in London from June 25 to 30 at the invitation of the British government under the presidency of the Duke of York. The Air Ministry has arranged a pageant on June 30.

UNIVERSITY AND EDUCATIONAL NOTES

According to a new agreement between the board of permanent officers of the Yale School of Medicine and the corresponding boards of Yale College and the Sheffield Scientific School, admission to the combined course in either undergraduate school will be on a competitive instead of an automatic basis as heretofore. Those seniors will be eligible as candidates for the course whose scholarship standing during the junior year has been seventy-five or above, and who have satisfied the science and language requirements of the medical school. Their applications, which are due before July 1, following the completion of junior year, will, however, be considered in conjunction with all other applications, and the medical class chosen from the entire number of candidates. The Yale undergraduates who are admitted will take the entire first-year medical work and receive credit for the B.A. or B.S. degree. The degree of M.D. is awarded after three years' additional study. As only sixty students are admitted each year from several hundred applicants, the decision to select all members of the first year class in the Yale School of Medicine on the same basis will interest premedical students throughout the country.

Dr. W. A. White, superintendent of the Government Hospital for Insane at Washington, D. C., announced the establishment of a school at St. Elizabeth's for the instruction of physicians in the treatment of mental and nervous diseases.

Professor D. H. Davis, of the department of geology of the University of Michigan, has accepted a professorship in the University of Minnesota.

Dr. Edward A. Doisy has been appointed professor of biochemistry at St. Louis University, the appointment to take effect on August 1, 1923. Dr. Doisy is at present associate professor of biochemistry at the Washington University School of Medicine.

Dr. J. C. M. Brentano has been appointed lecturer in physics at Manchester University.

DISCUSSION AND CORRESPONDENCE

THE FEEDING POWER OF PLANTS

In a recent paper in Science[1] under the caption quoted above, Mr. Truog elaborates and supplements the discussion of his theory on the "feeding power of plants" as detailed in earlier publications.[2] His most recent discussion, as well as his earlier ones, are open to such serious question in many important respects that we deem it essential to comment on the principal objections to his theory and his assumptions. Several minor points in the paper first cited above which are open to serious question are not discussed in this review because of the limited space available (in this paper) and because the importance of the points which we do discuss should not in any wise be dimmed by matters of lesser magnitude.

Mr. Truog makes the fundamental assumption that each and every plant species, or group of plants, is characterized by what we may term a specific avidity for the ions in solution in the root medium, and that such specific avidity is contingent upon the reaction of the cell sap and the behest of the law of mass action. This assumption is, in turn, based on the alleged or actual percentages of the various ions found in different kinds of plants. This implies, of course, the fundamental power of the individual root cell to absorb ions in a characteristic manner. In all this discussion, Mr. Truog evidently underestimates the fact that the differences between plants which are in question may be caused, not by the difference in the specific absorbing powers of individual cells, say of legumes and grasses for example, nor yet by the specific reaction of the cell sap, but by the difference in extent of root system, and the difference in the amount and intensity of CO_2 production by roots. The enormous differences which obtain among different kinds of plants as regards the extent of

[1] Science, N. S., 56, 1922, pp. 294-298.

[2] Science, N. S., 41, 1915, pp. 616-618. *Res. Bull.* 41, 1918, Wis. Agr. Exp. Sta. *Soil Science*, 5, 1918, pp. 169-195, and others there cited.

root are too well known to the student of plants to need discussion, and they can scarcely be considered as of anything but profound importance in the mechanisms of absorption of ions by plants. But, dependent in part upon the extent of the root system, is the degree of CO_2 production, and the latter must play a dominant rôle in making available to the root cells the ions contained in the undissolved compounds of the soil particles. That this is not mere speculation is evident from the striking data adduced by Turpin[3] on CO_2 production by the roots of different plants and the importance thereof in the total amount of CO_2 produced in soils. It is even more strikingly supported by recent investigations of J. D. Newton in this laboratory, which have not yet been published, but which show a marked difference between peas and barley as regards the intensity of CO_2 production per unit weight of roots or tops under controlled conditions in sand cultures. Newton's results indicate further that legumes, as such, are not characterized by a greater Ca content than non-legumes, as such. For example, he found no significant difference between the Ca content of barley, peas and vetch, in solution cultures in which the plants were grown separately or together in the same solution. This was true in solutions of low and of high Ca content. Between beans and barley, the difference appears to have been greater in favor of the beans. On the other hand, in soil cultures with barley and peas grown together, the peas take up much more Ca than the barley. This supports the contention which we have made above that the intensity of CO_2 production, as well as the extent of the root system, may determine the amounts of ions absorbed independently of the specific power of plant species, genera or families in that regard. In this connection, it must be further emphasized that the nature of the environment of the plant, both as regards root and top, may play as important a rôle as any factor in inducing a certain rate and degree of absorption of ions. For example, Waynick[4] showed in experiments in this laboratory that the wheat plant varied *enormously* in its power of absorbing the common ions of culture solutions, depending on the constitution of the solution and the presence or absence of effective quantities of unessential ions. Our studies and observations on individual variabilities in plants in regard to their chemical composition, as in other respects, constrain us, moreover, to say that no justifiable conclusions on specific absorbing powers of different kinds of plants may be drawn on the data available to date. This observation is particularly cogent as regards the attempt to classify the plants supposedly requiring much calcium in accordance with their power to "feed" on calcium and phosphorus. The data employed for this purpose were derived chiefly from Wolff's "Aschenanalysen" and those represent data gathered from many men in many places. Since variability is so marked in plants of a pure strain grown under carefully controlled conditions, what can we expect in the case of Wolff's data but a degree of variability which invalidates the drawing of fundamental conclusions from them? The importance of the variability of the soil, as well as of the plant, as investigations of this laboratory have amply demonstrated, can not be overemphasized in connection with such conclusions as Mr. Truog attempts to draw from ash analyses and similar data.

