balanced growth may be small. Culture response to large or rapid perturbations cannot be described satisfactorily by unstructured models.

For many systems, segregation is not a critical component of culture response, so nonsegregated models will be satisfactory under many circumstances. An important exception is the prediction of the growth responses of plasmid-containing cultures (see Chapter 14).

Because of the introductory nature of this book, we will concentrate our discussion on unstructured and nonsegregated models. The reader must be aware of the limitations on these models. Nonetheless, such models are simple and applicable to some situations of practical interest.

6.3.2. Using Unstructured Nonsegregated Models to Predict Specific Growth Rate

6.3.2.1. Substrate-limited growth. As shown in Fig. 6.11, the relationship of specific growth rate to substrate concentration often assumes the form of saturation kinetics. Here we assume that a single chemical species, S, is growth-rate limiting (i.e., an increase in S influences growth rate, while changes in other nutrient concentrations have no effect). These kinetics are similar to the Langmuir–Hinshelwood (or Hougen–Watson) kinetics in traditional chemical kinetics or Michaelis–Menten kinetics for enzyme reactions. When applied to cellular systems, these kinetics can be described by the *Monod equation:*

$$\mu_g = \frac{\mu_m S}{K_s + S} \tag{6.30}$$

where μ_m is the maximum specific growth rate when $S >> K_s$. If endogeneous metabolism is unimportant, then $\mu_{net} = \mu_g$. The constant K_s is known as the *saturation constant* or *half-velocity constant* and is equal to the concentration of the rate-limiting substrate when the specific rate of growth is equal to one-half of the maximum. That is, $K_s = S$ when $\mu_g = \frac{1}{2}\mu_{max}$. In general, $\mu_g = \mu_m$ for $S >> K_s$ and $\mu_g = (\mu_m/K_s)S$ for $S << K_s$. The Monod equation is semiempirical; it derives from the premise that a single enzyme system with Michaelis–Menten kinetics is responsible for uptake of S, and the amount of that enzyme or its catalytic activity is sufficiently low to be growth-rate limiting.

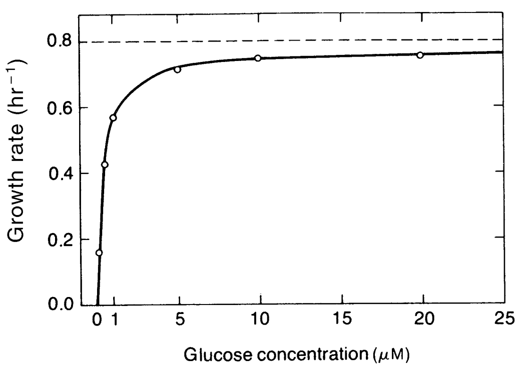

Figure 6.11. Effect of nutrient concentration on the specific growth rate of *E. coli.* (With permission, from R. Y. Stanier, M. Doudoroff, and E. A. Adelberg, *The Microbial World*, 5th ed., Pearson Education, Upper Saddle River, NJ, 1986, p. 192.)