their magnitude and the time at which they may occur. For example, the effects of the curve for the year 1990, shown in Figure 2-34, which assumes a major breakthrough that leads to an increase in the maximum average human lifespan from 75 to 100 years, is tested in the model runs in section 2.6.

Unless otherwise indicated, in the model runs in this chapter and in Chapter 7, the relationship actually used in World3 for the lifetime multiplier from health services LMHS will be that shown by the solid line in Figure 2-38, which gives a maximum average life expectancy of 56 years at subsistence food levels and of 78.4 years at high food levels.

```
LMHS.K=CLIP(LMHS2.K,LMHS1.K,TIME.K,1940)                23, A
    LMHS   - LIFETIME MULTIPLIER FROM HEALTH SERVICES
                (DIMENSIONLESS)
    CLIP   - A FUNCTION SWITCHED DURING THE RUN
    LMHS2  - LMHS, VALUE AFTER TIME=PYEAR
                (DIMENSIONLESS)
    LMHS1  - LMHS, VALUE BEFORE TIME=PYEAR
                (DIMENSIONLESS)
    TIME   - CURRENT TIME IN THE SIMULATION RUN

LMHS1.K=TABHL(LMHS1T,EHSPC.K,0,100,20)                  24, A
LMHS1T=1/1.1/1.4/1.6/1.7/1.8                            24.1, T
    LMHS1  - LMHS, VALUE BEFORE TIME=PYEAR
                (DIMENSIONLESS)
    TABHL  - A FUNCTION WITH VALUES SPECIFIED BY A TABLE
    LMHS1T - LMHS1 TABLE
    EHSPC  - EFFECTIVE HEALTH SERVICES PER CAPITA
                (DOLLARS/PERSON-YEAR)

LMHS2.K=TABHL(LMHS2T,EHSPC.K,0,100,20)                  25, A
LMHS2T=1/1.4/1.6/1.8/1.95/2.0                           25.1, T
    LMHS2  - LMHS, VALUE AFTER TIME=PYEAR
                (DIMENSIONLESS)
    TABHL  - A FUNCTION WITH VALUES SPECIFIED BY A TABLE
    LMHS2T - LMHS2 TABLE
    EHSPC  - EFFECTIVE HEALTH SERVICES PER CAPITA
                (DOLLARS/PERSON-YEAR)
```

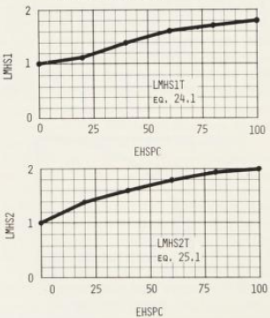


Figure 2-38 Lifetime multiplier from health services table

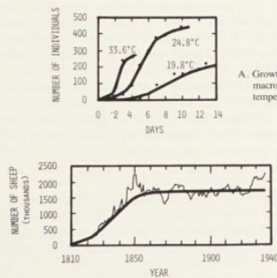
Lifetime Multiplier from Crowding LMC It is a common belief that the human population is self-regulating with regard to its own density. A self-regulating population is one that exhibits pure exponential growth only at low density and gradually decreases its growth rate as a function of its own increasing numbers. Finally, at high density a self-regulating population reaches a steady state with a zero net growth rate and no further population increase.

Many animal populations do indeed exhibit self-regulating behavior, gradually leveling off to some equilibrium population size. Such behavior results in a characteristic "sigmoid" or "logistic" growth curve (see Figure 2-39). In some cases these experimentally observed sigmoid growth curves can be fitted with the following modification of the exponential growth equation:

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right).$$

Here N is the total number of individuals in the population, K is the maximum supportable population in a given geographic area (sometimes called the carrying capacity), and r is the maximum rate of growth of the population under optimum conditions (in ecologists' terms, the biotic potential). The maximum possible growth rate is exhibited only when N is very small. As the size of the population increases, the intrinsic growth rate r is reduced by the factor (K−N/K), which finally equals zero when N = K.

This equation does not give a *causal* explanation of the factors reducing the growth rate at high population densities. It does not even specify whether the reduc-



A. Growth of the water flea (Moina macrocopa) at three different temperatures

B. Growth curve of sheep subsequent to their introduction in Tasmania

Figure 2-39 Sigmoid growth curves
Source: Kormondy 1969.