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CONTENTS.

AN INVESTIGATION INTO THE EFFECTS OF WATER AND AQUEOUS SOLUTIONS OF SOME OF THE COMMON INORGANIC* SUBSTANCES ON FOLIAGE LEAVES.

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(Read 4th May, 1901.)

CONTENTS.

* The inorganic substances referred to include some of the strong acids, a few alkalies, and some of the more common mineral salts.

INTRODUCTION.

SINCE so many questions, relating more or less directly to the main one, are involved in the progress of the proper discussion of the chief subject, and since the field is so very broad, it became necessary to select from the very large number of experiments involved, those which seemed to tend more directly towards a full development of the subject. As the main question is an investigation into the effect of certain solutions of inorganic salts upon foliage leaves, and, as the intelligent answer to this question depends so largely upon the capability of leaves to absorb water and the more dilute solutions, *e.g.*, rain water, soil water and spring water, it was found necessary to investigate the matter of the absorption of water and aqueous vapour by leaves. This naturally led to a consideration of the atmospheric conditions which might, through time, give rise by adaptation to certain qualities which leaves may have acquired through ages past. Enquiry was made at the Weather Bureau at Washington, to learn to what extent inorganic salts were known to pervade the atmosphere, either in the neighbourhood of the sea or inland, but it was found that, so far as America was concerned, no work of any importance had up to the present been done. The investigations made in Europe were too general in character to apply directly to the subject under discussion. This made it necessary to investigate the matter experimentally, and a series of experiments was performed to ascertain if the salts of the sea did permeate the atmosphere without the aid of spray or winds. These experiments are described in detail further on.

Investigation was also made into the question suggested by a statement of Sachs, that distilled water which remains upon a leaf of a plant becomes alkaline.

Plants adapted to a moist climate were selected and arranged as shown in Fig. 7, the roots being supplied with nothing but distilled sterilized water and air, while the leaves were fed with a nutrient solution furnished by means of an intermittent spray. Composition of the nutrient solution:—H_2O, 1000.0 grams; KNO_3 1.0 grams; $MgSO_4$ .5 grams; $CaSO_4$ .5 grams; K_3PO_4 .5 grams; $FeSO_4$ .01 grams. The object of this experiment was to determine whether a plant could *use* a nutrient solution so applied. On account of the long duration of the experiments, the solution had to be changed from time to time.

To learn from another point of view how a nutrient solution affects the early growth of young leaves developing from the bud, a series of experiments was performed with young willow twigs, during the months of March and April, this being the time of the year when the process of the opening of buds seems to depend only upon a favourable temperature. This experiment was designed also to test water absorption by young leaves.

The solutions (other than nutrients) used in the experimental work in connection with this paper were made by dissolving the molecular weight, in grams of the substance, in a liter of water. This method of preparation is similar to that indicated by Pfeffer* (Ewart's Trans. 1900, p. 146), and by Detmer and Moor (p. 326), who designate them *normal solutions*. This method is also that adopted by True (1898, p. 410-411) and (1900, p. 185). These, however, are not *normal solutions* as defined by Mohr† and other analytical chemists. When salts contained water of crystallization, or hygroscopic water, it was found more convenient to determine the specific gravity of the solution and from this calculate its concentration. A convenient apparatus for finding the specific gravity of a solution was arranged; and as such apparatus may be of some use in a laboratory of plant physiology, a full description with diagram is given (Fig. 1). The stock solution once obtained, there was no difficulty in preparing solutions of less concentration as occasion required. The solutions of hydrochloric and of sulphuric acids were *normal solutions*, as were those of potassium and of sodium hydrate. These were procured ready prepared from the chemical supply house.

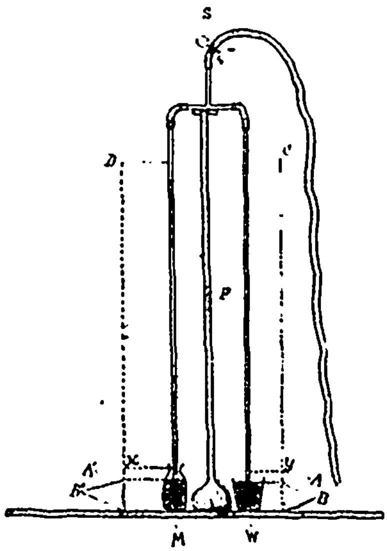

FIG. 1.

Two small glass tubes, held in a vertical position by the support P, are finely graduated and connected by a "T" tube to the leg of which is attached a rubber tube. One of the tubes is inserted in distilled water at the temperature required, the other in the liquid to be measured. The stop-cock S is opened and the ascent of liquid due to capillarity, A and A', measured. Then by sucking on the rubber tube the liquids rise to D, etc. Now the sp.g. of M is $\frac{Cy}{Dx}$.

* See bibliography at the end.

† Titrimethode, p. 56.

Both kinds of solutions, since they differ so little when in dilute form, are designated in this paper, "*m*"; and the dilution is indicated by a number written as the denominator of a fraction.

Since so much seemed to depend upon the question of water-absorption by leaves, a rather full discussion is entered into, more particularly upon the literature pertaining to this subject, in order to establish upon what grounds present views of plant physiologists are based. Some experiments were made to test water-absorption directly, but it was found that more light could be thrown upon the subject from other sources. It was from the indirect side mainly that the question was attacked, as it seemed, in the judgment of the writer, to be more productive of fruitful results; so the question of guttation drops, dew-drops, and calcareous incrustations upon certain plants, was examined in some detail with a view to learn something of their cause, chemical nature and function.

For the examination into the effects of solutions applied to the cut ends of the petioles, leaves were selected which would readily show an acid or an alkaline reaction, and which would live for a considerable time in water without sending out roots. It was not so much to determine how long leaves could endure the solution and live, as to examine into the effects produced by the solutions so applied, and to learn something of the cause of death. The same is true with regard to the application of the solutions to leaf surfaces; and a comparison is made of the effects of some of these upon Spirogyra, with that upon leaves.

