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<i>Minute Amounts of Chemical Elements in Relation to Plant Growth</i> : PROFESSOR D. R. HOAGLAND .....	557
<i>Science in General Education at the College Level</i> : DR. LLOYD W. TAYLOR .....	560
<i>Scientific Events</i> : <i>Conferences in Biochemistry at the University of Chicago; Honorary Degrees Conferred by New York University; Honorary Degrees Conferred by Columbia University; Dinner in Honor of Professor McClung. Recent Deaths</i> .....	565
<i>Scientific Notes and News</i> .....	568
<i>Discussion</i> : <i>Fundamental Laws of Operations in Mathematics</i> : PROFESSOR G. A. MILLER. <i>Stability in Nomenclature</i> : DR. A. C. SMITH. <i>Aneuploidy in a Hepatic Species</i> : DR. G. B. WOLCOTT. <i>Eating of Bone by the Pregnant and Lactating Gray Squirrel</i> : PROFESSOR A. J. CARLSON .....	571
<i>Scientific Books</i> : <i>Cosmic Rays</i> : PROFESSOR GORDON FERRIE HULL. <i>Non-Uniform Gases</i> : PROFESSOR WILLIAM PHELPS ALLIS .....	574
<i>Societies and Meetings</i> : <i>The North Carolina Academy of Science</i> : DR. BERT CUNNINGHAM .....	575
<i>Special Articles</i> : <i>Biotin—an Essential Growth Factor for Certain Staphylococci</i> : DR. J. R. PORTER and MICHAEL J. PELCZAR, JR. <i>Changes in the Connective Tissue of the Uterus and Vagina of the Rat Associated with Advancing Age</i> : DR. J. M. WOLFE and OTHERS. <i>Radioactive Nitrogen in the Study of N<sub>2</sub> Fixation by Non-leguminous Plants</i> : DR. S. RUBEN, W. Z. HASSID and M. D. KAMEN .....	576
<i>Scientific Apparatus and Laboratory Methods</i> : <i>Heparin as an Anticoagulant for Permeability Studies</i> : DR. F. R. HUNTER, L. D. STRINGER and H. D. WEISS. <i>A New Technic for Staining Vaginal Smears</i> : DR. EPHRAIM SHORR. <i>Solutions of Chlorophyll in Salt Water</i> : DR. JOHN SHAFER, JR. ....	579
<i>Science News</i> .....	8

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## MINUTE AMOUNTS OF CHEMICAL ELEMENTS IN RELATION TO PLANT GROWTH<sup>1</sup>

By Professor D. R. HOAGLAND

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A GENERAL survey of the history of plant and animal nutrition during the past two decades records notable advances in scientific knowledge, many of which have been made possible only because of the recognition and experimental control of organic and inorganic substances in micro-quantities. The investigator of the nutrition of higher plants, which can grow in solutions of purely mineral character, has certain advantages of technique not enjoyed by the investigator of animal nutrition, in the study of the relation to the growth of the organism of very minute amounts of

chemical elements. Yet the plant physiologist has not always profited by these advantages. For a long period the standard teaching was that only ten chemical elements (nitrogen, phosphorus, sulphur, calcium, magnesium, potassium, iron, carbon, hydrogen and oxygen) were generally indispensable for the growth of higher plants. Many other elements, if found to be effective at all, were regarded merely as plant stimulants or poisons. Following earlier work in France, Mazé<sup>2</sup> presented in 1914 certain evidence, based on controlled water-culture experiments, of the requirement for normal growth of the maize plant of chemical elements not included in the list of ten, but his experiments

<sup>1</sup> Presented before the National Academy of Sciences, April, 1940, as a highly condensed review, for the information of those who have not had occasion to refer to the literature of this field.

<sup>2</sup> P. Mazé, *Ann. Inst. Pasteur.*, 28: 21-68, 1914.

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