biological processes, such as respiration, nitrification, catalase activity, etc., probably require iron. We have recently determined that apart from its essential function in both the growth and respiration of *Azotobacter,* iron is also essential in the chemical mechanism of nitrogen fixation by this organism. Under certain conditions of relative iron starvation, natural or synthetic iron-containing humic acids may supply this iron, replacing the more customarily supplied inorganic or organic iron compounds. In this sense the humic acids may be said to influence directly the mechanism of fixation. Under ordinary conditions, humic acids have no such direct influence, but exert the same quantitative stimulation whether the organisms are grown in free or in various forms of fixed nitrogen.

In conclusion, a few of the implications of these findings, apart from their relation to respiration, growth, and nitrogen fixation by *Azotobacter,* may be mentioned. There are undoubtedly fifty or more different plant and animal growth stimulators described in the literature, such as bios, yeast water, plant extracts of various kinds, organic extracts, peat extracts, soil extracts, auximones, egg albumen, egg extract, Rhizopin, vitamin B and possibly other vitamins, in which the chemical reason for stimulation is in practically no case known. Humic acid is thus probably one of the few growth promoters of which the chemical constitution of the active constituent has been definitely determined. It is possible that many, perhaps the majority, of the promoters consist substantially of iron bound in an organic, highly available form, since their action appears to be very similar to that of humic acid; indeed, it may be suggested that the real problem in connection with the chemical nature of the active fraction of these promoters would perhaps more often be to show that they do *not* function chiefly because of contained iron. Many media, *viz.,* legume nodule bacteria media, stock culture media, are made up to contain yeast water, plant extracts, egg extract, or bios, of complicated and relatively unknown general composition; the use of humic acids, particularly synthetic ones, would perhaps often provide desirable substitutes in some degree avoiding this objectionable feature. It is probable, for instance, that the recent yeast-growth stimulant prepared by Fulmer, Williams, and Werkman[2] in the sterilization of synthetic yeast medium at elevated temperatures is similar to our synthetic humic acids, the iron being derived from the probable 1 p.p.m. iron impurity contained in the 5 per cent. sucrose employed.

It is possible that iron added as humic acid to water cultures of higher green plants would upon occasion be superior to most of the forms of iron now employed, especially in the matter of requiring much less frequent addition. Whereas inorganic iron compounds tend in general to precipitate as the pH is increased, the converse obtains with respect to humic acid, above pH 4. Even compounds like ferric citrate precipitate in neutral solutions, upon long standing, whereas properly prepared humic acids remain soluble indefinitely. Many higher plants grown in water cultures must be maintained under relatively acid conditions, in order to derive sufficient iron from the forms usually supplied; the use of humic acid might permit satisfactory or improved growth under substantially neutral or alkaline conditions.

The nutritional value of humus and soil organic matter in agricultural cropping is recognized generally, being ascribed, however, chiefly to indirect effects upon soil moisture, texture, aeration, etc. How far the nutritional value is directly referable to rendering iron more available, particularly in soils in which the inorganic iron solubility is low, is an important problem of agricultural science which would appear to be in some measure enlarged by the present investigations. It is our hope, in view of the fact that the latter have been concerned solely with *Azotobacter,* that the general problem of the influence of natural and synthetic humic acids upon the growth and nutrition of higher plants under field and water culture conditions will receive the attention of plant physiologists equipped to deal with the question.

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WASHINGTON, D. C.

[2] *J. Bact.,* 21, 299, 1931.

## BOOKS RECEIVED

BRITISH MUSEUM OF NATURAL HISTORY. *Guide to the Exhibition Galleries.* Pp. x + 249. Illustrated. 1s. *Short History of Collections.* Pp. xi + 62. 6d. *Guide to Exhibition Illustrating the Early History of Paleontology.* Pp. vi + 68. Illustrated. 9d. The Museum.

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