On commencing the work of experimentation, and upon examining into the literature pertaining to the subject, it was found that the question first to be answered was in regard to whether living green foliage leaves absorb water through the epidermis, or through the stomata, in some way or other, from the surrounding medium, either as liquid or as vapour. The popular notion is that water is so absorbed, but the view expressed by many of the recent text-books on botany is quite generally opposed to this. Some writers have "proved" experimentally that water could be absorbed, while others apparently equally reliable "proved" the opposite. This condition of affairs rendered it necessary to examine the question in detail by careful and prolonged experiment, and to study with considerable care, the literature which pertains directly and indirectly to this subject. That water-absorption is the very "corner-stone" of the problem is at once apparent, because all the solutions used are aqueous, and many of them are in very dilute form. Plants under experimentation are always regarded as *living* plants—not simply as so much tissue—and from this point of view the phenomena are chiefly considered.

In order to clear the way to the main issue it was found necessary to investigate certain questions which at first sight may appear not directly a part of the subject; but it is only through these subordinate and relative questions that we are able intelligently to explain, with any degree of exactitude, the various elements, as connected with, and forming a part of the whole general subject which is a unit. It is recognized to be of importance that one who undertakes a problem should confine himself strictly to that problem; but it is of greater importance that one should, while confining himself within the limits of his problem, understand and explain not only the details relative to it, but the relationship of that problem, if solved, to scientific knowledge already obtained. In other words he must be able to assimilate his results with the laws of science. This is mentioned in order that it may be fully understood at the outset that the question has branched out into directions not contemplated at the commencement.

The "spotting" of the tobacco leaf is dealt with in some detail because of its economic importance, it being a particular aspect of the question involved under the heading:—"The effects of solutions applied to leaf surfaces."

II.—HISTORICAL RÉSUMÉ.

As has just been said in the introduction, the question of water-absorption by leaves, being so important a part of the general subject, and having been dealt with by several writers (some as early as the middle of the 17th century), will have a prominent place in this chapter, not only because of its importance of itself, but also because it is the only side of the problem that has been investigated to any considerable extent, though unfortunately with results that seem never to have settled the question. The subject of the absorption of dilute solutions by leaves, being so closely related to that of water-absorption, would be in a similar position to-day, were it not that attention has been turned in this direction by the practice of spraying plants, subject to fungous diseases, with solutions known as fungicides; and of killing of weeds by means of a spray of a poisonous solution.

The first author of any note was Mariotte (1679, p. 133), who showed by experiments that living foliage leaves could absorb water both as rain and as dew. His work was important, and he has been quoted by many, especially by the earlier writers, possibly in part because of his careful and close reasoning coupled with his rather unique experiments. After Mariotte the records of work done in this connection are fragmentary and scattered, and it was not till about fifty years later, when the experiments of Stephen Hales (1726, p. 56) were published, that a new impetus was given to the subject. In 1753 Bonnet (1754, p. 26) made some important investigations relative to water absorption and came to the same general conclusions as did Mariotte and Hales, namely, that water was absorbed by leaves with evident advantage to plants, and that water-absorption was a normal function of leaves. Senebier in his text (1800, 3, p. 94) refers to the works of Bonnet and Hales, and, after reviewing some of their experiments, concludes that water is aborbed. In the work of Dutrochet (1837, p. 328), one finds the idea that water is absorbed somewhat extended, and as Dutrochet puts it—"Physiologistes ont consideré les feuilles comme des sortes de racine aériennes destinées à puiser dans l'atmosphère l'eau et les autres principes qui contribuent à la nutrition du végétal." This view seems rather too strong on the side of water-absorption when one examines the works of the earlier writers whom he quotes, and upon whose works he very largely bases his statements.

All the works just mentioned are now looked upon as classic, and the names will be remembered as long as plant physiology is deemed a subject worthy of investigation. These works form a sort of epoch, not only in matter of time, but also in views and conclusions; and one is struck by the singular similarity in aims and argument among those authors.

In the botanical works of Treviranus (Vol. I., 1835), we find that the views upon the question are opposed in part to that of the authors just mentioned, especially to that of Bonnet and Hales; and his work introduces a side of the question which has stood its ground up to the present time. That a function of foliage leaves was to absorb water and dew, had up to this time been looked upon as established, not so much because of the works and views of Mariotte, Hales, Bonnet, Senebier and Dutrochet were accepted as proving so much, but rather because the view was according to the popular notion and seemed self-evident. The experiments of Treviranus, and of others of less note, about the same time, raised some startling questions in regard to the then recognized power of leaves to absorb, and it would be well to give the words of Treviranus—"Man muss daher wie ich glaube eine Einsaugung von tropfbarer Flüssigkeit durch Blätter nur da zulassen, wo entweder die Oberhaut fehlt oder, wie bei, unausgebildeten und ueberhaupt bei zarten Blättern sehr dünn ist." . . . . . . "Nur Dunst wird eingesogen."

Two rather important papers by Garreau (1849, 1851) appeared later, the first of which dealt with this question of water-absorption. Garreau goes into the matter thoroughly and examines this question from the standpoint of anatomy, as well as that of physiology, and concludes that water can be absorbed. One ought to draw attention to the fact that *do* absorb and *can* absorb are two different things a point which will be discussed in the chapter dealing with water-absorption.

Hugo von Mohl (1852) gives but little attention to the subject, but states in a somewhat general way that water-vapour is absorbed. It is important to notice that the view here expressed by von Mohl was a cautious one, and that it was now considered by no means certain that water-absorption was a function of leaves. Then came the work of Duchartre (1861, p.109), whom one might call the founder of the position taken by writers of modern text books in regard to absorption of water by leaves. One finds Duchartre's work almost always referred to, while the works of several others of no less importance seemingly ignored. One reason probably for this is that Duchartre had performed his experiments with growing plants; while most of those holding opposite views had based their conclusions upon experiments with detached leaves and cut shoots. Moreover, Duchartre held that the moistening of a leaf surface by rain or dew only caused a diminished transpiration, which resulted in an increase of turgor; and stated also that as transpiration was a normal function of leaves it was not easy to see how absorption could also be a normal function at the same time.

