# T H E S I S.

## OBSERVATIONS EXTENDING OVER THREE YEARS ON THE AMOUNT OF CARBONIC ACID IN THE GROUND AIR IN RELATION TO THE EARTH TEMPERATURE AT THE DEPTH OF THREE FEET WITH CHARTS.

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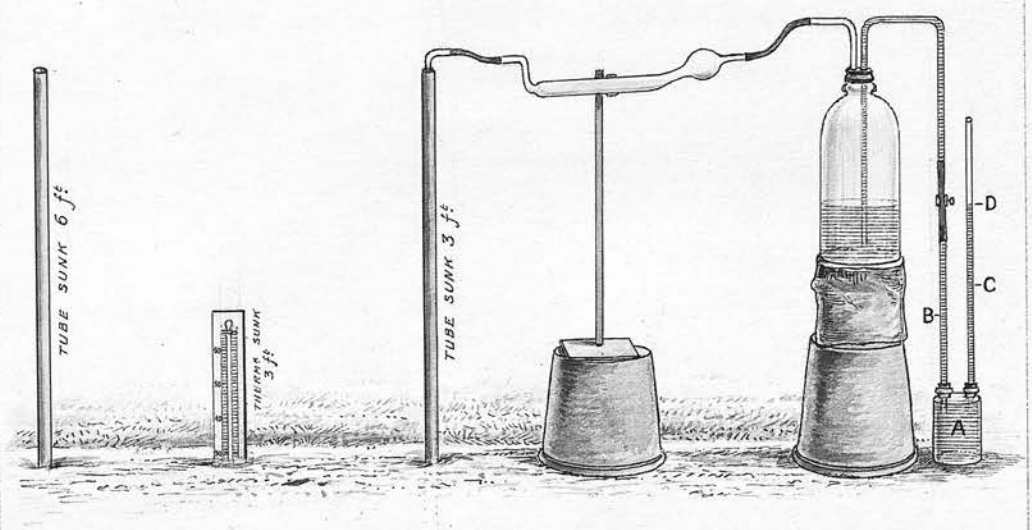
TUBE SUNK 6 ft.
THERMS. SUNK 3 ft.
TUBE SUNK 3 ft.
D
C
B
A

# OBSERVATIONS EXTENDING over THREE YEARS on the amount of CARBONIC ACID in the GROUND AIR in RELATION to the EARTH TEMPERATURE at the DEPTH of THREE FEET with CHARTS.

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The connection between certain conditions of soil and the incidence of some infectious diseases has long been recognised by Physicians but the way in which these conditions operate has been variously explained.

It is to Pettenkofer we owe the first attempts to scientifically investigate this relation and the results of his investigations are contained in his elaborate treatise "Zum gegenwartige stand der Cholera Frage." According to Pettenkofer the conditions necessary for the epidemic occurrence of Cholera and Typhoid Fever are :-

(1) Porosity of the soil.
(2) Organic pollution of the soil.
(3) Moisture, and
(4) Sufficiently high temperature.

Since these conditions are favourable to the growth and development of micro-organisms in the soil and since carbonic acid is one of the products of the action /

action of micro-organisms on organic matter, Pettenkofer considers that the amount of this gas present in the ground air is a measure of the pollution of the soil and of the amount of decomposition going on in it. Fodor in his book entitled "Luft, Boden und Wasser" records the results of his investigations into the variations of the amount of carbonic acid in the ground air at Buda Pesth during three years, 1877-1879, and shows that the curve of carbonic acid in ground air, taken at a depth of one metre from the surface, markedly coincided with the curve of Enteritis or Summer Diarrhoea of children in these years.

He considers that the source of the infection in enteritis is to be found in the processes of decomposition going on in the upper layers of the soil, the amount of the production of this substance being related to the amount of carbonic acid found in the ground air.

