ing mornings, at 8 a.m., for gratuitous distribution. Lists of members present will be issued as soon as possible after the commencement of the meeting, and will be placed in the same room for distribution. The published volumes of the British Association can be ordered in this room, for Members and Associates only, at the reduced prices appointed by the Council. The tickets will contain a map of Newcastle-upon-Tyne, and particulars as to the rooms appointed for Sectional and other meetings. For the convenience of Members and Associates, a branch post office (which will be available also for communication between Members attending the meeting) will be opened in the Reception Room. Members and Associates may obtain information about local arrangements, and facilities afforded by the railway companies, on application to the Local Secretaries, Newcastle-upon-Tyne.

THE GOVERNMENT'S TECHNICAL INSTRUCTION BILL.

THE following is the Bill to Facilitate the Provision of Technical Instruction, introduced into the House of Commons by Sir W. Hart Dyke, and read a first time, on July 24:—

Be it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:

I. (1) A local authority may from time to time out of the local rate supply or aid the supply of technical or manual instruction, to such extent and on such terms as the authority think expedient, subject to the following restrictions, namely:—

(*a*) The local authority shall not out of the local rate supply or aid the supply of technical or manual instruction at an elementary school to scholars receiving instruction in the obligatory or standard subjects prescribed by the minutes of the Education Department for the time being in force; and

(*b*) The amount of the rate to be raised in any one year by a local authority for the purposes of this Act shall not exceed the sum of *one penny* in the pound.

(2) A local authority may, for the purposes of this Act, appoint a Committee consisting either wholly or partly of members of the local authority, and may delegate to any such Committee any powers exercisable by the authority under this Act, except the power of raising a rate or borrowing money.

II. (1) The managers of any school or other institution giving technical instruction in the district of a local authority may make an arrangement with the authority for transferring their school or institution to it, and the local authority may assent to any such arrangement.

(2) The provisions of Section 23 of the Elementary Education Act, 1870, with respect to arrangements for the transfers of schools, shall apply in the case of arrangements for the tranfers of schools or institutions in pursuance of this section, with this modification, that for the purposes of transfers to a local authority references to the School Board shall be construed as references to the local authority, and references to the Education Department as references to the Department of Science and Art.

III. The conditions on which Parliamentary grants may be made in aid of technical or manual instruction shall be those contained in the minutes of the Department of Science and Art in force for the time being.

IV. (1) For the purposes of this Act the expression "local authority" shall mean the Council of any county or borough, and any urban or rural sanitary authority within the meaning of the Public Health Acts.

(2) The local rate for the purposes of this Act shall be—

(*a*) In the case of a County Council, the county fund;

(*b*) In the case of a Borough Council, the borough fund or borough rate;

(*c*) In the case of an urban sanitary authority not being a Borough Council, the district fund and general district rate, or other fund or rate applicable to the general purposes of the Public Health Acts;

(*d*) In the case of a rural sanitary authority, the rate or rates out of which special expenses incurred in respect of any contributory place or places are payable under the Public Health Act, 1875.

(3) A County Council may charge any expenses incurred by them under this Act on any part of their county.

(4) A rural sanitary authority may charge any expenses incurred by them under this Act on any contributory place or places within their district.

(5) A local authority may borrow for the purposes of this Act—

(*a*) In the case of a County Council, in manner provided by the Local Government Act, 1888;

(*b*) In the case of a Borough Council, as if the purposes of this Act were purposes for which they are authorized by Section 106 of the Municipal Corporations Act, 1882, to borrow;

(*c*) In the case of an urban sanitary authority not being a Borough Council, or of a rural sanitary authority, as if the purposes of this Act were purposes for which they are authorized to borrow under the Public Health Acts.

V. In this Act—

The expression "technical instruction" shall mean instruction in the principles of science and art applicable to industries, and in the application of special branches of science and art to specific industries or employments. It shall not include teaching the practice of any trade or industry or employment, but, save as aforesaid, shall include instruction in the branches of science and art with respect to which grants are for the time being made by the Department of Science and Art, and any other form of instruction which may for the time being be sanctioned by that Department by a minute laid before Parliament and made on the representation of a local authority that such a form of instruction is required by the circumstances of its district.

The expression "manual instruction" shall mean instruction in the use of tools, and modelling in clay, wood, or other material.

