can become biology because they shape the emerging nervous system" (2012, 31). As Downey and Lende explain, "the predominant reason that culture becomes embodied . . . is that neuroanatomy inherently makes experience material" (2012, 37). Ultimately, they conclude, "The material environment, both natural and artificial, provides structure and information to the growing organism while being incorporated with its inherited biological legacy" (2012, 44).

The Four Evolutionary Processes

What controls the patterns of gene frequencies that characterize a given population? As we have seen, **natural selection** among variant traits is responsible for evolutionary changes in organisms, and **mutation** is the ultimate (and constant) source of new variation. These two important evolutionary processes shape the histories of living organisms; however, they are not the only processes in the natural world that can alter gene frequencies.

Most genetic variation results from mixing already existing alleles into new combinations. This variation is the natural result of chromosomal recombination in sexually reproducing species. However, gene frequencies can be drastically altered if a given population experiences a sudden expansion resulting from the inmigration of outsiders from another population of the species, which is called **gene flow**. A population that is unaffected by mutation or gene flow can still undergo **genetic drift**—random changes in gene frequencies from one generation to the next. Genetic drift may have little effect on the gene frequencies of large, stable populations, but it can have a dramatic impact on populations that are suddenly reduced in size by disease or disaster (the *bottleneck effect*) or on small subgroups that establish themselves apart from a larger population (the *founder effect*). Both of these effects accidentally eliminate large numbers of alleles.

Therefore, modern evolutionists recognize four evolutionary processes: mutation, natural selection, gene flow, and genetic drift. Chance plays a role in each. The occurrence of a mutation is random, and there is no guarantee that a useful mutation will occur when it is needed; many mutations are neutral, neither helping nor harming the organisms in which they occur. Nor is there any way to predict the factors that make population migrations possible or to foresee the natural accidents that diminish populations. Unpredictable changes in the environment can modify the selection pressures on a given population, affecting its genetic makeup. Moreover, as we saw in Chapter 2, *niche construction*—the enduring consequences of efforts organisms make to modify the environments in which they live—can sometimes alter the selection pressures they, their descendants, and other neighboring organisms experience in those environments. As we shall see, control of fire and the invention of clothing made it possible for early humans to colonize cold environments that were inaccessible to earlier ancestors, who lacked these cultural skills. Niche construction of this kind buffers us from experiencing some selection pressures, but it simultaneously exposes us to others.

Today, many biologists and anthropologists agree that the most intense selection pressures our species faces come from disease organisms that target our immune systems and from human-made environmental threats, such as pollution and the ozone hole (Farmer 2003; Leslie and Little 2003). Evidence that microorganisms are a major predatory danger to humans comes from research on the connection between infectious diseases and polymorphic blood groups (i.e., blood groups that have two or more genetic variants within a population). Biological anthropologists James Mielke, Lyle Konigsberg, and John Relethford (2011) point out, for example, that the diseases human beings have suffered from have not always been the same. When our ancestors were living in small foraging bands, they were susceptible to chronic parasitic infections, such as pinworms, or diseases transmitted from animals. After the domestication of plants and animals, however, human diets changed, settled life in towns and cities increased, and sanitation worsened. Populations expanded, individuals had more frequent contact with one another, and the stage was set for the rise and spread of *endemic* diseases (i.e., diseases particular to a population) that could persist in a population without repeated introduction from elsewhere. As a result,

> the increase in endemic diseases started to apply selective pressures that were different from those exerted by chronic diseases. These diseases usually select individuals out of the population before they reach reproductive age. Differential mortality (natural selection) based on genetic variation in the blood types would be expected to influence genetic polymorphisms. Thus recurrent epidemics of diseases such as smallpox,

natural selection A two-step, mechanistic explanation of how descent with modification takes place: (1) every generation, variant individuals are generated within a species as a result of genetic mutation, and (2) those variant individuals best suited to the current environment survive and produce more offspring than other variants.

mutation The creation of a new allele for a gene when the portion of the DNA molecule to which it corresponds is suddenly altered.

gene flow The exchange of genes that occurs when a given population experiences a sudden expansion caused by in-migration of outsiders from another population of the species.

genetic drift Random changes in gene frequencies from one generation to the next caused by a sudden reduction in population size as a result of disaster, disease, or the out-migration of a small subgroup from a larger population.