D. decubens, Döbereiner thinks that it may be an intermediate form between the completely independent nitrogen-fixing bacteria and nodule-forming symbionts like the rhizobia. She has suggested that this kind of symbiosis may be a good model for the development of symbioses between nitrogen-fixing bacteria and grasses or grain crops.

Legumes, especially soybeans, are excellent sources of vegetable proteins, which is why soybeans are in such demand in world markets. Cereals, which lack symbiotic nitrogen-fixing bacteria, have proteins of poorer quality and quantity. According to Döbereiner, tropical grasses, supplied by their symbiotic bacteria with ammonia for amino acid and protein synthesis, may one day compete with legumes as protein synthesizers because these grasses are much more efficient photosynthesizers than are legumes.

Evidence acquired by Ralph Hardy and U. D. Havelka of E. I. duPont de Nemours and Company, Wilmington, Delaware, indicates that the amount of nitrogen fixation on legumes grown in the field is determined by their capacity to photosynthesize. Photosynthesis is the ultimate source of the energy needed for nitrogen fixation, both in the form of adenosine triphosphate (ATP) and of the reducing power needed to convert molecular nitrogen to ammonia. In addition, it provides carbon compounds that combine with the ammonia and form amino acids.

Havelka and Hardy found that stimulating photosynthesis in legumes by increasing the concentration of carbon dioxide available to the plant also stimulated nitrogen fixation by their rhizobia. In fact, the bacteria fixed more nitrogen in 1 week than they normally do during the 100-day growing cycle of soybeans. Hardy concedes that atmospheric carbon dioxide enrichment is not practical for large-scale application, but says that these experiments indicate the magnitude of the effects that might accrue from increasing photosynthetic efficiency. Other strategies such as the use of chemicals to inhibit the reactions that decrease photosynthetic efficiency or the selection and breeding of plant strains that have lower levels of these reactions may be more feasible.

Until recently there were no examples of symbiotic associations between rhizobia and plants other than legumes. That situation changed when M. J. Trinick of the CSIRO in Wembley, Australia, found a *Rhizobium* in nodules on the roots of a tree, *Trema cannabina*, in New Guinea. It may not be possible to induce bacteria such as this one and those studied by Döbereiner to form associations with cereal crops. But these discoveries mean that the genetic variability and potentials of nitrogen-fixing bacteria are greater than

Speaking of Science

Human Biogeography: Similarities between Man and Beast

How similar are the patterns of distributions of human populations to those of other animal species? In some cases, quite similar, according to a small group of anthropologists and biogeographers. Their common interest concerns some qualitative mathematical models that were developed to describe the patterns of distributions of species of plants and animals. The utilization of these models to describe human populations appears to be an example of how techniques and ideas from one field may be applied to another.

The excitement which this interdisciplinary transfer can provoke was in evidence at a recent meeting* of biogeographers, population geneticists, and anthropologists. Discussions focused on attempts to use specific biogeographical models to analyze the distributional behavior of certain primitive peoples who live in arctic, desert, rain-forest, and island environments. For example, W. Fitzhugh of the Smithsonian Institution in Washington, D.C., is applying one such model to descriptions of Arctic Eskimos. He finds that a model that provides an estimate of the probability that a population will go extinct as a function of population size and environmental fluctuations is appropriate to describe patterns of colonizations by small groups of Eskimos and their subsequent extinctions in the harsh and fluctuating arctic environment.

Another biogeographical model that may provide insight into human behavior is a model of bird distributions proposed by J. Diamond of the University of California at Los Angeles Medical School. Diamond suggests that this model may be used to describe the distributions of Polynesians and Melanesians at the time of the European discovery—a suggestion of great interest to the meeting participants. Diamond's theory can be used to classify bird species into two sets: supertramps and overexploiters. The supertramps are good colonizers but not good competitors and thus are found only on small or remote islands. The overexploiters are good competitors but poor colonizers and are found on large islands close to land masses.

Diamond notes that the past distributions of the Polynesians, who are known for their ability to disperse over water, were like those of the supertramps, whereas the Melanesians were distributed like overexploiters. He proposes that it would be interesting to ask whether Polynesians shared other traits with supertramps—such as rapid population growth and a lack of self-regulation of population size—and whether the Melanesians shared the corresponding opposite traits with overexploiters.

R. Levins of the University of Chicago points out that implicit in the analysis of distributions of Polynesians and Melanesians is the assumption that the two groups can be distinguished from each other. This assumption leads to the question of what characterizations of human populations should serve as the units of analysis when biogeographical models are applied to anthropology.

* The meeting, entitled The Smithsonian Conference on the Application of Models in Theoretical Biology and Biogeography to Anthropology was held on 30 April to 2 May 1974 in Washington, D.C., under the auspices of the Wenner-Gren Foundation for Anthropological Research, Inc., and the Smithsonian Institution.

once thought, so that plant scientists and agronomists have new tools with which to work.