VI. This Act shall not extend to Scotland or Ireland.

VII. This Act may be cited as the Technical Instruction Act, 1889.

PROFESSOR LOOMIS ON RAINFALL.[1]

THE subject of this chapter is the mean annual rainfall in all the different countries of the globe, with a discussion of the conditions favourable and unfavourable to rainfall, and an examination of individual cases of rainfall in the United States, Europe, and over the Atlantic Ocean, and the areas of low barometric pressure without rain.

To begin with, Prof. Loomis has compiled a list of 1427 stations, and arranged them in order of latitude. With each station is found its altitude, its mean annual rainfall, and the number of years of observation. This list would have been considerably larger if all the stations where the amount of rainfall is measured were quoted, for in England alone there are 2200 stations where rainfall is regularly measured, in the United States 2000, whilst the total number of stations in France is 1500. The plan adopted by the author has been to select a few stations from those countries which rejoiced in a plentitude of rain-gauges, but in regions where few stations exist all the measurements were used.

Following upon each enunciation of causes which affect rainfall is found a tabular statement demonstrating its truth.

The conditions favourable to rainfall, according to Prof. Loomis, begin with the fact that the north-east and south-east trade winds, on approaching the belt of calms near the equator, and being gradually deflected upward, are cooled by expansion, so that the aqueous vapour is condensed, and the belt of calms becomes a belt of rain. This equatorial rain-belt, of course, moves with the sun in declination, and some observations included in table lxxxiv. strikingly exemplify this movement by giving for twelve months respectively the number of rains in a hundred observations between latitudes 20° N. and 10° S., the maximum of falls moving with the sun.

A second cause for abundant rainfall is the influence of mountains, for when a strong wind meets a mountain it is forced up the side of the mountain, and elevated into a colder region, the result being that its vapour is precipitated by the cold of elevation. Table lxxxv. gives a comparison of the rainfall in two regions situated within twenty-five miles of each other, but of different altitudes, and from it the conclusion is deduced that the rainfall on a mountain from 4000 to 10,000 feet high is more than double that at neighbouring places near the sea-

[1] "Contributions to Meteorology," Chapter III., by Elias Loomis, LL.D., Professor of Natural Philosophy and Astronomy in Yale University, &c. Revised Edition. (New Haven, Connecticut, U.S., 1889.)

level. A third condition favourable to an abundant rainfall is proximity to the ocean, especially when the prevailing wind comes from the ocean. Capes and headlands projecting considerably into the ocean generally show a rainfall greater than interior stations only a few miles distant; and lastly, Prof. Loomis notes that the great and non-periodic depressions of the barometer are always accompanied by a considerable fall of rain, and that the average tracks of these depressions are marked by an excess of rainfall.

The following are some of the conditions unfavourable to rainfall. Fresh winds blowing in a nearly uniform direction throughout the year, such as prevail within a portion of the system of trade winds, especially in mid-ocean. The rainfall on Ascension Island is quoted as a case in point, observations for two years showing that the direction of the wind was south-east or very nearly so during the time, the rainfall during these two years being 2·31 and 4·30 inches respectively. This condition of things prevails over the Atlantic Ocean within the region where the trade winds blow with considerable force and are seldom interrupted.

A second condition unfavourable to rain is a position on the leeward side of a range of mountains running in a direction nearly at right angles to that of the prevalent wind. An illustration of this principle is seen on the Malabar coast of Hindustan. On the ocean side of the range of mountains the rainfall is 250 inches annually, whilst on the eastern side of the range the air is very dry, and the amount of the mean annual rainfall is less than 25 inches.

When there is a second range of mountains, parallel and within 100 or 200 miles of the first, the influence of this cause is considerably intensified, and this diminution is still more decided when a place is surrounded by mountains, or nearly so. Salamanca is so situated, and the mean annual rainfall there is less than 10 inches.

Elevated plateaus have generally less rainfall than insulated mountain peaks of an equal elevation; this is illustrated by the fact that Leh, being situated on that remarkable plateau of Tibet, has a mean annual rainfall of less than 3 inches. Another similar case is found in the tableland (the Punos) between two great chains of the Andes; and it is observed that the average height of the Sahara being over 1500 feet, this elevation may contribute in some degree to the smallness of the rainfall.