Attributing to an essential element one or more kinds of functions in living cells is a procedure followed without more than the most slender evidence in its support. Highly speculative as this procedure may be, however, it becomes particularly questionable when the functions of elements like Ca and K are supposed to rest upon diametrically opposed bases.

There are other points in the paper under review which require even more critical examination than the one in the foregoing paragraph. We can not conceive of the application of the law of mass action to anything but definite chemical reactions between definite reacting substances and hence there is little likelihood of gleaning anything from an application of the law such as Mr. Truog makes. The reactions in question do not lend themselves to such simple treatment. We deal there unquestionably with complicated dynamic phenomena, which, in turn, may involve certain mass ac-

[3] *Research Memoirs Cornell Agr. Expt. Sta.*, Mem. 32, April, 1920.

[4] *Univ. Calif. Publ. Agr. Sciences*, Vol. 3, No. 9, p. 243, July, 1918.

tion phenomena, but clearly they are not such as to permit of the simple interpretation given, as even casual consideration of their nature will reveal. It is assumed, for example, that K is precipitated in the living cells through its interactions with the chemical constituents in those cells so as to permit the constant flow of K in solution into the cell from the medium. But any one who has studied the composition of cell sap from a variety of plants can not help but be impressed by the enormous quantities of soluble (not precipitated) K salts which the sap contains and, in all likelihood, in the form of *simple dissociated chemical compounds*. The data obtained on kelp and on other algæ, and those obtained by Kostychew and Eliasberg[5] on other plants, as well as unpublished data recently obtained by Hoagland on cereals, and by Hoagland and Davis on Nitella (a plant used by Osterhout in permeability studies), support the significance and cogency of this statement. Since space forbids our considering several examples, let us study the results on Nitella. This simple alga absorbs K readily from exceedingly dilute solutions thereof and from solutions having a high p_H value to a region within the cell of lower p_H value. This, in itself, proves Mr. Truog's assumption to be fallacious. Hoagland and Davis have found further, in agreement with Osterhout and Crozier that that alga lives in a medium whose p_H varies from 7.2 at night to 9.4 during the day, yet the hydrogen ion concentration of the vacuolar sap of that plant is represented by an approximately constant value of p_H 5.2. Further, Nitella lives in a solution whose Cl content varies from 20 to 30 p.p.m., yet the vacuolar sap of the alga has a Cl concentration of approximately 3,500 p.p.m. Moreover, in suitable media, all the Cl may be taken up by the alga and yet none will pass out of the cell unless the latter is injured, or the normal permeability is changed. Does this in any way support the attempt to apply the law of mass action to absorption of ions by plants after Truog's concept? The general principles gleaned from the work with Nitella should be applicable to plants generally.

[5] Hoppe-Seyler's Ztschr. physiol. chem., Vol. III, pp. 228-235 (1920).

It is, of course, regrettable that this review must be curtailed and that, therefore, a fuller discussion can not be accorded the points which are considered above, and some discussion to important ones which have not been mentioned. Enough has been said, however, to indicate the insecurity of Mr. Truog's theory and of the assumptions upon which it is based. The indications from recent research are that the reaction of plant sap in nearly all plants that have been investigated varies only in a very narrow range (Haas' work on natural indicators being exceptional), and that the conclusion that the ability of plants to absorb K from their media depends on the reaction of the cell sap and that sap of a high p_H permits plants to absorb K more efficiently from dilute solutions thereof than that of a low p_H are probably erroneous.

We may mention, further, in passing, that experimental evidence has been adduced in this laboratory to show that plants do not require Ca in the form of carbonates or bicarbonates since they can grow in solutions so acid that such compounds can not exist to the extent considered necessary.

Finally, we may say in closing that the term "feeding power of plants" is not only insecure, because of its vague support in fact, as partly indicated above, but also because absorption of ions is in no correct sense a feeding by plants and the sooner we give up referring to the mineral elements in soils as plant foods and of speaking of culture solutions as nutrient solutions, the better it will augur for the attainment of that clarity of expression, as well as thought, which are requisite to constant progress in plant physiology, as in other sciences.

A. R. DAVIS
D. R. HOAGLAND
C. B. LIPMAN
DIVISION OF PLANT NUTRITION,
THE UNIVERSITY OF CALIFORNIA

THE PERSONAL EQUATION OF THE ASTRONOMERS

THE data reported by Tucker in his communication on "Reaction time and fatigue"[1]

[1] Tucker: SCIENCE, LVII, No. 1468, February 16, 1923, pp. 204-5.