Ballard (Supplement to the Report of the Medical Officer of the Local Government Board of England 1887) considers that the essential cause of diarrhoea resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organisms and that the maximum Diarrhoea Mortality is usually observed in the week on which the temperature recorded by the four /

four foot earth thermometer attains its mean weekly maximum. The variations in the amount of carbonic acid in the ground air in Edinburgh has been investigated by Professor Hunter Stewart (Transactions of the Royal Society of Edinburgh "On the Variations of the amount of Carbonic Acid in the Ground Air") whose results in the main confirm the work of Fodor, and the following investigations were undertaken to see whether the soil in another part of Edinburgh, which differs both in nature and exposure from that in which Professor Hunter Stewart carried out his experiments, would give similar results. The amount of air aspirated in each experiment was one litre. Each observation occupied about half an hour and this time being liable to be broken in upon by other engagements, in order to overcome the occasional loss of an observation, recourse was had to an automatic syphon breakage, so that, when a litre of air was aspirated the action ceased. The observations recorded by the use of the automatic break were tested by counter observations recorded in the usual way, and were found to exactly agree the one with the other. The apparatus for this action consisted of a double necked Wolff bottle A, fitted with singly bored rubber corks through each of which passed a glass tube. The tube at B. was in connection with the syphon tube of the aspirator and that at C was open to the air. The /

The capacity of the apparatus was such that a litre of water filled the bottle and rose to a point D, in the open glass tube. The aspirator was so arranged that when a litre had been discharged the water in the aspirator was at the same level as the water in the tube C.

Firm clay within a few feet of the surface is a characteristic of the Edinburgh district. The rich humus and loam on the surface resting on the more or less impermeable subsoil of clay forms the natural laboratory for the production of carbonic acid in this locality and therefore the observations although possessing some points of general are of more local interest.

The locality in which the observations were made was old soil in an open space, grass grown, away from trees and shrubs, twenty paces from a dwelling and an equal distance from a flower border. The soil which had been undisturbed for many years consisted of of loam to the depth of about three feet, overlying a bed of stiff clay.

The general plan of conducting the observations was as follows :-

(I have shown the arrangement of the apparatus in situ in figure I.)

The ground air was aspirated through two iron tubes each having an internal diameter of one inch sunk into the ground three and six feet respectively. The /

The six feet tube was for nearly half of its length in firm clay and the aspiration of air through it was most difficult. The time taken in drawing a litre of air was sometimes more than twelve hours and the amount of carbonic acid in the air thus aspirated was never more than one-tenth of the amount obtained on the same day from the tube sunk at the depth of three feet. On this account I discontinued examining the air from a depth of six feet.

A ground thermometer was introduced in the immediate neighbourhood to the depth of three feet and observations of the ground temperature were made simultaneously with those of the amount of carbonic acid at this depth.

Occasional interruptions were caused by the ground water, after heavy rain, blocking the tube, and by severe frost.

This paper shows a correspondence between the maximum of carbonic acid and the maximum reading of the earth thermometer at three feet. Late summer, when the temperature of the soil at three feet rose to the maximum, showed also the greatest amount of carbonic acid. Throughout the entire year much rain always produced a marked temporary increase in the amount of carbonic acid. These facts probably find their explanation in the increased bacterial life called into renewed activity by the heat and moisture.

Moisture, as after much rain, may also act by mechanically /

mechanically sealing up the pores of the soil and thus preventing the normal escape of carbonic acid into the general atmosphere. The highest reading of the earth thermometer was towards the end of August when it ranged in the neighbourhood of 56° Fahr. Edinburgh is not what is known as a "Diarrhoea Town" that is, one in which that disease plays havoc with the infantile population in late summer and early autumn, but still, it is observed that most cases of infantile diarrhoea do occur at the time corresponding with the maximum reading of the earth thermometer at three feet, as is shown by reference to the Report of the Medical Officer of Health, Edinburgh 1898.