Another condition unfavourable to rainfall is the dryness of the atmosphere, under which head Prof. Loomis gives three special cases, viz. remoteness from the ocean, measured in the direction from which the prevalent wind proceeds, areas of high barometric pressure, and high latitudes. This last conclusion does not state that the average rainfall regularly diminishes as we go northwards, the same as the mean temperature; but if the mean annual fall be taken for every 10° of latitude the important influence on the amount of rainfall is very decided, and is emphatically exhibited in high latitudes. The general table of observations, arranged in order of latitude, which began this chapter, shows that for the four stations whose latitude exceeded 71° the mean annual rainfall was 7·44 inches, whilst the paucity of observations of the fall of rain or snow that have been made during the various Arctic expeditions also demonstrates the fact.

A review is next made of the regions which show a very small rainfall, and the causes inquired into where the observations of pressure, temperature, and humidity of the air, and the direction and force of prevailing winds rendered it possible to obtain some definite information as to the meteorological condition of the region.

Prof. Loomis has thoroughly investigated the conditions of rainfall in the United States, and from the tables of observations he arrives at the inference that the depression of the barometer accompanying extraordinary rainfalls is not very great, the average pressure at the low centre being 29·63 inches for the part of the United States north of latitude 36°, and the average pressure at the stations of greatest fall being 29·77 inches.

Table cxii. gives all the cases where the barometer fell below 29 inches at any station in the United States or Canada between September 1872 and June 1884, and also the station where the greatest rainfall occurred for the preceding twenty-four hours. The conclusion drawn from such a comparison is that a moderate depression of the barometer is as favourable to great rainfall as an extremely great depression, which would seem to indicate that rainfall has but little connection with barometric depression. It must, however, be remembered that the depression at the centre of a low area depends not merely upon the barometric gradient, but upon the geographical extent of the low area.

The following are some of the conclusions Prof. Loomis arrives at respecting the causes of rainfall in the United States. One of the most common causes of rain is an unstable condition of the atmosphere resulting from an unusually high temperature combined with unusual humidity. Another very common cause of rain frequently associated with this is a cold northerly or westerly wind in the western segment of the low area, and proximity to the ocean or to a large inland sea.

The investigation affords important evidence respecting the influence of rainfall upon areas of low pressure, viz.—

No great barometric depression with steep gradients ever occurs without considerable rainfall.

In great rain-storms the barometric pressure generally diminishes while the rainfall increases.

The greatest depression of the barometer generally occurs about twelve hours after the greatest rainfall.

A great fall of rain is favourable to a rapid progress of the centre of least pressure, while a small rainfall is generally attended by a less rapid progress.

It is also noted that some of the characteristics of areas of low pressure with little or no rain are:—

(1) Feeble barometric gradients.
(2) Moderate winds.
(3) Slow changes of barometric pressure.
(4) Slow progressive movement.

Whilst in similar areas of low pressure with excessive rainfalls all these conditions are reversed.

In order to study the influence of rainfall upon barometric pressure under different geographical influences, Prof. Loomis has compiled for Europe a similar set of tables to those concerning the United States. Of the 106 stations having a rainfall of not less than 2·5 inches in twenty-four hours, eighty-six are situated south of latitude 48°, and fifteen are north of latitude 48°, indicating that heavy rains are about six times as frequent in the south as in the north of that latitude. Prof. Loomis thinks that the summary of observations relating to Europe seems to indicate that great rains occur on the west side of the low centre more frequently than they do in the United States.

Tables have also been prepared showing the rainfall over the North Atlantic as far as observations permitted. An unexpected fact exhibited by these tables is the prevalence of rainfalls with the barometer somewhat above 30 inches.

A comparison of the results that have been obtained for the United States and for Europe brings Prof. Loomis to some important conclusions respecting the influence of local causes in modifying the relation of rainfall to barometric pressure.

The conclusions are, for stations east of the Rocky Mountains:—

(1) South of latitude 36°, a rainfall of 2½ inches in eight hours at any station occurs on the east side of a low area more frequently than on the west side in the ratio of 2·6 to 1.

(2) North of latitude 36°, a rainfall of 2 inches in eight hours at any station occurs on the east side of a low area more frequently than on the west side in the ratio of 2·8 to 1.

