FIGURE 5.3 Changes in environment can have major effects on phenotype. Generational differences in height are often connected with changes in diet.

However, the term *adaptation* can also be used to refer to the *phenotypic traits* that are the outcome of adaptive processes. As Zaneta Thayer and Amy Non explain,

> Humans must adapt to multiple timescales of evolutionary change. . . . Very stable environmental trends can be accommodated through natural selection, the slowest mechanism of genetic change. Immediate, minute-to-minute fluctuations in the environment, such as changes in temperature, are accommodated via homeostatic processes, including changes in blood flow. At a more intermediate level on the timescale of months to years, organisms adapt to environmental conditions via developmental plasticity. (2015, 727–28)

The sickling trait in hemoglobin described in the previous section is a classic example of a genetic adaptation produced by natural selection, in response to environmental conditions that stabilized in regions where tropical forests were cleared for farming several thousand years ago, creating expanded breeding grounds for mosquitos carrying the malaria parasites and thereby increasing human exposure to the parasites. In this case, the form of the hemoglobin molecule is the phenotypic product of a single-locus gene of major effect. Most human phenotypic traits, however, are the product of pleiotropy, polygeny, and inputs from the environment.

The shivering response in humans illustrates adaptation to the brief timescale of minute-to-minute fluctuations in the environment, a response in human beings sometimes called "short-term **acclimatization**." Human beings are warm-blooded organisms who need to maintain a constant internal body temperature to function properly. When the surrounding temperature drops, however, and threatens to cool our internal organs below this threshold temperature (roughly 98.6° Fahrenheit), this temperature drop triggers a twitching response in the muscles that surround our vital organs as a way of generating heat. If we are able to increase our body temperature above the threshold—by going indoors, putting on clothes, or moving closer to the fire—the shivering stops.

Other forms of acclimatization take shape over more intermediate timescales. Such adaptations emerge over the course of many months or years, as human phenotypic plasticity is shaped by inputs from the particular environments within which individuals develop. That is, physiological or morphological changes resulting from developmental plasticity are not a consequence of genetic variation. Put another way, "developmental plasticity allows one genotype to give rise to multiple phenotypes in response to variation in the environment in which an organism develops" (Thayer and Non 2015, 728). For example, some environments in which human populations live, such as the highlands of the Andes Mountains in South America, are characterized by *hypoxia*; that is, less oxygen is available to breathe than at lower altitudes. Studies have shown that people who grow up in high altitudes adapt to lower oxygen levels by developing greater chest dimensions and lung capacities than do people living at low attitudes. These changes—sometimes called "developmental acclimatization"—are a consequence of human phenotypic plasticity and occur when the human body is challenged by a low level of oxygen in the environment. Studies have shown that individuals who were not born in such an environment increased in chest dimensions and lung capacity the longer they lived in such an environment and the younger they were when they moved there (Greska 1990).

One kind of biological mechanism that seems to allow environmental stresses to mold phenotypic plasticity are called *epigenetic marks*. Epigenetic marks are "chemical modifications to DNA that are associated with changes in the way genes are expressed or turned on, and are essential for normal development in mammals" (Thayer and Non 2015, 725). One kind of

acclimatization A change in the way the body functions in response to physical stress.