The geneticists are exploring and developing techniques with which to exploit these potentials in addition to gathering fundamental information about the genes required for nitrogen fixation and their control. A better understanding of the control of the expression of nitrogen fixation or *nif* genes could result in development of methods to increase nitrogen fixation and thus increase legume crop yields. It has long been known that ammonia, the product of nitrogen fixation, shuts off or represses the genes that direct the synthesis of nitrogenase, the enzyme that catalyzes nitrogen reduction.

This repression of nitrogenase synthesis has frustrated agronomists interested in increasing the yields of legumes, especially soybeans. Adding ammonia fertilizer to these crops does not increase ammonia assimilation by the plants because their nitrogen-fixing symbionts simply stop working. This is one of the reasons why soybean yields per acre have increased only slightly during the past 30 years while corn yields have more than doubled, partly as a result of a 15-fold increase in the amount of nitrogen fertilizer applied per acre.

A number of investigators have now implicated glutamine synthetase, an important enzyme for ammonia utilization, as a direct participant in *nif* gene control. Among the investigators studying this problem are Raymond Valentine, of the University of California at San Diego; Stanley Streicher, of the Massachusetts Institute of Technology (MIT), Cambridge; and John Postgate and R. A. Dixon, of the University of Sussex, England. These workers have found that mutants of such free-living bacteria as *Klebsiella pneumoniae* or *Azotobacter vinelandii* that lack glutamine synthetase are incapable of synthesizing nitrogenase. When the mutants acquire the glutamine synthetase genes as a result of conjugation with *Escherichia coli*, they can again make nitrogenase. (Conjugation is a bacterial mating process in which DNA is transferred from one organism to another.)

Bacterial strains in which glutamine synthetase is constitutive continue to synthesize glutamine synthetase under conditions in which they would normally turn it off. In the presence of ammonia, one of these strains (derived by Streicher and his colleagues) continued to synthesize nitrogenase, at levels up to 30 percent of those produced when ammonia was absent. These results indicate that nitrogenase is synthesized only when glutamine synthetase is present, although other factors may also be involved in *nif* gene control.

Winston Brill of the University of Wisconsin, Madison, has found that certain methionine derivatives that in-

Biogeographical units of analysis are individual animal species that cannot interbreed. But all human populations can interbreed.

J. Terrell of the Field Museum of Natural History in Chicago believes that there is no universally appropriate solution to this problem of distinguishing human populations. Defining the most appropriate human population unit depends on the problem to be studied and may be defined by language, genetic composition, or culture. Terrell has used languages as a basis of differentiating among peoples of the Solomon Islands. He finds that the number of languages spoken on an island is a function of island size, just as the number of animal species on an island is a function of its size.

Some of the anthropologists at the meeting noted that their attempts to apply biogeographical models to human populations have led them to rephrase the questions that they wish to answer and to subsequently gain new insights into interpretations of their data. For example, J. Yellen of the Smithsonian Institution has recently formulated questions about the behavior patterns of peoples that live in relatively stable environments, such as rain-forest and desert, as compared to patterns of those living in more fluctuating environments, such as savannah. Biogeographers find that species living in constant environments have lower birth rates than similar species living in fluctuating environments. Yellen proposes that this pattern may extend to human populations. He points to a study of the desert dwelling !Kung Bushmen in which N. Howell of the University of Toronto found that time between pregnancies of !Kung women was greater than one would expect on the basis of comparisons with other primitive peoples in more fluctuating environments.

The transfer of information across disciplines was not just one way. According to Diamond, anthropological studies of the history of human populations may also prove useful to biogeographers. In general, biogeographers only have information about the numbers of species in an area at the present time or at a few scattered times during the past. It is difficult to reconstruct the detailed history of distributional patterns from such data. Anthropologists, on the other hand, often have a continuum of data. For example, Fitzhugh has analyzed the past 4000 years of Arctic history. He is thus able to describe patterns of expansions and extinctions of populations that could never have been extrapolated from a few scattered samples of population distributions.

Although the application of specific biogeographical models to anthropology was the subject of most discussions at the meeting, the conference participants agreed that there is one other aspect of biogeographical theory that is immediately applicable to anthropology. That aspect is the existence of certain techniques of analysis. For instance, mathematical indices devised by biogeographers for comparing the diversities or similarities of colonies of species may be directly applied to comparisons of samples of artifacts from different archeological levels or sites.

Many of the participants expressed the hope that the development of a new interdisciplinary field of human biogeography will result in new ways of organizing data and formulating hypotheses in anthropology. They noted that certain fundamental concepts—such as immigration, extinction, competition, and population growth and regulation—are implicit or explicit in descriptions of human populations. Moreover, it is these concepts that are central to the most detailed biogeographical models. It is too early to say whether these models and the ideas that underlie them will ultimately have much effect on anthropology. But the attempt is worth noting and may lead to intriguing insights into human behavior.

—Gina Bari Kolata