non and more ballast. The Defence Standards Laboratories of the Department of Supply began preserving the six cannon and the ballast (10 tons of cast-iron and 15 hundredweight of stone) in March.

Fig. 1 shows a coral-encrusted cannon as it was raised from the sea-bed. Dr C. Pearson, one of the scientists involved in the cleaning operations, describes the progress so far. Appendages, such as those shown, were first radiographed and the coral was then gently removed mechanically. The coral had inhibited corrosion of the cast-iron cannon—the thicker the coral the better the protection. Corrosion has been confined to localized pits and to less than a quarter of an inch of the surface, which now consists of a mixture of graphite, iron oxide and iron sulphide. It is fortuitous that most of the hurriedly jettisoned cannon settled top side upwards where thick growth has preserved a good surface.

A cleaned cannon (Fig. 2) is 6 feet long and weighs about 1,200 pounds. The crowned monogram "GR2" and the gunfounder's markings at each end of the trunnions are easily distinguished. The thin corroded surface has to be stabilized by removing all chloride and water so that oxidation will not continue rapidly on exposure to the atmosphere. The chloride is being removed from the surface by electrosynthesis using an impressed d.c. current in 2 per cent sodium hydroxide, followed by prolonged washing in chromate-inhibited distilled water. This is the stage reached so far. The cannon are next to be dried and the surface sealed with an appropriate coating.

The cast-iron ballast, in pigs 6 inches square and 36 inches long, will receive similar treatment. Other items to be treated include wrought-iron spikes, rings and eye-bolts—all that remain of the gun carriages. Also in one cannon a piece of hemp wadding was found lodged in the breech in front of a 3 inch cast-iron cannon ball, and behind the ball a gunpowder charge. Dr Pearson says that it is intended that these relics will be preserved by early 1970, ready for the bicentenary celebrations of Cook's discovery of the east coast of Australia.

SYMBIOSIS

Host specifies Nodule Haemoglobin

from our Plant Physiology Correspondent

THERE are as many ways of tackling the problems of symbiosis as there are physiological interactions between the host and the symbiont. Some weeks ago I discussed results which suggested that the status of phytochrome in the host plant can influence the formation of root nodules in peas and beans (*Nature*, **223**, 673; 1969). More recently, M. J. Dilworth of the University of Western Australia has obtained results which indicate that the structure of leghaemoglobin in the nodules is genetically determined by the host plant, and not by the bacterial symbiont (*Biochim. Biophys. Acta*, **184**, 432; 1969).

The root nodule of the legume contains many bacteria of the genus *Rhizobium* which can fix atmospheric nitrogen into compounds that can be assimilated by the host plant. Two proteins, nitrogenase and leghaemoglobin, are found in the nodule and seem to be associated directly with the nitrogen fixation process, for neither is synthesized by host plant or bacterium when cultured separately. The presence of leghaemo-

globin (so called because it is found in legumes) is of some interest in itself, for neither bacteria nor higher plants commonly produce haemoglobins, although these proteins have been detected in certain fungi. Furthermore, the exact role of leghaemoglobin in the nodule is equivocal; it is not an integral part of the nitrogen fixation system, but must have an essential auxiliary function.

The most likely site for leghaemoglobin in the nodule is between the bacterial cell wall and the plant membrane which surrounds the bacterial cells. This halfway position offers no clue to which partner is responsible for specifying the structure of the protein.

Dilworth's approach has been to inoculate two separate species of legume, serradella (*Ornithopus sativus* Brot.) and yellow lupin (*Lupinus luteus* L.), with the same strain of *Rhizobium* (*R. lupini* WU 8). Leghaemoglobin from the nodule was extracted and analysed by DEAE-cellulose chromatography and polyacrylamide gel electrophoresis. It was possible to distinguish the two plant species on the basis of the physical characteristics of the leghaemoglobin they produced, although their root nodules contained the same bacterial strain. This suggested that the plant exerted the controlling influence in the synthesis of nodule leghaemoglobins. There was a possibility that inoculation with a different bacterial strain might result in the production of different species of haemoglobin which would suggest dual genetic control by the plant and the bacterium. A second experiment was run using a different strain of *Rhizobium* (*R. lupini* WU 425) but the results were consistent with those using *R. lupini* WU 8. Dilworth concludes that the host plant is the sole genetic determinant of the species of leghaemoglobin produced in the root nodule.

This conclusion agrees well with the earlier observation of Cutting and Schulman, who demonstrated by incorporation of labelled amino-acids that synthesis of leghaemoglobin is the sole responsibility of the host plant (*Fed. Proc.*, **27**, 768; 1968). Recently the presence of a haemoglobin-like pigment has been reported in soybean rhizobia grown in laboratory culture (Appleby, *Biochim. Biophys. Acta*, **172**, 71; 1969). This haemoglobin was not, however, similar to the nodule leghaemoglobin, which has prompted Dilworth to speculate that the rhizobial pigment may be a primitive form of present day nodule leghaemoglobin. The implication is that at some time in the evolution of the legume-*Rhizobium* symbiotic relationship the genetic information for the manufacture of proteins essential to the symbiotic partnership has been transferred from the bacterium to the host plant. Experiments similar to those of Dilworth should distinguish which partner specifies the structure of the nitrogenase enzymes. These enzymes are located in the bacterium and are known to be central to the nitrogen fixation process. It would be of enormous interest if they were to tell a similar tale to the leghaemoglobins.

GEOMATHEMATICS

Earth Studies by Computer

from our Geophysics Correspondent

THE sixth international symposium on geophysical theory and computers was held in Copenhagen from