Chart I shows weekly average of the morning and of the evening determinations of carbonic acid in the ground air at the depth of three feet from the surface from September 1894 to September 1895, expressed in cubic centimetres per litre and also the weekly mean temperature of the atmosphere and of the soil at a depth of three feet.

Charts II and III show the weekly average of the morning determinations from September 1895 to September 1897 with the corresponding curves of temperature as in Chart I.

The /

The diurnal variation in the amount of carbonic acid showed an evening excess over the morning as the year approached near to the summer solstice and beyond it to the maximum reading of the year which occurred in the last days of August. After this period a morning excess over the evening was observed as the year approached near to the winter solstice and beyond it to the minimum reading of the year which took place in the end of March. During March, April and May, and again in September, October and November, the morning and evening variations were but little marked and temporary conditions of weather probably produced them. The year may be divided as regards the morning and evening variations in carbonic acid into four periods, September to December, December to March, March to June and June to September. In the first and third of these periods the morning reading is in excess,and in the second and fourth the evening reading.

Any markedly high reading was always observed to follow a high rainfall. Excessively low readings on the other hand were observed after prolonged dry weather. A temporary increase after rain was constantly observed.

The remarkable rise in the amount of carbonic acid in February and March of 1895 during the period of prolonged frost, and when snow lay on the ground for about a month, is not easy of explanation. The idea /

idea suggested itself that perhaps this was due to an increase of temperature in the soil caused by the covering of snow preventing radiation of heat from the upper layers of the soil. From observations made in February 1900 I found that such a covering of snow had no effect on the ground temperature thermometer whatever. The increase in carbonic acid may be explained to some extent by the sealing up of the surface of the soil thus preventing the natural escape of carbonic acid into the atmosphere. It was not observed that severe frost, apart from a covering of snow on the ground, was followed by increase in the amount of carbonic acid. In each of the three years the highest reading was observed towards the end of August.

The remarkably low reading in October 1896 and again in August 1897 followed on a period of drought.

No observation was taken from February to June 1897.

The curves in the three Charts show a marked resemblance though they do not strictly coincide with each other.

Much rain was invariably followed by a marked increase in the amount of carbonic acid.

Observations were made on six days of each week.

The ground temperature curves are prepared from observations taken on the earth thermometer sunk to the depth of three feet in the immediate vicinity of the /

the tubes from which the ground air was aspirated.

The air temperature curves are prepared from observations taken in the immediate neighbourhood by R.C.Mossman, F.R.S.E., and kindly supplied by him. The period over which the observations in soil temperatures extend was from July 1895 to September 1897.

No difference between the morning reading and the evening reading of the earth temperature at three feet was ever observed. The observations of the ground thermometer readings were taken on three alternate days of each week. The annual range of the temperature of the earth thermometer at three feet was about 20° Fahr. The lowest reading was observed to be in the month of February when it was in the neighbourhood of 36° Fahr. and the highest reading in the month of August when it was in the neighbourhood of 56° Fahr.

There is observed to be a close correspondence between the annual curve of the earth thermometer and the annual curve of the amount of carbonic acid in the soil, that is, when the earth thermometer reading falls to the lowest annual point or rises to its highest annual point the amount of carbonic acid in the soil similarly approaches its lowest and highest points.

It is further to be observed by reference to the Reports of the Medical Officer of Health, Edinburgh, that there was a close correspondence between the /

the greater number of fatal cases of Infantile Diarrhoea and the highest reading of the earth thermometer at three feet.

