The world model contains numerous feedback loops representing demographic and technological-economic means of achieving a favorable balance between the population size and the supply of resources. These loops are intricately intermeshed, and they operate with different speeds and efficiencies. Since both the supply of and the demand for each resource are always varying and since societal responses of either type are usually delayed, a perfect population-resource balance is rarely actually attained. The system is usually in motion, compensating for a deficiency in one resource, depleting an oversupply of another, building up a greater demand for a third.

The function of the population sector in this total scheme is twofold:

1. It calculates the total population size, which is one determinant of resource demand.
2. It represents the demographic response of the population, through the birth rate and the death rate, to the changing resource supply.

The first function is a matter of straightforward arithmetic, although the dynamics of the population age structure can make the arithmetic rather complicated. Demographers have already developed the theory and the computerized models to carry out this sort of calculation (for a review, see Keyfitz 1971*a*).

The second function of the population sector—to represent endogenously the response of human birth and death rates to changing system conditions—is a far more difficult undertaking. It raises the most basic and perplexing questions about the behavior of human populations. What causes a population to grow, to stabilize, to decline? How do psychological and cultural factors interact with biological constraints to influence birth and death rates? How might the world population growth rate change as a result of technological or economic changes, such as increased industrialization, improved contraceptive techniques, or reduced infant mortality?

These questions are general and imprecise. They refer to the long-term dynamic patterns of population response to changing environmental conditions, not to specific, quantitative properties of the world population today. The model described here is an attempt to provide answers to these general questions. It is not intended to explain the precise history or predict the precise future of any given real population. It is a dynamic hypothesis about a generalized population. Thus it may be qualitatively applicable to all large populations, but it will be quantitatively accurate for none.

Most of the individual causal assumptions that make up the population sector are not proposed here for the first time. They have been taken from the works of many different scholars who have also sought to deduce general causal theories from their observations of various human populations. We have tried to organize these causal theories, translate them into a common format, choose a self-consistent set of theories, and examine the logical consequences of that set. The purpose of the exercise is not to produce a final, unimpeachable theory of population. Rather, it is to assemble the many separate pieces of the population puzzle that seem to be known now, and to understand the dynamic patterns they make when they are fitted together. The assembly process may of course reveal that some important pieces are missing or poorly defined. However, the broader view provided by the modeling attempt may at least indicate how to find or refine them.

Those who are interested in smaller population aggregates than the entire world population may find the basic causal structure postulated here a useful beginning for more precise short-term models. However, the model's parameters—the exact numerical forms assigned to the causal relationships—would certainly have to be altered to express differences in the cultures, technologies, and distributional inequalities of the various subpopulations of the world. Furthermore, migration, a most important type of human demographic response on the local level, is not an option on the global level and thus is not included in this model.

The dominant trends in the behavior of the world's population during this century, trends that a dynamic model must duplicate to pass a first test of confidence, are described in the following section of this chapter (2.2). The basic concepts and the general structure of the population sector are discussed next (sections 2.3 and 2.4). Each model equation is then presented in detail in section 2.5, along with the information that led to the form of the equation and to our choice of specific parameters. In the final section (2.6) computer runs of the population sector, driven by varying assumptions about external conditions, illustrate the possible behavior modes of the sector and its sensitivity to changes in parametric assumptions.

2.2 HISTORICAL BEHAVIOR MODES

Two basic dynamic characteristics are exhibited by all human populations: a tendency toward exponential growth, and a long delay in the population's adaptive response to changing external conditions. The actual rate of growth, the nature of the adaptive response, and the length of the delay vary, depending on many factors in the total system. Over the last hundred years the global population has been characterized by an increasing rate of exponential growth and by a response delay as long as one or two generations. In this section we present evidence for these historical trends in terms of changes in the mortality and fertility rates that have been observed in most subsectors of the world's population.

Exponential Growth

When any biological population grows, the pattern of growth over time tends to be exponential. The human population is no exception. Figure 2-2 shows the estimated growth of the world population, from 1650 to the present, and its projected growth until the year 2000. In the twentieth century, rapid exponential growth has been exhibited not only by the global human population but by nearly every national and regional population as well. For example, Figure 2-3 illustrates the population growth, both past and projected, of several nations and groups of nations from 1920 to 2000. The rates of growth are variable, but the overwhelmingly dominant behavior mode is exponential growth.

The tendency for the growth of any animal population to be exponential follows directly from the fact that the source of additions to the population is the population itself. The total increase in the population during any time period must be at least partially determined by the size of the population of reproductive age in that time