(3) A total rainfall of 9 inches in eight hours at all the stations east of the Rocky Mountains occurs on the east side of a low area more frequently than on the west side in the ratio of 6·2 to 1.

(4) Over the North Atlantic Ocean great rain areas occur on the east side of an area of low pressure more frequently than on the west side in the ratio of 2·6 to 1.

(5) In Europe a rainfall of 2½ inches in twenty-four hours at any station occurs on the east side of a low area more frequently than on the west side in the ratio of 2·0 to 1.

These results indicate that in the United States and Europe, as well as over the North Atlantic Ocean, great rainfalls are generally associated with a barometric pressure somewhat below the mean, and the precipitation occurs chiefly on the eastern side of a low area.

The relation of a rising to a falling barometer with rain points to the conclusions that at Philadelphia the amount of rain which falls while the barometer is descending is nearly three times as great as that which falls while the barometer is rising. The entire Atlantic coast of the United States north of latitude 36° exhibits results similar to those found for Philadelphia. Advancing westward from the Atlantic coast, the ratio of the precipitation when the barometer is falling, compared with that when the barometer is rising, changes somewhat rapidly, and before we reach the Mississippi River the ratio is reduced to 1·32.

In Great Britain the amount of rain with a falling is twice that with a rising barometer, but, advancing eastward, this ratio rapidly diminishes, and in Central Europe the precipitation is greater when the barometer is rising than when it is falling. Plates are appended, which exemplify in an emphatic manner all the facts that have been tabulated concerning rainfall. Five gradations of colour only have been used to indicate the rainfall of less than 10 inches to over 75 inches. By this means the main results have been rendered more prominent.

R. A. GREGORY.

THE SOURCES OF THE NITROGEN OF VEGETATION.[1]

NO problem relating to the nutrition of plants has given rise to so much discussion as that of the source of their nitrogen and the methods of its assimilation. It is obviously both a matter of the highest scientific interest, and also, owing to the high price of combined nitrogen in manures and the comparative ease with which it is washed out of the soil in the form of nitrates, one of great practical importance to the agriculturist and the community.

Ever since the discovery of the composition of atmospheric air by Priestley, Scheele, and Lavoisier, the question as to whether plants were able to absorb and utilize free nitrogen has attracted much attention. At the end of the last century, or beginning of this, Ingenhousz, Sennebier, Woodhouse, and De Saussure became interested in the subject.

Boussingault commenced his experiments in 1837; Ville, whose results conflicted with those of Boussingault, in 1849; and, shortly after, this last named investigator started a new series of experiments which confirmed his former conclusions that plants, under the conditions of the experiment, were not able to assimilate free nitrogen.

In 1857, experiments on the assimilation of free nitrogen by plants were started at Rothamsted; and in 1861 was published, in the Philosophical Transactions, the classical memoir of Lawes, Gilbert, and Pugh, on this subject.

In this earlier paper a brief history and summary of the results of other experimenters is given, and then the recent results obtained at Rothamsted. The conclusions arrived at were identical with those of Boussingault, that there is no evidence that plants assimilate nitrogen. Still the authors allowed that there were some difficulties with regard to the supply of nitrogen to leguminous plants, which assimilate from some source or another much more nitrogen than gramineous plants under similar conditions of supply of combined nitrogen.

It was admitted that, "if it be established that the processes of vegetation do not bring free nitrogen into combination, it still remains not very obvious to what actions a large proportion of the existing combined nitrogen may be attributed."

These views, that plants were unable to assimilate free nitrogen were widely and generally held for many years, though there have always been some dissentients.

In the meantime, however, the indefatigable investigators of Rothamsted have not been resting in the matter, but have added much to our exact knowledge of the supplies of combined nitrogen to the soil from the air, on the amount and nature of the combined nitrogen in soils and in crops, on the processes of nitrification in soils, and the amount of nitrogen removed from soils in crops and in drainage.

During the last few years the main question as to the availability of atmospheric nitrogen to plants has taken a somewhat different aspect: it is now often suggested that though the higher plants are unable to directly take up free nitrogen, yet indirectly it is brought under contribution in some way; the ways most generally favoured being either under the influence of electricity of low tension, or of microbes or some low forms of organisms; and by such means it is thought that nitrogen is brought into a form in which it is useful to the higher plants.