# DATA of CHART I.

| Date week ending | Estimation of Carbonic Acid - 3 feet deep Morning | Evening | Earth Thermometer 3 feet deep Fahrenheit | Air Thermometer |
|---|---|---|---|---|
| 1894 | | | | |
| Sept 9 | 13.32 | 12.31 | | 51.28 |
| 16 | 16.44 | 14.63 | | 54.9 |
| 23 | 12.23 | 13.26 | | 52.45 |
| 30 | 15.61 | 15.6 | | 50.11 |
| Octr 7 | 14.54 | 14.5 | | 49.6 |
| 14 | 14.1 | 14.06 | | 52.3 |
| 21 | 13.56 | 13.23 | | 42.05 |
| 28 | 10.7 | 10.73 | | 42.1 |
| Novr 4 | 7.35 | 7.85 | | 50.2 |
| 11 | 7.53 | 8.33 | | 47.54 |
| 18 | 7.16 | 7.1 | | 44.2 |
| 25 | 6.15 | 6.05 | | 44.7 |
| Decr 2 | 6.35 | 6.45 | | 41.4 |
| 9 | 7.34 | 7.4 | | 37.64 |
| 16 | 7.98 | 8.21 | | 46.21 |
| 23 | 6.91 | 6.76 | | 41.28 |
| 30 | 6.1 | 6.2 | | 39.82 |
| 1895 | | | | |
| Jany 6 | 6.28 | 5.21 | | 33.75 |
| 13 | 5.2 | 5.13 | | 28.7 |
| 20 | 5.03 | 5.3 | | 36.02 |
| 27 | 4.2 | 3.97 | | 32.52 |
| Feby 3 | 5.53 | 5.58 | | 30.54 |
| 10 | 12.53 | 6.91 | | 25.31 |
| 17 | 5.8 | 6.67 | | 29.01 |
| 24 | 11.01 | 10.38 | | 34.6 |
| Mar 2 | 9.77 | 9.25 | | 37.55 |
| 9 | 9.7 | 8.42 | | 38.12 |
| 16 | 8.05 | 7.47 | | 41.15 |
| 23 | 4.86 | 3.96 | | 45.74 |
| 30 | 4.07 | 3.31 | | 40.12 |
| Apl 6 | 3.48 | 3.64 | | 40.54 |
| 13 | 6.14 | 5.61 | | 45.12 |
| 20 | 5.74 | 5.61 | | 44.77 |
| 27 | 6.85 | 6.72 | | 50.9 |
| May 4 | 7.51 | 7.43 | | 49.8 |
| 11 | 6.55 | 6.47 | | 54.5 |
| 18 | 6.3 | 6.9 | | 52.02 |
| 25 | 5.2 | 6.02 | | 49.5 |

June /

Data of Chart I. (Contd).

| Date week ending | Estimation of Carbonic Acid - 3 feet deep Morning | Evening | Earth Thermometer 3 feet deep Fahrenheit | Air Thermometer |
|---|---|---|---|---|
| 1895 | | | | |
| June 1 | 6.99 | 6.83 | | 59.74 |
| 8 | 8.65 | 8.71 | | 58.27 |
| 15 | 8.08 | 8.49 | | 53.15 |
| 22 | 8.48 | 9.2 | | 53.37 |
| 29 | 8.32 | 8.87 | | 61.22 |
| July 6 | 9.88 | 10.7 | 54. | 59.01 |
| 13 | 8.915 | 9.6 | 54. | 57.8 |
| 20 | 8.83 | 10.04 | 53.5 | 57.9 |
| 27 | 11.13 | 12.21 | 54.4 | 54.72 |
| Augt 3 | 11.8 | 10.76 | 54.2 | 55.9 |
| 10 | 8.76 | 9.22 | 54.23 | 58.94 |
| 17 | 12.81 | 13.92 | 54.9 | 60.92 |
| 24 | 10.74 | 15.6 | 55.2 | 61.1 |
| 31 | 12.21 | 13.45 | 55.47 | 57.75 |

