One example of the first type of amensal interaction is the production of antibiotics by certain molds to inhibit the growth of others. Some microbes excrete enzymes that decompose cell-wall polymers. Such organisms destroy their competitors and also utilize the nutrients released by the lysed cells. The microbial synthesis of organic acids reduces pH and inhibits the growth of other organisms.

Predation and *parasitism* are interactions in which one population benefits at the expense of the other. These two interactions are distinguished by the relative size of organisms and the mechanisms involved. Predation involves the ingestion of prey by the predator organism. A good example of prey–predator interaction is the ingestion of bacteria by protozoa. This interaction is common in aerobic waste-treatment reactors such as activated sludge units. In parasitism, the host, which is usually the larger organism, is damaged by the parasite. The parasite benefits from utilization of nutrients from the host. A common example of parasitism is the destruction of microorganisms by microphages. Although the physical mechanisms in predation and parasitism differ, these two phenomena have many common features in their conceptual and mathematical descriptions.

In an open system, such as a chemostat where predator–prey interactions take place, the populations of predator and prey do not necessarily reach steady state but can oscillate at certain dilution rates. At the beginning of the operation prey concentration is high, but predator concentration is low. As the predators consume prey, the number of predators increases and the prey concentration decreases. After a while, a small prey population cannot support the large predator population, and the predator population decreases while prey population increases. Depending on the dilution rate and feed substrate concentration, these oscillations may be sustained or damped or may not exist.

Finally, note that these interactions can, and often do, exist in combination. For example, A and B may compete for glucose as a nutrient, but A requires a growth factor from B to grow. In such a case, both competition and commensalism would be present.

16.3. SIMPLE MODELS DESCRIBING MIXED-CULTURE INTERACTIONS

Multiple interacting species can give rise to very complex behavior. In some cases, coexistence of species is prohibited; in others, complex sustained oscillatory behavior may be observed. Multiple steady states are possible.

Writing the appropriate equations to describe mixed populations follows the principles we discussed in Chapter 6. In each case, a balance must be written for each species (organism, rate-limiting substrate, or product), and these balances will be the same as we have used previously. Although we may write chemically structured models for each organism, we will confine our discussions to the use of unstructured models for each species. Even so, the population model is still structured in the sense that the whole biomass is divided into distinct subpopulations.

These equations are often applied to chemostats that mimic many ecosystems. When these equations are solved, they often yield multiple steady states. For each steady state we need to analyze its stability. An unstable steady state will never be realized in practice; using phase-plane portraits, we can explore the approach to the steady state and