Important special papers upon the subject then began to appear, notably that of Cailletet (1872, p. 242), who showed by means of a manometer that water was readily absorbed under certain conditions: and Boehm (1877) who placed leaves (not detached) of seedlings under such conditions in which it was possible for them to absorb water to advantage when, under like conditions, the roots were unable to do so. The works of Mer (1878, p. 105) and Boussingault (1878, p. 289) corroborated those of Cailletet and Boehm. The work of Henslow

(1880, p. 313) was exhaustive, and he thought he had settled the question of water-absorption; and, as he says, he thought he had settled it in the affirmative. Lindley in his early work (1866, p. 193) referring to stomata, says:—"It is by means of this apparatus that leaves absorb water and gaseous matter from the atmosphere." In Lindley's "Theory of Horticulture," (1859), the belief is expressed that leaves do absorb fluid from the air; and it is stated that the stomata are well adapted to this purpose. Lindley refers at some length to the work of Knight (1886), in which it is stated that leaves may absorb to the extent that a descent of sap is produced in the alburnum, and also that one leaf may be made to supply its neighbour below it with water. Gregory (1886) proved that leaf hairs of many plants contributed actively to the supply of water in the plant.

Since this time but little work of importance has been done, though the question seems farther from being settled now than it was a hundred years ago. Of the later works on the subject, two of them are deserving of mention,—Burt (1893), and Ganong (1894, p. 136). The former concluded that leaves and cut shoots may absorb water, while the latter concluded that leaves do not function as water absorbers to an extent sufficiently great to be worthy of note.

As to the text books on botany and on plant physiology, other than those mentioned, commencing with Pfeffer, one finds that the positions taken, though varied to some extent, are generally and rather uniformly on the side of non-absorption; at least one might say, judging from the attention paid to the matter, it was considered of little or no physiological importance. It is interesting to notice further that of those works, such as Pfeffer (1881) and Detmer (1883), that have been recently revised, there is little modification of the view rather cautiously expressed in the early editions; and, with a proviso or two, practically the same stand is taken in the latest editions as in the first. This is as might be expected, for no work of any importance had been done in this line in the meantime. Sachs, in his "Plant Physiology" (1887) takes the ground that the question has not been at all satisfactorily settled. In Goodale's Physiology almost no attention is given to the matter. Van Tieghem (1884) states that water vapour is readily absorbed by the plant. Vines (1886) gives some attention to the subject, but leaves one to *infer* rather than to *read* his conclusions. He admits that under peculiar circumstances water and dilute solutions may be absorbed, but holds generally to the idea that this, if it be a function at all, is of but little consequence. In both works of Pfeffer scant attention is given the subject, and it is plain that Pfeffer had little, if any, experimental knowledge concerning it, though he cites some of the more important works relating thereto. In the work of Detmer (1883, p. 112) is discussed to some extent the question, with the conclusion, that if the tissue of the leaves is fully turgescent, then there will be no absorption, but if not turgescent, then they are capable of taking in water which may be in contact with the leaf surface. Sorauer (1895, p. 32) states that it is only in cases of extreme dryness that plants are able to make use of the heavy deposits of dew. The view expressed by Haberlandt (1896) is worthy of special notice because he goes into the matter more fully, and because his views stand out somewhat prominently in contrast to those expressed in almost all the other modern text books. He has no doubt whatever that foliage leaves can, and do, absorb water to the advantage of the plant, and he mentions some plants whose leaves function regularly as water-absorbers. In the work of Detmer and Moor (1893) we have the view rather cautiously expressed:—"The question of water-absorption by leaves is not of great physiological interest,"—and but a very few lines are devoted to the subject. In Macdougall's work (1898) it is stated that leaves do not absorb water. Very little is said concerning the question in Strasburger (1900), excepting that in some peculiar cases, as in that of scaly hairs, water may be absorbed. In a recent text book on Plant Physiology, that of Belzung (1900) the question is discussed with the conclusion that water is absorbed as dew, and may be absorbed under other peculiar circumstances.

From this brief summary it may be seen that the subject has had a rather peculiar history, and one which is not without interest from the standpoint of physiology as well as that of economic botany.

The question of the absorption by leaves of solutions introduces a new element into the discussion: and until quite recently very few experiments of importance relating to the subject have been performed. Whatever work has been done has been from the side of the injurious effects of solutions causing poisoning of the leaves, and even of the whole plant. Boitard (1829) noted that if mist contained saline matter it was injurious to plants; but no work relating to the question, so far as can be learned, was done until 1872, when R. Angus Smith (1872) was appointed to look into the effect produced upon vegetation in the neighbourhood of chemical works in England. That the fumes from these chemical works did affect the plants injuriously was readily seen, but whether it acted directly upon the leaves or upon the roots was a disputed question. Smith showed pretty clearly that the leaves were affected directly. Schlossing (1874, p. 1700), and Mayer (1874) showed that solutions of ammonium carbonate were absorbed by leaves; and Schlossing showed that the ammonia thus absorbed increased the growth of the plant. Boussingault (1878) showed that calcium sulphate, potassium phosphate and potassium nitrate may be absorbed by leaves of plants. There is no mention made by Boussingault as to how these substances affected the tissue of the leaf, or whether they proved of advantage or of disadvantage to the leaf of the plant as a living organ or organism.

Cuboni sprayed leaves with lime, and concluded that it increased the growth, if not by the absorption of the solution of lime, then by a stimulation. In Sachs' Lehrbuch reference is made to the work of Boussingault, and Sachs further states that the absorption may be proved by using a soluble lithium salt, then using the flame test to determine the extent of the absorption. Oliver (1893), after investigating the effects of urban fog upon vegetation, showed that certain acid vapours and other substances affected the leaves, injuring the chlorophyll. About this time investigations were made into the effects of the bordeaux mixture (other than as a fungicide) upon plants. Prominent among these investigators were Zimmerman (1893, p. 307), Rumm (1894, p. 445), Galloway (1895), Frank and Krüger (1894, p. 8), and Aderhold (1893). Aderhold concluded that the increase in growth was due to the lime of the bordeaux mixture being absorbed by the roots. Frank and Krüger held that it acted as a stimulus, as did also Rumm, while Zimmerman opposed this view maintaining that the solutions were absorbed directly by the leaves.