# DATA of CHART II.

| Date week ending | Estimation of Carbonic Acid - 3 feet deep Morning | Earth Thermometer 3 feet deep Fahrenheit | Air Thermometer Fahrenheit |
|---|---|---|---|
| 1895 | | | |
| Sept 7 | 10.06 | 55. | 58.92 |
| 14 | 10.76 | 55. | 57.84 |
| 21 | 9.8 | 53.9 | 56. |
| 28 | 10.30 | 53. | 61.8 |
| Octr 5 | 10.16 | 52.75 | 50.85 |
| 12 | 11.41 | 51.5 | 48.77 |
| 19 | 7.26 | 49.75 | 45.25 |
| 26 | 4.67 | 48.25 | 39.51 |
| Novr 2 | 5.60 | 45.5 | 39.15 |
| 9 | 5.43 | 43.25 | 44.9 |
| 16 | 4.86 | 43.5 | 44.07 |
| 23 | 4. | 43. | 43.32 |
| 30 | 4.4 | 43. | 42.54 |
| Decr 7 | 3.85 | 42. | 40.25 |
| 14 | 3.29 | 41. | 38.17 |
| 21 | 4.13 | 40.5 | 36.4 |
| 28 | 3.58 | 40. | 34.35 |
| 1896 | | | |
| Jany 4 | 4.02 | 39. | 43.85 |
| 11 | 4.43 | 40. | 38.72 |
| 18 | 3.64 | 39.5 | 40.8 |
| 25 | 3.47 | 39. | 39.9 |
| Feby 1 | 3.63 | 40. | 43.08 |
| 8 | 4.31 | 41.13 | 44.71 |
| 15 | 3.97 | 43.1 | 46.45 |
| 22 | 4.05 | 44. | 41.47 |
| 29 | 4.43 | 40.73 | 36.81 |
| Mar 7 | 3.43 | 39.8 | 40.3 |
| 14 | 3.205 | 41.15 | 41.15 |
| 21 | 3.75 | 41. | 43.37 |
| 28 | 4.05 | 41.5 | 43.87 |
| Apl 4 | 4.57 | 41.3 | 45.65 |
| 11 | 5.03 | 43.5 | 49.85 |
| 18 | 6.05 | 44. | 44.61 |
| 25 | 4.83 | 44.65 | 53.02 |
| May 2 | 5.76 | 46. | 47.85 |
| 9 | 6.38 | 47.1 | 53.4 |
| 16 | 4.90 | 49.2 | 56.61 |
| 23 | 3.85 | 50. | 54.6 |
| 30 | 3.19 | 51.2 | 56.77 |

June /

DATA of CHART II. (Contd).

| Date week ending | Estimation of Carbonic Acid - 3 feet deep Morning | Earth Thermometer 3 feet deep Fahrenheit | Air Thermometer Fahrenheit |
|---|---|---|---|
| 1896 | | | |
| June 6 | 6.15 | - | 52.88 |
| 13 | 4.14 | 53. | 60.57 |
| 20 | 5.57 | - | 60.48 |
| 27 | 6.34 | 54. | 57.92 |
| July 4 | 7.006 | 54.5 | 56.71 |
| 11 | 9.18 | 54.5 | 58.77 |
| 18 | 8.97 | 54.7 | 61.05 |
| 25 | 8.54 | 56.6 | 58.84 |
| Augt 1 | 10.23 | 55. | 56.9 |
| 8 | 12.85 | 55.1 | 56.2 |
| 15 | 14.26 | 54.8 | 57.75 |
| 22 | 14.47 | 54.9 | 57.05 |
| 29 | 14.31 | 54.6 | 56.14 |