In Sir J. B. Lawes and Dr. Gilbert's new memoir they give a summary of some previously published Rothamsted results, chiefly relating to nitric acid in soils and subsoils; also of the results of Cameron, S. W. Johnson, Hampe, Wagner, and Wolff, on the assimilation of nitrogen by plants, from more or less complex organic bodies like urea, uric acid, hippuric acid, and tyrosine.

A number of new determinations of nitric acid in soils and subsoils, and of total combined nitrogen in the surface soils of the Rothamsted experimental plots are given; and also the results of numerous experiments with dilute solutions of organic acids on soils, to ascertain the action of such dilute acids, in some degree comparable to the acid sap of the roots of plants, on the organic nitrogenous matter of soils.

In the second part of the memoir are summarized the recent results and conclusions of other workers relating to the fixation of free nitrogen.

Probably the results of Berthelot, which have from time to time been published in the *Comptes rendus*, have influenced the opinions and the course of inquiry in recent years more than any others. In 1876 and 1877, Berthelot found that various organic compounds under the influence of the silent electric discharge, even of low tension, were able to fix free nitrogen, and concluded that such fixation of nitrogen takes place in ordinary soils under normal conditions. In 1885 he published results showing the fixing of free nitrogen by certain soils under conditions which led him to believe that the action must be due to the influence of micro-organisms, and to such action M. Berthelot seems now inclined to impute most influence in the matter. Although the gains in nitrogen, expressed in percentages, were very small, yet there was gain in all cases when the soils were exposed either in the open, or in a room, or in closed flasks, and no gain when the soils were sterilized. Unless there be some unrecognized source of error, such as might easily be imagined in the case of the freely exposed soils, one seems bound to accept Berthelot's conclusions. Dehérain's results at Grignon are next discussed; they are chiefly on the gains or losses occurring on experimental field plots, and are perhaps not of such a nature as to materially assist one at the present stage of the inquiry.

Joulie's results, as given in the *Bulletin de la Société des Agriculteurs de France* in 1886, showed exceedingly large gains of nitrogen, which he is inclined to ascribe to the action of microbes; here the gains of nitrogen were certainly more than take place in ordinary farm practice, and occurred with buckwheat, which is not usually considered as a "nitrogen collector."

Dietzell's experiments are mentioned; in all cases but one, in which there was a slight gain in nitrogen, the results are fully accordant with established facts. B. Frank, who has recently written a paper on the whole aspect of the question, has published some experiments of his own. He concluded, as have others, that two opposite actions are at work in the soil—one setting nitrogen free, and the other bringing it into combination, the latter being favoured by vegetation—but that there is no decisive evidence to show how this combination is brought about; it does not necessarily follow that the plant itself effects the combination. Some of Frank's experimental conditions, however, were considerably removed from those occurring in the ordinary course of farm practice.

The very important and most interesting experiments of Hellriegel and Wilfarth follow. The first of these were described at the Berlin meeting of the *Naturforscher-Versammlung*, in 1886; subsequent experiments were described at the Wiesbaden meeting in 1887, and they were further given in a paper by König, published in Berlin in 1887; but the full text and details of their work were not published in time for Messrs. Lawes and Gilbert to refer to. A paper on these results appeared last November in *Beilageheft zu der Zeitschrift des Vereins für die Rübenzucker-Industrie*, and the work of these investigators is described by M. Vesque in the January number of *Annales Agronomiques*.

The experiments date from 1883 onwards, and were on cereals, buckwheat, rape, and various leguminous plants. The plants were grown in pots in washed siliceous sand, to which the necessary cinereal constituents were added. In this all the plants grew normally until the nitrogen in the seed was used up; then the plants not belonging to the Leguminosæ ceased growing until supplied with some combined nitrogen, nitrate of soda was used, when growth was proceeded with almost exactly in proportion to the amount of nitrogen supplied. With the Leguminosæ the results were more eccentric: sometimes the plants died of nitrogen-hunger; sometimes after a time of such hunger they recovered and produced abundant growth. To

[1] "On the Present Position of the Question of the Sources of the Nitrogen of Vegetation, with some New Results, and Preliminary Notice of New Lines of Investigation." By Sir J. B. Lawes and Prof. J. H. Gilbert. Phil. Trans. 1889, clxxx. B. pp. 1–107.