It has recently been observed that the application of ether vapour to foliage leaves stimulates the plant to a more rapid development, and horticulturists have taken advantage of this to force plants for the market (Fisher, 1900, p. 283-284). This shows rather clearly that chemical substances applied to the leaves of plants may be made to promote growth as well as to injure the plants. In the work of Lawes and Gilbert (1883), it is shown that certain substances in the air, especially in the neighbourhood of towns and cities, at times, affect injuriously the foliage of plants. Some investigations with this end in view, were recently carried on by Wieler and Hartleb (1900, p. 188) with a view to learn the effects of HCl upon the assimilation of plants.

The question of the destruction of weeds by poisonous chemical substances, has quite recently become a prominent one with experiment stations, and this question has thrown much light upon the subject directly under discussion; for it has been shown that certain poisonous solutions may kill some plants and actually promote growth in others. Some experiments have been performed with this end in view,—notably Wales (1900), Foulkes (1897) and Bollery (1899). The object of these investigators was to find a solution which when sprayed on the leaves of a grain crop, would kill the weeds and not injure the grain. The weed most troublesome was *Brassica sinapistrum* which occurs so commonly in grain fields. They found that a 2 solution of $CuSO_4$ would kill the mustard and, not only not injure the wheat or oats, but actually increase the yield at harvest. Other experiments have been performed within the past year, both at Ottawa, Ont., and Guelph, Ont., as well as in England and France, with similar results to those obtained by the authors just mentioned.

The matter of the destruction of weeds in gravel walks and waste places is not so important, though some work has been attempted with this end in view. Jones and Orton (1899) used several substances such as NaCl, $CuSO_4$, arsenic, kerosene, carbolic acid, etc., and found carbolic acid and sodium arsenate the best. Superphosphates were found by Mazières (1899, p. 851) to be very effective in killing some Cruciferous plants, while ammonium sulphate and other salts were tried with varying results.

It will be seen at a glance that this physiological problem is being pressed forward from its economic, rather than from its scientific side; and that it is only within the last few years that attention has been drawn to the fact that an increase in growth resulted in some cases from the application to leaf surfaces of substances in solution. There are many experiments, if the records are trustworthy, which prove beyond a doubt that a spray of certain solutions may increase the growth of plants; but there are several views as to the real cause of the increase—(1) it may act as a stimulus pure and simple—(2) it may act upon the soil and through this upon the roots—(3) it may be absorbed as food by the leaves. The experiments described in this paper aim at answering this question.

III.—ABSORPTION OF WATER BY FOLIAGE LEAVES.

THE experiments relating to this subject were designed to determine whether detached leaves and cut shoots could absorb water. Four series of experiments were arranged. For the first series the leaves were collected on June 6th, at 4 p.m., and *allowed to wilt until 9.30* a.m., June 7th, when some of them were placed in distilled water and left immersed for twenty-four hours. The others were similarly immersed six hours after the first, and left for eighteen hours (Fig. 2). The second series of experiments was *with cut shoots*, and was conducted similarly to the first, excepting that no weighings were made. The third was to test absorption by the petiole. The fourth series was designed to test by *measurement* the amount *of water absorbed by a leaf under* conditions such as are shown in Fig. 4.

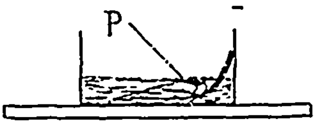

FIG. 2.
Leaf immersed in water. P, a strip of litmus paper.

Immediately after the leaves (series I. and II.) were immersed, a small strip each, of red and of blue litmus paper was laid on each leaf at a point where part of the leaf was close to the surface of the water (Fig. 2). This was to determine if acids or alkaline substances left the leaf tissue to enter the surrounding water, for if such substances did so, it was not unreasonable to suppose that this indicated that the water from the vessel had entered the tissue of the leaf according to the laws of diffusion.

The question of the passage of neutral salts through the epidermal tissue under similar conditions is discussed in Chapters IV. and V.

It is thought that the weighing of the leaves before and after immersion would not of itself decide the question, because it is impossible to know that the leaves are externally in the same condition as when weighed previous to immersion; and, moreover, as the leaves are constantly changing in weight by losing water by evaporation, very accurate quantitative results are not easy to obtain. Since substances are extracted from leaves by the application of distilled water (Chapters IV. and V.), account of this must be taken in the weighings.

In order to bring out more prominently the results it was thought well to use a scale of numbers—12 . . . . 0, the number 10 indicating complete restoration of normal turgidity, and 0 indicating no restoration, and therefore no absorption. The other numbers represent grades of restoration, twelve being greater than normal in the plant, two things being taken into consideration in grading the leaves—(1) the increase or decrease in weight, (2) the visible rigidity.

EXPERIMENTS TO TEST WATER ABSORPTION BY DETACHED LEAVES.

EXPER. I.; TIME ABSORBING 24 HOURS.

Leaf.	Reaction.	Turgescence grade by No.	Reaction of water after stirring.	Is water in intercellular spaces?
Napaea	acid	10	acid	no
Rosa acicularis	acid	3	acid	no
Echinops	neut.	12	neut.	no
Polygonum	acid	5	acid	no
Dicentra	neut.	12	acid	no
Clematis	acid very	10*	acid	no
Plantago	alkal.	0	alkal.	no
Silphium	alk., very	10	alk., slightly	some
Inula	neut.	10	sl., acid	no
Potentilla	neut.	7	acid	some
Nasturtium	neut.	10	acid	no†
Thermopsis	neut.	8	acid	no†
Hydrophyllum	neut.	10	acid	no
Geranium	neut.	10	acid	no
Onopordon	neut.	10	acid	no
Aesculus	alkal.	10	neut.	no
Funkia	acid	7	acid	no
Viola	alkal.	6	acid	some
Helianthus	alkal.	9	acid	no
Rudbeckia	alkal.	9	acid	no
Serratula	alkal.	9	acid	no
Tilia	neut.	8	sl., acid	considerable
Poterium	acid	10	acid	no
Silphium	alkal.	10	neut.	no
Xanthorrhiza	alkal.	8	acid	no

EXPER. II.; TIME ABSORBING 18 HOURS.

