signs including heart rate, respiratory rate, muscle tone, reflexes and skin tone
 - b) A measure of the newborn infant's condition that assesses five signs including the presence of teratogens, respiratory rate, muscle tone, reflexes and skin tone
 - c) A method of determining whether a foetus is at risk of being born prematurely
 - d) A type of ultrasound test that determines whether a foetus is a girl or boy
3. Which of the following is not generally involved in the timing of an individual's sexual development?
 - a) Nutrition
 - b) Relationships with parents
 - c) Genetics
 - d) Brain lateralization
4. Dynamic systems theories understand the development of motor skills as occurring through a combination of which of the following?
 - a) Brain development, the child's present movement possibilities, the goal of the child, and environmental support
 - b) Hormones and nutrition
 - c) Genetics and environment
 - d) Prenatal development, what happens as birth and parental encouragement

ANSWERS: 1-D, 2-A, 3-D, 4-A

Suggested Reading



Malina, R. M., Bouchard, C., & Oded, B. O. (2004). *Growth, Maturation, and Physical Activity* (2nd edition). Champaign, IL: Human Kinetics.

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Moalem, S. (2014). *Inheritance: How our genes change our lives and our lives change our genes*. New York: Grand Central Publishing.

Thelen, E., & Smith, L. B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*. Cambridge, MA: MIT Press.



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