thermometer, which was provided with a porcelain tube, we were able to go up to 590°. Comparisons of the platinum and gas-scales were carried out at over 150 different points, each comparison consisting of either ten or twenty readings of the different instruments.

By the intermediary of the platinum thermometers a determination of the boiling point of sulphur on the nitrogen scale was also made. The mean of three very concordant sets of determinations with the different thermometers gave 445°·27 as the boiling point on the scale of the constant volume nitrogen thermometer, a value differing only 0°·7 from that found by Callendar and Griffiths for the same temperature expressed on the constant pressure air scale.

If for the reduction of the platinum temperatures in our comparisons we adopt the parabolic formula, and the value of δ obtained by assuming our new number for the sulphur-point, we find that below 100° the differences between the observed values on the nitrogen scale and those deduced from the platinum thermometer are exceedingly small, and that even at the highest temperatures the differences only amount to a few tenths of a degree.

Full details as to the instruments employed and the methods adopted are given in the paper.

"Agricultural, Botanical, and Chemical Results of Experiments on the Mixed Herbage of Permanent Grass-land, conducted for many Years in succession on the same Land. Part III.—The Chemical Results." By Sir JOHN BENNET LAWES, Bart., D.C.L., Sc.D., F.R.S., and Sir J. HENRY GILBERT, LL.D., Sc.D., F.R.S. Received August 10, 1899.

(Abstract.)

The experiments were commenced in 1856, and are still in progress, so that the present is the forty-fourth year of their continuance. There are about twenty plots, two of which have been continuously unmanured, and the remainder have respectively received different descriptions or quantities of manure of known composition. A report on the "Agricultural Results" was published in the 'Phil. Trans.,' Part I, 1880; and a second on the "Botanical Results" in the 'Phil. Trans.,' Part IV, 1882. The present paper deals with a portion of the "Chemical Results."

In all cases, of both first and second crops, the dry matter and the ash, and in most the nitrogen, have been determined. In selected cases determinations have been made of the amount of nitrogen existing as albuminoids, and in some of the amount of "crude woody fibre," and of crude fatty matter. More than 200 complete ash-analyses have also been executed.

It was found that the chemical composition of the mixed herbage was very directly dependent, not only on the seasons and on the supplies within the soil, but very prominently also on the description of plants encouraged, and on the character of their development; so that it was essential to a proper interpretation of the variations in the chemical composition, to bear in mind the differences in the botanical composition. Hence a summary table was given showing the characteristic differences in the botanical composition under the different conditions as to manuring, the influence of which on the chemical composition it was sought to illustrate.

As the investigation involved the consideration of the chemical composition of the mixed produce of about twenty plots over forty or more seasons, including the discussion of the results of more than 200 complete analyses of the ashes of the separated or the mixed herbage, attention was called to the state of existing knowledge as to the *rôle* or function in vegetation of the individual constituents found in the ashes of plants; and this was seen to be very imperfect. Further, in calculating the percentage composition of the "pure ash," the plan usually adopted was to exclude not only the sand and charcoal, but also the carbonic acid. The authors considered, however, that the presence and the amount of carbonic acid associated with the fixed constituents in plant-ashes was a point of considerable significance; and they entered into some detail as to the methods of determining the carbonic acid in ashes, and as to the results obtained.

In order to throw some light on the connection between the growth of the crops and their mineral composition, results relating to the separated gramineous, the separated leguminous, and the separated "miscellaneous" herbage of the mixed produce, grown without manure and by different manures, were first discussed. To obtain more definite evidence illustrating the connection between character and stage of growth and the composition of the products—especially the ash-composition—results relating to the bean plant, taken at successive periods of growth, and also to the first, second, and third crops of clover, were next considered. Lastly, in further illustration, results as to the nitrogen and the ash-composition of crops of three different natural orders—wheat representing the Gramineæ, Swedish turnips the Cruciferæ, and beans and clover the Leguminoseæ—were given.