Zizia	acid	9	acid	no
Saxifraga	acid	9	acid	no
Quercus	acid	5	acid	some
Convallaria	acid	9	acid	no
Epidendrum	neut.	10	neut.	no
Acer	neut.	8	neut.	no

* Branch with six leaves more turgid than either of the two separate ones.

† The cut end of the petiole had dipped under the surface of the water.

EXPERIMENT TO TEST WATER ABSORPTION BY DETACHED LEAVES BY USING THE BALANCE TO DETERMINE THE INCREASE IN AMOUNT.

EXPER. IA.: TIME ABSORBING 24 HOURS.

Leaf.	Weight in grams.	
	Weight Wilted.	Weight after Immersion.
Napaea..........	.8632	.9821
Rosa.............	.634	.6372
Echinops........	.512	.711
Polygonum.......	.6501	.698
Dicentra......	.3213	.4381
Clematis......	.6318	.7316
Plantago.........	1.9316	1.930(loss)
Silphium.	3.218	3.9311
Inula.	6.8321	7.1214
Potentilla	.3019	.3022
Nasturtium	.9870	1.0830
Thermopsis.......	.3216	.3321
Hydrophyllum	.5025	.5834
Geranium.........	1.1230	1.0624
Onopordon..	2.1123	2.9106
Aesculus.... ...	5 2314	7.1216
Funkia...........	.3101	.3233
Viola........	.7123	.7864
Helianthus.	.8916	.9126
Rudbeckia........	.7328	.8611
Serratula	.8102	.9386
Tilia	1.6381	2.1111
Poterium	.7216	.8014
Silphium....... ..	1.1236	1.2116
Xanthorriza.. .	1.5128	1.5812

EXPER. IIA.: TIME ABSORBING 18 HOURS.

Leaf.	Weight in grams.	
	Weight Wilted.	Weight after Immersion.
Zizia.......	.5138	.5812
Saxifraga.	1.213	1.7126
Quercus	1.3261	1.8120
Convallaria. . ..	1.1206	2.101
Epidendrum	.8162	.9613
Acer	1.2136	1.3026

From these experiments there is little room for doubt that the leaves had absorbed water, which resulted in a renewal of turgor, to a greater or less extent, and which produced a substantial increase in weight. Before weighing the leaves—upon taking them from the water,—they were dried between sheets of absorbent paper for a couple of minutes, but, as was said before, it was difficult to know just when the surface water was dried off, and in some cases this was evident in the abnormal increase in weight. Experiments with cut branches were arranged in a similar manner, and the results recorded show a condition similar to that recorded in the table given above, but no weighings were made for two reasons, (1) the branches being large and cumbersome could not be weighed with a fine and delicate balance, and if weighed with an ordinary pulp balance, accurate results could not be expected; (2) if turgor be restored wholly or in part, this can easily be recognized by the general appearance, especially so in the case of cut shoots.

Branches of the following plants were tested:—Rosa, Polygonum, Clematis, Potentilla, Zizia, Acer, Dicentra, Hydrophyllum, Quercus and Tilia; and as the results were practically the same as those given concerning single leaves, it was deemed unnecessary to give a record of the special observations. In all cases care was taken to have the cut end of the shoot *not* immersed in the water. It is clear that, had the cut end of the shoot touched the surface of the water, or dipped below it, the value of the experiment would have been destroyed.

The water in which these leaves were immersed was found to have acquired some substances from the tissue of the leaves, as shown by the litmus indicator. Since leaves lose substance to the surrounding water, weighing of the leaf alone will not determine increase due to absorption of water. It was partly because of this fact that the weighings were correlated with other phenomena in estimating the grade given in column three. The restoration of turgor in cut shoots was more readily determined because the smaller branches, the petioles, as well as the blades of the leaves, aided in making comparisons. These results as tabulated are corroborated by Cailletet, Boussingault and Henslow, who used slightly different methods.

Duchartre opposed these views by saying that leaves and cut shoots do not function as living plants, and that they may be compared to the detached limb of an animal. It is not difficult to see, that for purposes of comparison, there is little similarity. His chief experiments were performed with plants in flower-pots, and in consequence he had to use a coarse balance for making his weighings.

He gives these records:—

Weight of plant in evening........	1730.6	grams.
Weight next morning (six o'clock)...........	1733.2	"
Weight after wiping leaves.	1730.8	"
Weight of plant in evening....	1677	"
Weight next morning (six o'clock)...........	1679.4	"
Weight next morning (nine o'clock)..................	1677	"

One can see that the weighings could not have been very accurate, and the differences given prove little or nothing either way, as they are scarcely beyond the margin of error in using coarse balances as indicated by those figures. When one examines Duchartre's work, he is more and more struck with surprise at the prominence given to it, in face of the work done by such men as Cailletet, Boehm, Henslow and others. It is not so much an examination into the writings of these men, as it is a study of their experiments, that carries conviction.

In order to supplement the experiments to demonstrate the capability of leaves to absorb water, an apparatus was arranged somewhat after the method of Bonnet (Fig. 3). Leaves with petioles of considerable length were selected and placed with the petioles in the form of a "U" dipping into a vessel of water. The blades and the cut ends were exposed to the air. Leaves placed under these conditions remained green and turgid much longer than leaves exposed wholly to the air. Several kinds of controls were arranged to support this experiment. This indicates that leaves can absorb water through the surface of the petiole.

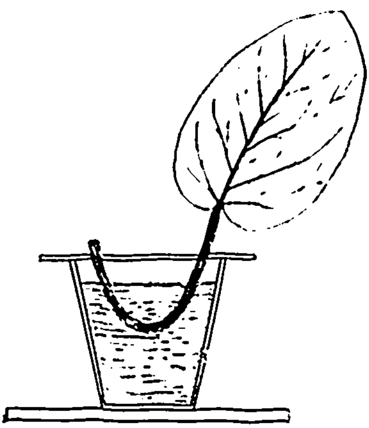

FIG. 3.
Leaf with petiole immersed in water.

