Guatemalan Mayan children constitute a genetic adaptation to a harsh natural environment. However, by comparing measurements of these traits in populations of Mayans who migrated to the United States with those in Guatemala, Barry Bogin was able to disprove these claims because "the United States–living Maya are significantly taller, heavier and carry more fat and muscle mass than Mayan children in Guatemala" (Bogin 1995, 65). Similarly, other biological anthropologists working in the Andean highlands have refuted the hypothesis that hypoxia is responsible for poor growth among some indigenous populations (Leonard et al. 1990; de Meer et al. 1993). They point out that the genetic explanation fails to consider the effects on growth of poverty and political marginalization.

At the beginning of the twenty-first century, it has become fashionable for many writers, particularly in the popular media, to treat genes as the ultimate explanation for all features of the human phenotype. Given the great achievements by molecular biology that followed the discovery of the structure of the DNA molecule, this enthusiasm is perhaps understandable. But discussions of human adaptive patterns that invoke natural selection on genetic variation alone are extremely unsatisfactory. For one thing, they mischaracterize the role genes play in living organisms. Speaking as if there were a separate gene "for" each identifiable phenotypic trait ignores pleiotropy and polygeny, as well as phenotypic plasticity. It also ignores the contribution of the other classic evolutionary processes of genetic drift and gene flow, as well as the influences of historical and cultural factors on human development (as in the case of the Mayan migrants). Researchers in the Human Genome Project originally expected that, given our phenotypic complexity, the human genome would contain at least 100,000 genes; today, we know that the actual number is more like 20,000, only twice as many as the roundworm *Caenorhabditis elegans*, one of the simplest organisms that exists (http://www.genome.gov/11007952). Clearly, the number of genes possessed by an organism is not coupled in any straightforward way to its phenotypic complexity.

The gene-centered approach gained considerable influence in anthropology after 1975 because of the widespread theoretical impact of a school of evolutionary thought called "sociobiology." Sociobiology attracted some anthropologists who proposed explanations of human adaptations based on sociobiological principles. Other anthropologists have been highly critical of sociobiology. However, after four decades, some proposals emerging from this debate have come a long way toward meeting the objections of sociobiology's original critics.

It is important to understand that much of this research is based on **formal models**. These models are "formal" because scientists use the tools of formal logic or mathematics to find answers to particular questions about the evolution of human behavior. For example, evolutionary psychologists typically assume that the psychological abilities possessed by modern human beings are adaptations that were shaped by specific environmental challenges early in our species' evolutionary history. They employ formal psychological tests on contemporary human subjects to demonstrate the presence of these abilities and then use logical deduction to "reverse engineer" from these contemporary abilities back to the hypothetical selective pressures that would have shaped these abilities. By contrast, scientists who study gene-culture coevolution, cultural group selection, or niche construction use mathematical formulas to predict outcomes of particular kinds of human interactions under different hypothesized conditions. Computers allow them to simulate, for example, what happens when certain behavioral patterns are repeated for many generations. The researchers then examine the reports of ethnographers or other social scientists to see if any of the outcomes produced by their mathematical calculations match the actual behavior patterns found in real human societies.

No beginning anthropology textbook can offer an in-depth introduction to formal modeling of human biological and cultural evolutionary processes (Table 5.3). But students should be aware of this dynamic and contentious field of research, in which anthropologists, biologists, ecologists, psychologists, and other scientists collaborate. Students should also be aware that many anthropologists—cultural anthropologists in particular—are highly critical of formal models, especially formal models of cultural evolution. They point out that formal modeling cannot work unless actual human interactions, which are messy and complex, are tidied up and simplified so that they can be represented by variables in mathematical equations. Reverse engineering has also been criticized for being overly reliant on logical deduction, rather than empirical evidence, in the generation of hypotheses about the human past. Critics argue that these approaches produce nothing more than cartoon versions of everyday life that often reveal systematic Western ethnocentric bias.

In our view, the perspective with the most promise is that of niche construction, which articulates in unusually clear language a point of view many anthropologists and others have held for a very long time. And they are not the only ones. As ecologist Richard Levins and biologist Richard Lewontin pointed out in 1985,

> [using] cultural mechanisms to control our own temperature has made it possible for our species to survive

formal models Mathematical formulas to predict outcomes of particular kinds of human interactions under different hypothesized conditions.