ECOLOGICAL CONSTRAINTS ON GENETIC ENGINEERING

Martin Alexander
Laboratory of Soil Microbiology
Department of Agronomy
Cornell University
Ithaca, New York 14853

INTRODUCTION

The aim of this paper is to present, briefly to be sure, the views of a microbial ecologist with a strong practical bent. These views, I believe, have relevance to genetic engineering to control environmental pollutants. I shall point out several ways by which the chances of success can be increased and some of the problems that may be encountered.

Ecology has much to offer to the research and technology designed to develop genetic means to control environmental pollutants. Although much of ecology is not directed at issues of current environmental concern, a large literature is directed to practical problems that relate to the behavior of organisms and the interrelationships between organisms and environmental stresses. Some of the basic aspects of ecology are highly relevant and should be brought to bear in considerations being given to genetic approaches to minimize environmental pollution. Nevertheless, molecular geneticists, microbiologists, and biochemists have not applied ecological insights or turned to ecologists to assess whether that field has information and approaches that might be useful. It is also unfortunate that ecologists have not been significantly involved in devising technologies to minimize environmental problems arising from organic chemicals.

It is my purpose to address two issues. The first is the application of information from microbial ecology that should be useful in devising genetic approaches and microbial technologies to destroy chemical pollutants. In this area of my discussion, I shall deal with possible failure modes, that is, environmental or ecological problems that may result in failures in the currently used
genetic approaches. By focusing on failure modes, I do not want to leave the impression that I am pessimistic about the use of modern genetics for answering some major environmental problems; quite the contrary. I believe that an approach involving genetics, microbiology, environmental engineering, and ecology will allow us to minimize the number of failures and maximize the number of successes.

My second issue is the possible ecological consequences of genetic engineering. The nay-sayers on the one side frequently have been prophets of doom, whereas many of the proponents of the new technologies have paid little attention to unpredictable effects of novel technologies.

EFFECT OF CONCENTRATION

Pollutants are commonly distinguished on the basis of whether they are derived from single, discrete sites (point sources) or from multiple sites (nonpoint sources). Point sources include effluents from factories that manufacture chemicals, for example, and nonpoint sources include pesticides applied to agricultural land. The concentrations in the former instance are often high; those in the latter instance are almost invariably low. However, if a chemical derived from a point source is not readily destroyed, it may exist in many areas at low levels as it is diluted in adjacent waterways or moves through soil to enter groundwaters.

Microbiologists, molecular geneticists, and biochemists rarely are concerned with concentrations in the ranges at which organic pollutants occur in natural water or soils. They use substrates in the range of several percent or, if they are adventuresome, high parts-per-million range. Alas, such are not the levels commonly encountered in rivers, lakes, groundwaters, estuaries, soils, or sediments, and never in the open ocean. It was taken as incontrovertible fact that reactions which occurred at the concentration convenient for the laboratory-oriented scientist would also take place in nature. The rate might be slower, presumably in direct relationship to the concentration, but all else would be the same.

Let us consider a few cases in point. First, no microorganism has yet been shown to grow on a defined substrate at concentrations at which pollutants are frequently of practical concern, such as 10 ppb (10 ng/ml). The data in Fig. 1, for example, show the microbial mineralization of a test chemical at low concentrations but not at still lower concentration. If a microorganism will not grow at low pollutant concentrations, genetically engineered strains may not function in nature because it is probably not feasible to introduce sufficient numbers to saturate the environment with the catabolically active cells. I do not mean to suggest that genetic engineering is useless in these circumstances; possibly genetics should be