The general result was, that there were very characteristic differences in the composition of the ashes of different crops according to the amounts of nitrogen they assimilated. Red clover, for example, yields large amounts of nitrogen over a given area, part of which is due to fixation, but much is certainly taken up as nitrates from the soil; and the results show, that the greater the amount of nitrogen assimilated the more is the ash characterised by containing fixed base in combination with carbonic acid; presumably representing organic

acid in the vegetable substance before incineration. The conclusion was that, independently of any specially physiological function of the bases, such as that of potash in connection with the formation of carbohydrates, for example, their office was prominently also that of *carriers of nitric acid*, and that when the nitrogen had been assimilated, the base was left as a residue in combination with organic acid—which was represented by carbonic acid in the ash. Further existing knowledge —as to the condition in which combined nitrogen is found in soil waters, as to the action of nitrates used as manures, as to the presence of nitrates in still-growing plants, and as to the connection between the nitrogen assimilated and the composition of the ash as had been illustrated—pointed to the conclusion that, at any rate a large amount of the nitrogen of the chlorophyllous vegetation on the earth's surface was derived from nitrates; whilst, so far as this was the case, the *raison d'être* of much of the fixed base found in the ashes of plants would seem to be clearly indicated.

The various results and conclusions above referred to were found to afford material aid in the interpretation of the differences in the chemical composition of the mixed herbage of the different plots which was next considered, so far as the first crops over the first twenty years were concerned.

For the purposes of the illustrations the differently manured plots were arranged in four groups as follows:—1. Plots without manure or with farmyard manure. 2. Plots with nitrogenous manures alone. 3. Plots with mineral manures alone. 4. Plots with nitrogenous and mineral manures together. Average results for each plot, generally for a period of eighteen years, 1856—1873, and including the percentages of nitrogen, crude ash, and pure ash, in the dry substance of the produce; also the percentage composition of the pure ash were brought together in a table, and are discussed in detail. The close dependence of the chemical composition of the mixed herbage on its botanical composition, and on the character of development of the plants, was throughout illustrated. It was further shown, that the mineral composition of the mixed herbage was very directly dependent on the supplies available to the plant within the soil. Indeed, when it was considered that the mixed herbage of permanent grass land includes plants of very various root-range and root-habit, and that some of them vegetate more or less almost the year round, it was not surprising to find that the composition of the produce was, upon the whole, a somewhat close reflection of the available supplies within the range of the roots. It was, in fact, much more so than in the case of individual crops grown separately. Within certain limits, this was the case even with the constituents of, so to speak, less functional importance than those which more obviously determined the description of plants encouraged and the character of their development. It was at

the same time obvious, that when the more functionally important constituents are available in relative abundance, those which are of less importance in this respect were taken up and retained in less amount than they otherwise would be; the result being determined in great measure by the character of growth induced.

For example, if potash be liberally available the produce is much more stemmy, and the amount of soda, of lime, and to some extent of magnesia also, will be less relatively to the potash. In defect of sufficient potash, on the other hand, more of soda, or of lime, or of both, will be taken up and retained; but the herbage will at the same time be more leafy and immature. That is to say, the constituents are not mutually replaceable in the processes of growth, but accordingly as the one or the other predominates, so will the product of growth be different.

There can be no doubt, that luxuriance or vegetative activity is intimately associated with the amount of nitrogen available and taken up. Further, it may be stated that chlorophyll formation to a great extent follows nitrogen assimilation. But the results relating to the increased amount of non-nitrogenous substance yielded in the mixed herbage under the influence of the various manures clearly indicated that the nitrogen being taken up, and the chlorophyll formed, the carbon assimilation, and the carbohydrate formation, depended essentially on the amounts of potash available. It may be stated as a matter of fact that, in practical agriculture, artificial nitrogenous manures are chiefly used for crops containing a comparatively low percentage of nitrogen in their dry substance, and yielding comparatively low amounts of nitrogen per acre. Indeed, they are mainly used for the increased production of the non-nitrogenous bodies—the carbohydrates —starch and cellulose in the cereals, starch in potatoes, and sugar in the sugar-cane and in root crops, for example. And now, in the case of the mixed herbage of grass land, it was seen that, provided the mineral constituents, and especially potash, were abundantly available, a characteristic effect of nitrogenous manures was to increase the production of the non-nitrogenous bodies.