3 ENERGY HARVEST AND NUTRIENT CAPTURE

INTRODUCTION

THE PROBLEM of adaptation has to be addressed in a rigorous way if the ultimate goal of population biology—development of models that predict the fate of a population or species in different environments—is to be realized. As Gates (1975) has pointed out very eloquently, the flow of energy, the flow and cycling of minerals, and the gains and losses of biomass are the fundamental mechanisms that control and regulate the growth of populations. Consequently, population biologists must become conversant with the approaches that measure these fluxes—the area popularly known as physiological ecology—and incorporate them into their models.

Energy and mass exchange are ultimately related through the process of photosynthesis (Figure 1). Light, water, CO_2, and minerals are the primary independent variables (resources) that affect plant growth. The shape of the plant, including leaves, roots, and leaf canopies, and the biochemistry of the photosynthetic apparatus determine the way that energy and mass exchange of the plant takes place. These fundamental physiological and biophysical mechanisms determine the chemical energy that the plant will dispose of for further leaf and root growth and for reproduction.

We first present a discussion of the environmental and evolutionary constraints on the photosynthetic characteristics of higher plants (Mooney and Gulmon, article 13). Carbon-gaining capacity is of basic importance to evolutionary success. Plants that are able to maximize carbon gain within the constraints of the environment are presumably able to gain advantages in competition with other plants, provide better defenses against predators, and have more energy to devote to reproduction.

The availability of water has a fundamental influence on the metabolism and growth of the plant. Water economy and carbon

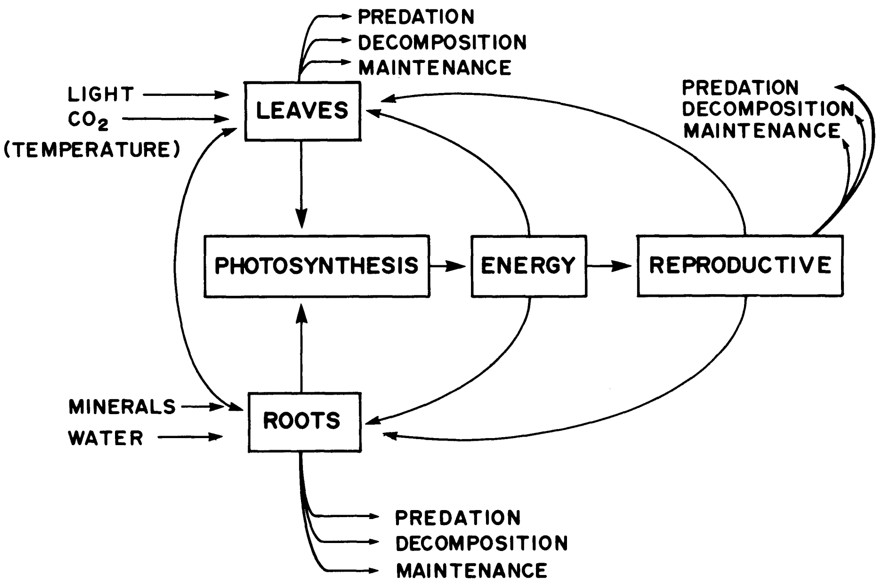

Figure 1. Generalized physiological model of a plant. The information of concern is chemical energy its generation from the four principal independent variables (light, CO_2, minerals, water); its allocation to vegetative growth (roots, leaves) and reproductive structures and its loss through predation, death of tissues, and use in maintenance.

balance are intimately linked, as Chabot and Bunce point out (article 14). Species differ in their ability to maintain a positive carbon balance under different degrees of environmental drought. Because of the inevitable link of water loss and CO_2 gain through stomata, generally, the more drought resistant a species is, the lower its relative carbon-gaining capacity under high water levels. This sets up limits (both upper and lower) to the range of humidity conditions under which a given drought adaptation confers competitive superiority. In article 15, J. A. Teeri explores this problem in relation to C_4 plants. Specifically, he investigates the correlation of a number of macroclimatic factors with the distribution and abundance of species with the C_4 photosynthetic pathway in the United States.

Leaves and roots are the structures that confer drought resistance and determine the shape of the carbon-acquisition curves. T. A. Givnish (article 16) presents a mathematical optimality model of leaf form, and M. Caldwell (article 17) discusses the costs of root construction and root function. The inevitable conclusion is that, although there are heuristic advantages to studying them separately, leaves and roots constitute an integrated system in the ultimate sense.

Part 3 is closed by a discussion of canopy function and environmental interaction in which P. Miller and W. Stoner present a model that accurately predicts phenological behavior and microhabitat distribution of species of the California chaparral and incorporates the concepts discussed in the preceding articles.

Twenty years ago, the subjects dealt with in this section were being explored cautiously by a small number of physiologists and biophysicists. Today, physiological ecology has grown into a very exciting and conceptually rich field. As these articles show, enough knowledge has been gained to begin integrating this outlook with the more traditional view of population biology.