A point brought out, during the course of these experiments, was that leaves, *e.g.* Primula, possessing trichomes, seemed to absorb through the petiole more to the advantage of the leaf than did those without trichomes.

In order to enquire into the matter more fully, an apparatus was arranged as shown in Fig. 4, where the capability of a leaf to absorb water in one surface and transmit it to the other is tested. Leaves of

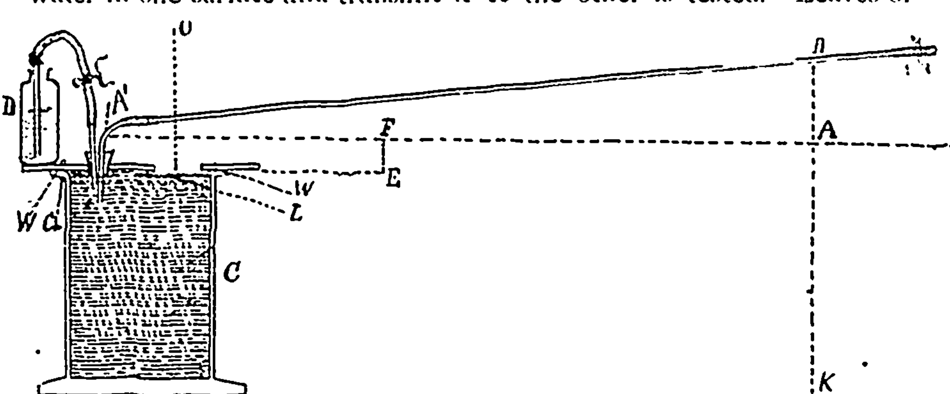

FIG. 4.

Apparatus for testing the power of absorption and transpiration of leaves. C, a tank containing water or a solution. W W, a piece of plate glass ground to fit the edge of the tank C. O, an aluminum gauze. L, a leaf. Cl, a clamp. D, a jar from which the tank can be supplied from time to time. EF, represents the height of liquid due to capillarity. AB represents the amount of pressure up against the leaf L. The margin of the jar is first smeared with grafting wax. As the water evaporates through O the liquid flows towards the left from B, and can be measured readily. When it has reached A' open the clamp on the tube at D and suck the end B until the water comes to the desired point, then close the clamps at B and D; then open clamp at B. BA may be made long or short to increase or decrease the pressure as may be required.

Acer, Ampelopsis, Liriodendron and Tilia were tested, first with the lower surface in contact with the water, and then with the upper surface in contact. It was found that in the case of Tilia it was with the greatest difficulty that leaves free from small holes could be obtained, and that when one was found, apparently without holes, there was observed a very rapid transmission of water through the leaf, and it was necessary to elevate and lower the measuring tube with the greatest care so as to keep the liquid in contact with the leaf and yet to have no pressure against its surface. With the leaf of the Liriodendron the transmission was very slow, and several centimeters pressure did not materially hasten it. During the course of the experiments it was noticed that the humidity of the atmosphere affected the rate of transmission of water. There was a decrease in the rate of transmission of water, associated with a decrease in the humidity of the atmosphere, as indicated by the psychrometer. This was also the case when filter paper was in the position of the leaf, but there was in no instance an increase in volume as resulted with the leaves.

The records given in the following table show the change in volume of liquid in the apparatus to which the leaf was fixed, the temperature of the room, and the relative humidity of the atmosphere. The measurements upon the horizontal tube of the apparatus are made from a fixed point, so that the figures in the column under "distance" at once indicate an increase or decrease in the volume of liquid in the tank.

I.

Date.	Time. (o'clock).	*Distance.	Temperature.	Humidity.
June 21	4.50	772	74	75
" 22	8.45	731	75	93
" 22	1.00	678	73	85
" 22	4.35	703	77	82

II.

Date.	Time. (o'clock).	*Distance.	Temperature.	Humidity.
June 24	1.20	125	73	73
" 25	8.35	150	68	75
" 25	12.20	78	72	80
" 25	12.55	53	72	80
" 25	2.25	6	73	81
" 25	5.00	56	73	85

III.

Date.	Time. (o'clock)	*Distance.	Temperature.	Humidity.
June 27	8.30	197	71	76
" 27	11.45	159	72	79
" 27	2.00	34	76	76
" 27	2.05	681†	76	76
" 27	3.20	19	76	76
" 27	4 20	56	77	80
" 27	5.10	75	75	80
" 28	8.30	141	72	80

IV.

Date.	Time. (o'clock)	*Distance.	Temperature.	Humidity.
June 22	4.35	703	77	82
" 23	8.10	995	71	79
" 23	10.00	1025	74	74
" 23	12.40	1019	74	77

* The larger number denotes DECREASE, and the smaller INCREASE.

† Pressure raised to ten inches for five minutes.

V.					VI.				
Date.	Time. (o'clock).	*Distance.	Temperature.	Humidity.	Date.	Time. (o'clock).	*Distance.	Temperature	Humidity.
June 25	5 00	56	73	85	June 22	8.45	772	75	93
" 26	8 35	212	68	75	" 22	1 00	712	73	85
" 26	1 00	175	70	76	" 22	2 40	691	76	80
" 26	2 20	128	73	77	" 22	4 35	691	77	82
" 26	4 10	41	72	81	" 23	8.10	995	71	79
" 26	5.10	28	72	81					

I. Liriodendron leaf; upper side up; pressure four inches; diag. VII.
II. " " lower " " " " "
III. Ampelopsis " lower " " " " "
IV. " " upper " " " " "
V. Acer " lower " " " " "
VI. Acer " upper " " " " "

SUMMARY OF MEASUREMENTS.

UPPER SIDE OF LEAF UPPERMOST.

Exper.	Day.	Night.
1	28 mm. (increase in tank).	41 mm. (increase in tank).
4	-24 (decrease in tank).	-292 (decrease in tank).
6	81 (increase in tank).	304 " "

LOWER SIDE OF LEAF UPPERMOST.

