ported their results: a map of how the genes for two kinds of leghemoglobin are organized.

In the course of arriving at this basic knowledge, Verma has come to understand a good deal about the crucial way leghemoglobin helps legume plants and *Rhizobia* live together. He has demonstrated, conclusively, that this protein is coded for by not one but a family of plant genes. He showed that it appears about a week after soybean is infected by *Rhizobia* (nitrogen fixation commences 10 days after infection) and that it is assembled from two components, one contributed by the bacterium (the heme structure) and the other (the protein) elaborated by the plant; also, the structure is assembled just inside the membrane that the plant builds to enclose the bacteria.

Verma still doesn't know how the bacteria communicate with the plant and control the expression of the leghemoglobin genes, but he can describe how both partners mutually benefit from the interaction. Nitrogenase, the bacterial enzyme that actually fixes nitrogen, can only function at very low concentrations of oxygen, and leghemoglobin, we know, absorbs oxygen. The soybean plant bathes its bacterial guests with leghemoglobin, thus allowing the enzyme to function and fix nitrogen. In exchange for the fertilizer produced by the bacteria, the plant provides a home and the nutrients needed to sustain its guest microorganisms.

"By early '76," Verma says, "I realized that there had to be not just one but a whole slew of genes in order to achieve symbiosis." He has recently discovered evidence for such genes in a set of more than 20 proteins produced by the soybean and, apparently, necessary to the development of symbiosis. Verma calls the proteins nodulins, and he found them by developing a sensitive immunological probe.

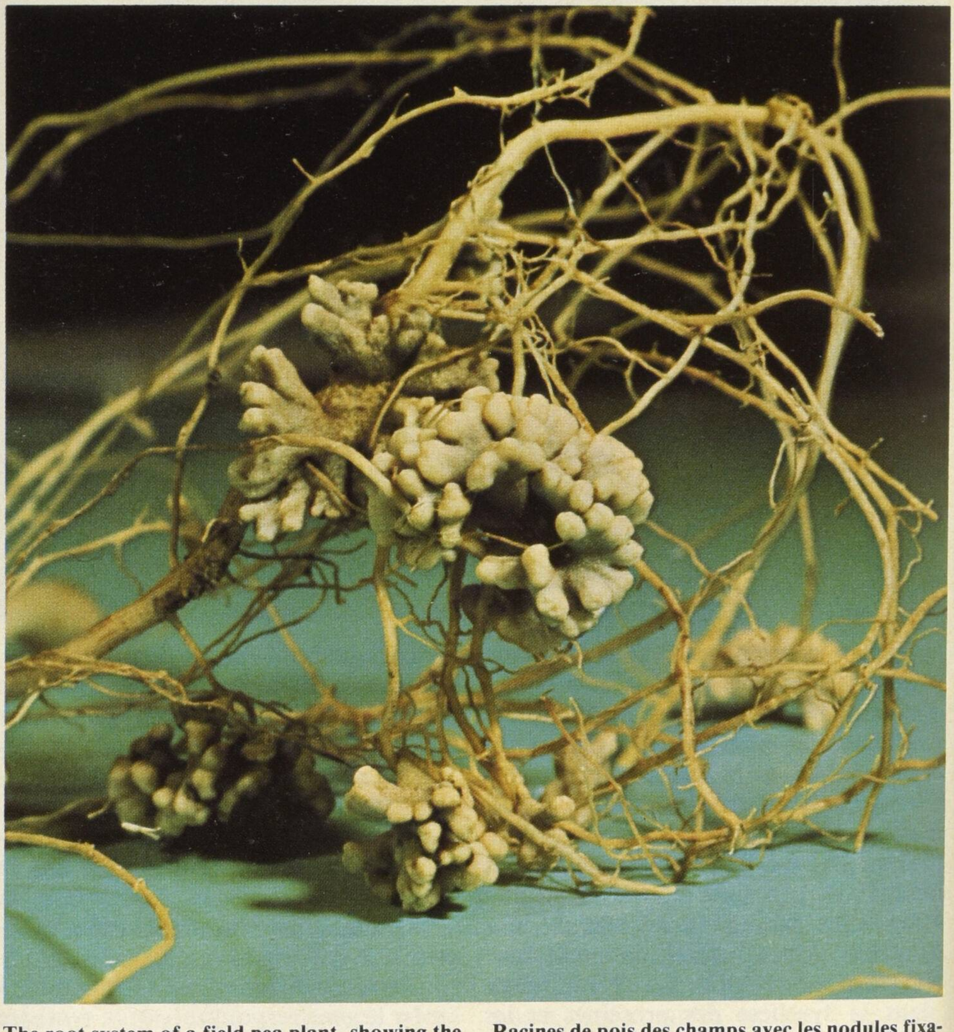
In sum, the method involves raising antibodies in test animals to the host of proteins found in infected root cells, then removing all those antibodies that are also raised in uninfected root cells. This leaves only the antibodies targeted on proteins that arise as a result of the symbiotic or infected state — the nodulins, and, of course leghemoglobin. Verma's research team is now working out ways of isolating relatively large quantities of these newly discovered proteins.

And after this, what next? Among other things, Dr. Verma plans to fish out the genes which code for the nodulin proteins; also, he intends to look for molecules that might traverse the membrane separating the symbiotic partners — such substances could account for their apparent communication. Finally, having identified all the soybean genes involved in its cooperation with nitrogen fixing *Rhizobia*, Verma hopes to look for ways of transferring these genes into the plants which form the world's main food crops.

But to hope that this work, if successful, will eliminate malnutrition and famine in the world would be naive; that will require more than just a technical revolution. Such a condition can come about only after equitable ways of distributing the world's food are adopted. It is not naive, however, to expect a range of useful applications to spin off from this basic research; tests to select legume varieties which best fix nitrogen, for example; and, from the study of how plants and microbes manage to live happily together, measures are possible for controlling pathogenic infections both in plants and animals.

Desh Verma, and his fellows, are obsessed. "There's hardly a moment in my life when I'm not thinking about biology," he says. "I'm fascinated with science, and I find symbiosis an absolutely mind-boggling phenomenon, particularly where it has turned out to be so useful to mankind." □
Séan McCutcheon

Séan McCutcheon is a freelance writer working in Montreal.



The root system of a field pea plant, showing the nodules responsible for nitrogen fixation. These swellings are root cells that contain Rhizobial bacteria in "walled off" structures where they are able to convert the nitrogen of the atmosphere into a form available to the plant. Besides providing this anaerobic or oxygen-free environment, the plant supplies "trigger" substances that initiate the fixation process.

Racines de pois des champs avec les nodules fixateurs d'azote. Dans ces renflements, ou cellules radiculaires, des bactéries rhizobiales séparées par des cloisons fixent l'azote atmosphérique pour donner un composé utilisable par la plante. Celle-ci fournit en contrepartie un milieu anaérobie, ou exempt d'oxygène, favorable à la fixation de l'azote et produit des substances qui déclenchent cette réaction.