# DATA of CHART III.

| Date week ending | Estimation of Carbonic Acid - 3 feet deep Morning | Earth Thermometer 3 feet deep Fahrenheit | Air Thermometer |
|---|---|---|---|
| 1896 | | | |
| Sept 5 | 8.70 | 53.9 | 57. |
| 12 | 9.42 | 52.5 | 55.62 |
| 19 | 9.65 | 53.3 | 54.12 |
| 26 | 7.61 | 51.4 | 48.81 |
| Octr 3 | 4.65 | 50. | 52.72 |
| 10 | 8.15 | 49. | 45.31 |
| 17 | 6.95 | 47.3 | 43.14 |
| 24 | 4.80 | 45.4 | 40.12 |
| 31 | 4.27 | 42.3 | 39.31 |
| Novr 7 | 3. | 42.2 | 40.11 |
| 14 | 2.7 | 42. | 43.41 |
| 21 | 2.05 | 43. | 41.85 |
| 28 | 4.90 | 43. | 44.64 |
| Decr 5 | 4.15 | 42.4 | 38.51 |
| 12 | 2.05 | 41.8 | 40.94 |
| 19 | 3.50 | 39.7 | 34.32 |
| 26 | 2.05 | 38.8 | 37.84 |
| 1897 | | | |
| Jany 2 | 2.15 | 39.2 | 42.27 |
| 9 | 2.20 | 39. | 39.37 |
| 16 | 1.05 | 37.1 | 34.32 |
| 23 | 1.25 | 36.2 | 33.2 |
| 30 | 0.85 | 35.5 | 31.27 |
| Feby 6 | 0.25 | 36. | 34.62 |
| 13 | | | 38.12 |
| 20 | | 36.6 | 45.24 |
| 27 | | | 46.52 |
| Mch 6 | | | 38.87 |
| 13 | | 37.2 | 40.37 |
| 20 | | 38.4 | 41.58 |
| 27 | | 38.8 | 49.37 |
| Apl 3 | | 39.4 | 35.24 |
| 10 | | 40. | 39.9 |
| 17 | | 39.7 | 44.6 |
| 24 | | 40. | 43.64 |
| May 1 | | 42.6 | 46.02 |
| 8 | | 44. | 45.5 |
| 15 | | 44. | 46.9 |
| 22 | | 47.4 | 49.9 |
| 27 | | 47.8 | 48.15 |

June /

Data of Chart III. (Contd).

| Date week ending | Estimation of Carbonic Acid - 3 feet deep | Earth Thermometer 3 feet deep Fahrenheit | Air Thermometer |
|---|---|---|---|
| 1897 | | | |
| June 5 | 4.30 | 49.2 | 54.37 |
| 12 | 4.20 | 50.4 | 52.08 |
| 19 | 4.75 | 51.5 | 52.07 |
| 26 | 5.8 | 52.2 | 56.74 |
| July 3 | 4.35 | 53.2 | 57.9 |
| 10 | 4.32 | 53.1 | 55.18 |
| 17 | 4.32 | 53.4 | 60. |
| 24 | 6.17 | 55.4 | 60.2 |
| 31 | 6.62 | 55.8 | 61.45 |
| Augt 7 | 4.70 | 56.1 | 65. |
| 14 | 5.75 | 56. | 60.5 |
| 21 | 6.58 | 56. | 58.75 |
| 28 | 10.05 | 55.7 | 58.4 |

Chart I. Showing weekly average of the morning and of the evening determinations of carbonic acid in the ground air at the depth of three feet from the surface from september 1894 to September 1895, expressed in cubic centimeters per litre and also the weekly mean temperature of the atmosphere and of the soil at a depth of three feet.