2	206 mm. (increase).	-25 mm. (decrease).
3	272 "	-216 "
5	184 "	-286 "

NUMBER OF STOMATA PER SQUARE mm.

Leaf.	Upper Surface.	Lower Surface.	Average.
Acer, (5 and 6)................	0	300-350	325
Ampelopsis, (3 and 4).............	0	80-120	100
Liriodendron, (1 and 2)...	0	180-220	200

* The larger number denotes DECREASE, and the smaller INCREASE.

These experiments are difficult to conduct, and several had to be discarded owing to defects in the leaves and to the entrance of air when filling the apparatus. It was thought that a living leaf would act, in a measure, just as a paper would in the same position, but it was found that there was no important point in common between them. The loss of water from the jar, over which the paper was placed, was uniform and constant, this being shown by the movement of water along the horizontal tube. The number in the column under "distance" indicates a distance from the fixed point placed out towards the open end of the tube, so that the larger number indicates a diminished volume of liquid in the apparatus, and the smaller number an increased volume. The diameter of the tube was such that 10 cm. in length indicated 1 cub. cm. of water.

From these experiments we may conclude that the leaves used, absorbed water, as vapour from the air, and as liquid from the tank. There was generally a loss of water from the tank during the night and a gain during the day. The increase in amount in the tank during the day was much greater when the lower side of the leaf was exposed to the air.

In regard to changes occurring at night, there seemed to be little difference, whether the leaves had their upper side up, or their lower side up. During the day, however, there was a remarkable difference.

The table showing the relative numbers of stomata is given, though no application is made of it further than to show that the stomata are found upon the lower surface only.

Filter paper, placed in the position of the leaf in the experiment, produced a steady decrease in amount of water in the tank.

The question of water absorption by *attached* leaves is not so easily dealt with. In an experiment with willow twigs it is shown that water, as well as a nutrient solution, may be absorbed by developing leaves. (See exper. Chapter X).

Some plants, *e.g.*, Ampelopsis, (Fig. 11), have certain peculiarities of leaf structure which seem to indicate an adaptation for absorption. Such are the corrugations over the veins and in the regions of the stomata. It may be that the striations around the bases of the trichomes in Primula (Fig. 5, 1) serve a similar purpose. The tissue next the epidermis over the veins in Ampelopsis is composed of thin-walled parenchyma cells without chlorophyll (Fig. 10, H). Just how far one is justified in reasoning from anatomy to function is not easy to say. These anatomical conditions are not mentioned as proof, but as evidence in favour of absorption.

Stahl has endeavoured to show that corrugations and hairs over the veins, aid in shedding water, but this does not accord with the results of the experiments performed by the writer and recorded in Chapter VII. The hairs along the veins, by capillary action, cause solutions to ascend the petiole and pass out over the veins to such an extent that the leaf *becomes coated with salt when the* water evaporates. Henslow (1888) and Garreau (1851) held that such corrugations and hairs over the veins aided in absorption, as well as in spreading drops of water over the leaf.

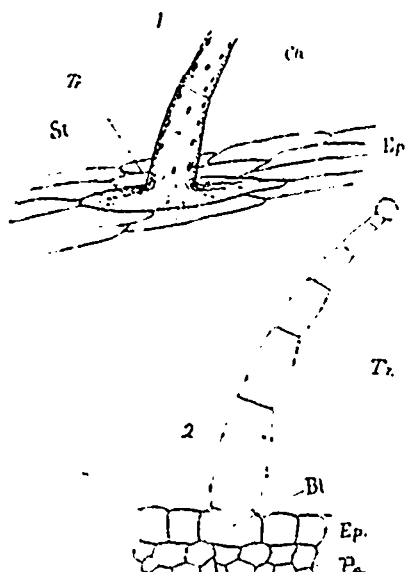

FIG. 5.

(1). A semi-perspective view of a trichome of Primula stellata, partially laid over towards one side showing trichome Tr. in part: Chloroplasts, ch.; striations, St.; surface view of epidermal cells, Ep.

(2). Optical section of a trichome Tr.: part view of cross section of petiole showing basal cell Bl. of trichome, also epidermal layer and parenchyma Pa.

It is shown elsewhere in this paper that solutions are absorbed by leaves even when the plant is in a saturated atmosphere (Chapters VI. and VII.).

The evidences in support of water absorption by leaves upon the plant may be summarized as follows :—*Detached* leaves absorb water, and since they function, in a *measure, as when attached to the living plant (Chapter VII.), it* may be concluded that *attached* leaves absorb. Dilute solutions are absorbed, and therefore water *may be* absorbed. Certain anatomical structures make it seem probable. Since distilled water will extract inorganic salts from leaves, it follows that water may enter the tissue during the process. The historical evidence is overwhelmingly in favour of absorption. Since substances contained in water of guttation and in dew, are resorbed by leaves under certain conditions, it seems probable that water may be absorbed. This last mentioned point will be discussed in detail in the following chapter.

IV.—INCRUSTATIONS, GUTTATION DROPS, DEW.

Certain plants, belonging to the orders *Saxifragaceæ* and *Plumbaginaceæ*, are frequently, when under natural conditions, found with incrustations upon the leaves, and the chief object of this chapter is to make clear, if possible, the cause and the function of these peculiar deposits of lime and other substances upon foliage leaves.

The chemical composition of this deposit has been examined by several botanists, notably Treviranus, Mohl (1861, p. 227) and Volkens (1884), and they all agree that the inorganic part of the deposit is composed almost wholly of $CaCO_3$. They found also a certain amount of organic matter associated with it, but this they did not analyze in detail.

