

might have been expected a lively discussion sprung up over the conflicting results of Boussingault and Ville, and Dr. Pugh associated himself with Messrs. Lawes & Gilbert for the purpose of reinvestigating the subject, and, if possible, of reaching decisive results.

It is, of course, foreign to the purpose of this paper to describe his investigation in detail, including as it did, besides the main question, many experiments upon various collateral points. The main features of the investigation, however, are readily comprehended. He grew plants in a soil freed from all compounds of nitrogen by ignition and washing, and confined them in an atmosphere also deprived of all nitrogen compounds; the plants being supplied with all other necessary foods, if they had the power to assimilate the free nitrogen of the air, they should have grown, and a comparison of the amount of nitrogen in the plants with that in the seed would show how much had been assimilated.

The results of the investigation were entirely negative, no assimilation of nitrogen being observed, either by graminaceous or leguminous plants. This investigation was a model of careful and accurate experimenting in every detail, and was for a long time believed to have settled the question. It is, therefore, a striking illustration of the difficulty of reaching absolute truth about natural processes, as well as of the need for caution in drawing conclusions from experimental results, that while the more recent investigations have not in the least degree impugned the accuracy of Dr. Pugh's work, they have nevertheless practically reversed his conclusion.

Another interesting fact is that many practical students of agriculture refused to accept these negative results and insisted that leguminous crops did in some way assimilate nitrogen from the air and thus serve to enrich the soil in that element, and for a long time there was a sort of subdued but irrepressible conflict between the teachings of scientific investigation and the results of practical observation. About 1881, a more acute stage of

the discussion was precipitated by the publication of results obtained by Schulz, a German. Schulz's estate of Lupitz possessed by nature a very poor sandy soil. By manuring with potash compounds and growing leguminous crops, chiefly lupines, Schulz was able to vastly increase its fertility. In his publications, he attributes this increased fertility to the assimilation of atmospheric nitrogen by the leguminous crops. A very lively discussion followed the publication of these results and various hypotheses were advanced to bring the results into harmony with the supposed teachings of science. Curiously enough, just about the time this discussion subsided, experimental results began to be published which differed radically from those of Boussingault and of Lawes, Gilbert & Pugh, in that they showed a very considerable assimilation of free nitrogen. Among the earliest of these results were those obtained by Prof. W. O. Atwater, at the Wesleyan University in Conn., with peas, by the method of sand culture. Since then, the substantially concordant results of Hellriegel & Wilfarth, Wolff, Breal, Lawes & Gilbert, Frank, Prazmowtki and others have established the fact that leguminous plants grown under suitable conditions do acquire large amounts of nitrogen from the air, either directly or indirectly.

As was before stated, this conclusion does not in the least impugn the accuracy of Dr. Pugh's experimental work. The key to the apparent discrepancy between the results of earlier and later investigation lies in the words "suitable conditions." These later investigations have shown that the assimilation of free atmospheric nitrogen by leguminous plants is intimately connected with the formation of the so-called root tubercles, and, furthermore, that these root tubercles are the result of the action upon the plant of certain bacteria which enter into a very curious and interesting symbiosis with the plants.

It has been shown that leguminous plants grown in sterilized soil, that is to say, in soil in which all organisms have been destroyed by heat, do not form tubercles and do not assimilate free nitrogen,