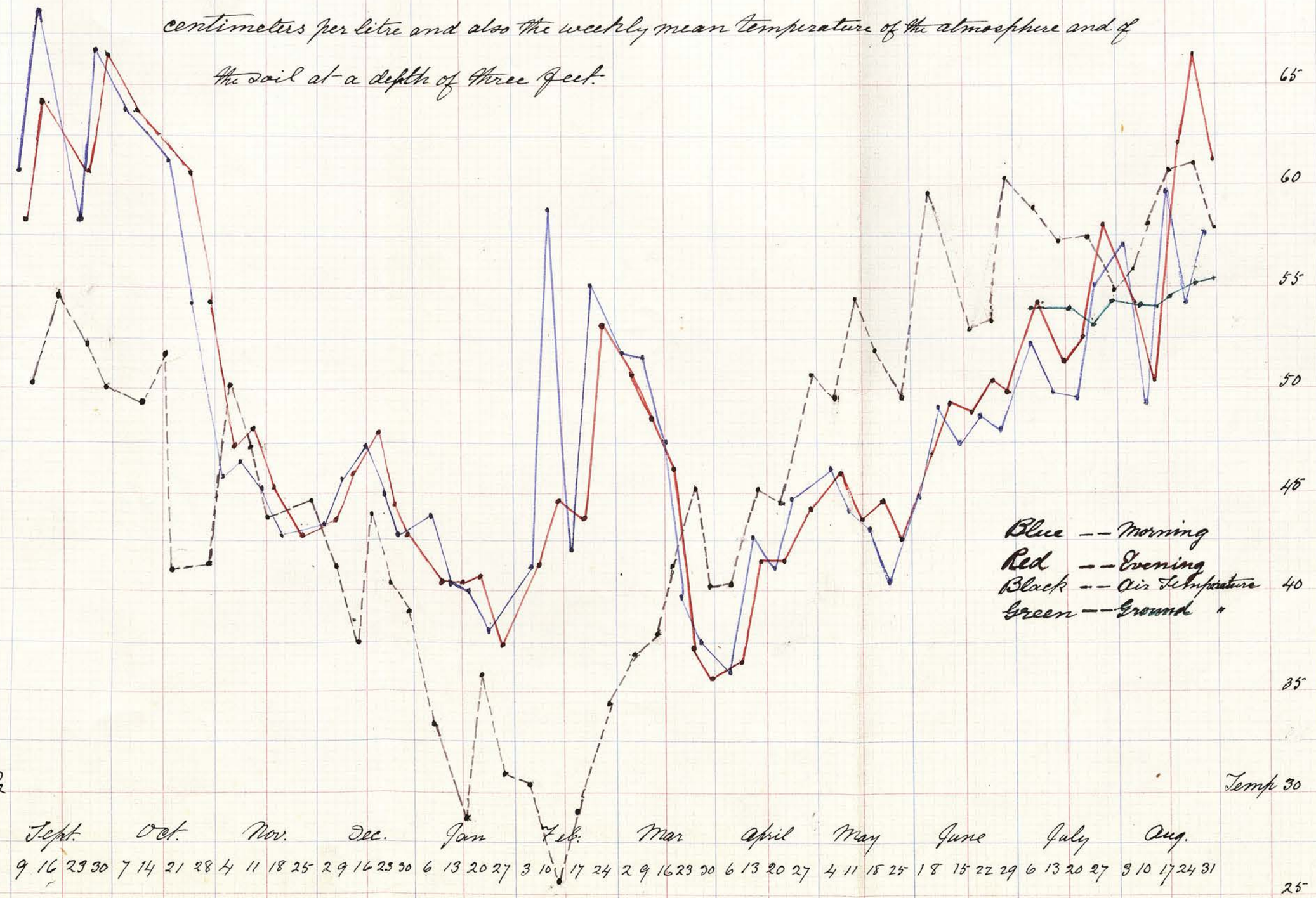
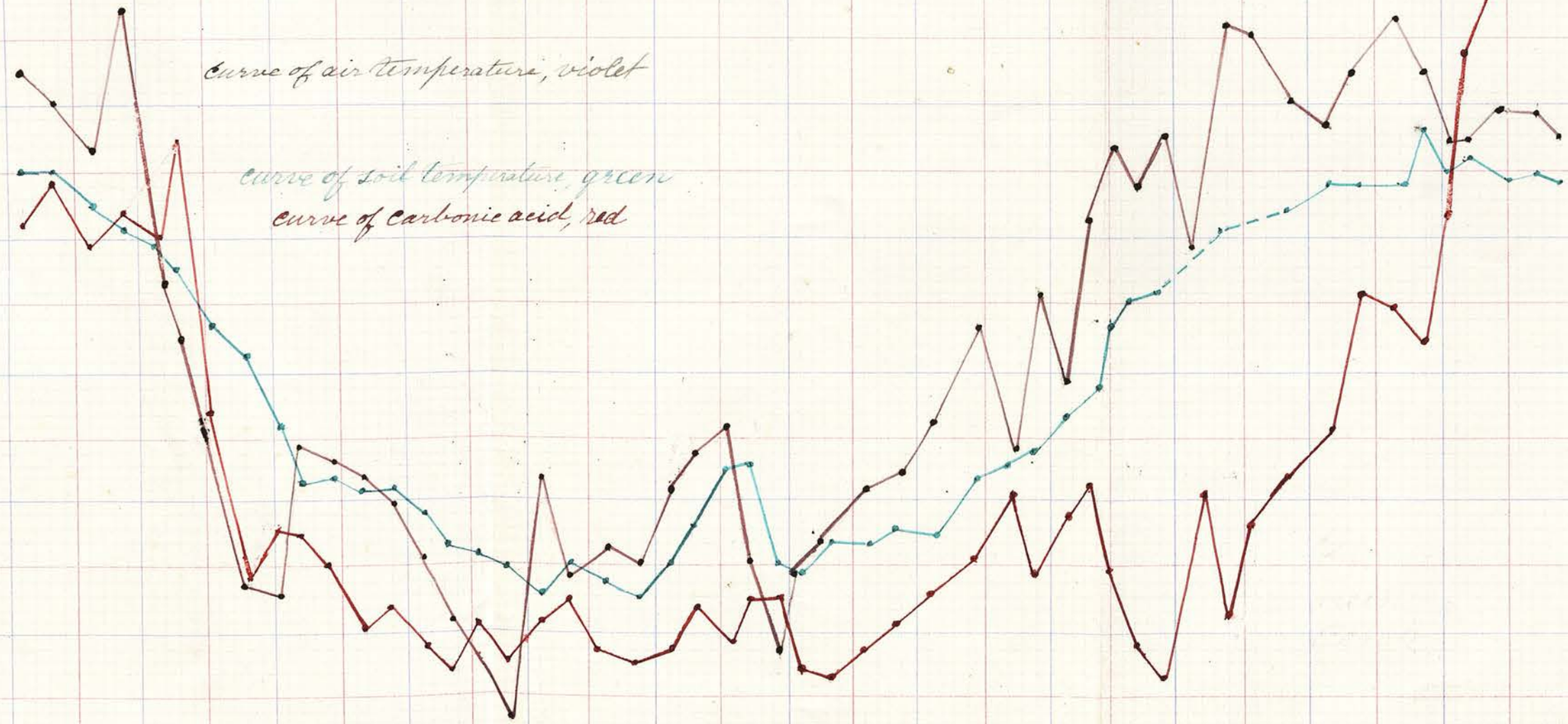


Chart II Showing the weekly average of the morning determinations of carbonic acid in the ground air at the depth of three feet from the surface from September 1895 to September 1896 expressed in cubic centimetres per litre and also the weekly mean temperature of the atmosphere and of the ground at the depth of three feet.




C.C.s / $CO_2$

17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2

70 65 60 55 50 45 40 35 30 25

Temp Fahr.

Week ending

Sept. 7 14 21 28 | Oct. 5 12 19 26 | Nov. 2 9 16 23 30 | Dec. 7 14 28 28 | Jan 4 11 18 25 | Feby 1 8 15 22 29 | Mar 7 14 21 28 | April 4 11 18 25 | May 2 9 16 23 30 | June 6 13 20 27 | July 4 11 18 25 | Aug. 1 8 15 22 29

Chart III Showing the weekly average of the morning determinations of Carbonic acid in the ground air at the depth of three feet from the surface from September 1896 to September 1897 expressed in cubic centimetres per litre and also the weekly mean temperature of the atmosphere and of the soil at the depth three feet.