To see if this deposit could be produced artificially, dew-drops were taken in early morning from time to time, from leaves of the following plants,—Trapæolum, Lilac, grass, Mentha, and Polygonum, and placed upon clean cover-glasses. The cover-glass being now kept free from dust, the dew was allowed to evaporate. When the drop had evaporated, a deposit of a whitish crystalline substance remained, showing clearly that the dew-drop had held in solution some salts. Upon carefully heating the cover, and then examining with a lens or microscope, one could see that a certain amount of charred substance had been produced by the heating. This charring indicates the presence of some organic substance. The inorganic portion is soluble in dilute HCl, with liberation of CO_2, showing that a carbonate is present. The quantities were too small to permit of a further test for the base or bases in solution, but as considerable of this substance is re-dissolved in distilled water, there arises the suggestion that it is not all $CaCO_3$, but very probably largely potassium carbonate with potassium oxalate.

Since the dew is, in part at least, formed by the condensation of aqueous vapour of the atmosphere, the question arises as to the source of the salts which were deposited when the drops were evaporated. Did they come from the tissue of the leaf or were they derived from the atmosphere? To answer this question a series of experiments was conducted to determine whether similar substances could be *extracted* from leaves by the application of distilled water.

Leaves were gathered on December 12th, and after two hours placed in distilled water in positions as shown in Fig. 2. In no case did the cut end of the petiole dip beneath the surface of the water. The leaves had lost almost nothing by transpiration during the time intervening between gathering and placing in the dish of water.

Leaf.	Reaction, 24 hours.	Reaction, 144 hours.
Pelargonium	Alkal.	Strongly alkal.
Abutilon	"	Alk.
Rosa	"	Strongly alk.
Eupatorium	"	Acid.
Crassula	Weakly alk	Alk.
Heliotropium	" "	Strongly alk.
Begonia	Neutral	Slightly alk.
Panicum	Alk.	Alk. especially at margin.
Impatiens	Weakly alk	Acid.
Arabis	" "	Alk.
Primula st	Neutral	Acid.
Primula ob	"	Strongly alkal
Tropæolum	"	On leaf, acid, water alk.

The water was then allowed to evaporate, which it did in a period of about ten days. The dishes were protected from dust by placing a tray loosely over the top.

The water had not penetrated into the intercellular spaces of the leaves to any noticeable extent. The amount of substance given off by the leaves was considerable in every case, and in some cases was quite remarkable. When the water had all evaporated from the dishes, and the leaves were removed, a beautiful white "print" of the leaf was left upon the bottom of the glass dish. This "print" was deeper at the margin of the leaf, and was composed of feathery white crystals. In the case of three or four of the leaves used, the surface in the neighbourhood of the veins was not in actual contact with the bottom of the dish. Here water lay during the experiment, and in this region there was a prominent accumulation of crystals. Where the leaf surface actually touched the glass there was little or no deposit. This would remove all doubt as to the possibility of dust particles or gases from the air having anything to do with the crystalline deposit. The alkaline or the acid quality of the liquid was peculiar, in that the results in twenty-four hours differ from those in six days, as shown in the table. This is probably due to chemical changes peculiar to the material composing the cell sap in each case; and also due, perhaps, to different degrees of diffusibility of the substances entering the surrounding water from the leaf; and it may have been due to bacteria. In all cases the juice compressed from similar leaves, at the time of gathering from the plant, and twenty-four hours afterwards, was decidedly acid. Then it is fair to conclude that the leaf juices, or cell sap, did not pass out by mechanical means, or by mere filtration, for then the surrounding water would be acid. This throws some light on the question as to why Duchartre, De Candolle, Ganong and others reached the conclusion that plants, as growing plants, could not absorb water through the leaves. The fact was, that in the washing, spraying or drenching of the leaves, some of the cell contents had been taken out into the water by osmosis; and so naturally in the resulting weight there would be a slight decrease owing to this loss of substance, though at the same time there may have been water absorbed which the balances could not show,—nay, there *must* have been if the water used for drenching was pure water.

That leaves when immersed in distilled water lose a considerable amount of substance, was proved by De Saussure (1805) who made some analyses to determine, not only the nature of the substance extracted by the water, but also the amount actually taken out. He collected some leaves of Corylus on May 1st and found that they yielded upon analysis 26 per cent. of dissolved salts which were mostly alkaline. Similar leaves, after being submerged for fifteen minutes in distilled water, yielded only 8.2 per cent. of dissolved salts. The phosphates, he found, were not perceptibly affected by the drenching. De Saussure does not give any details of his analysis of the salt taken out of the leaf by the water, beyond that it is a combination of alkaline salts,—that is to say that they are salts of potassium, calcium, and, it may be sodium. The writer has also found that this substance extracted by water is composed of potassium and calcium carbonates and potassium oxalate, with traces of organic substance. Hence it is found that the residues from the evaporation of the dew-drops, and of this liquid in which the leaves were submerged are practically the same.

According to Van Tieghem (1898, p. 313) the liquid found upon plants in early morning contains in solution calcium bicarbonate in considerable quantity. This is the calcium compound absorbed by the roots of plants, according to Roux (1900, p. 331). As it is a very unstable compound, breaking down readily into $CaCO_3$, CO_2 and H_2O, it is only reasonable to suppose that it is largely through this bicarbonate that the carbonate is found upon leaves in the form of incrustations. From *this decomposition CO_2 may be furnished to the plant. It may be that* the chemical action resulting in the formation of calcium oxalate in the leaves of some plants, and calcium carbonate in others, results also in a liberation of CO_2.

It has been observed by (Senebier t. 3, p. 98) Morozzo, that dew-drops, remaining upon the leaves until late in the morning, have an acid reaction upon test paper, and that this reaction is due to CO_2 contained in the dew-drop. Senebier analyzed dew and found that when treated *with lime-water it gave a flocculent precipitate, which when tested with* H_2SO_4 produced an effervescence of CO_2. He concluded, however, that the dew-drop is always a deposition from the atmosphere, and that it occurs in drops for the same reason that water spread upon an oiled surface will collect in drops. He collected dew in large quantity and made some analyses which are rather striking. From 3791 kilos of filtered dew, he obtained 2276 grams of a solid as a residue from the evaporation of the water, and, after treating this residue with alcohol, then filtering, he obtained as a solid 603.74 milligrams; on dissolving this in acetic acid, he obtained 421.29 milligrams of an insoluble white substance which he concluded was $CaSO_4$. From these results we may conclude that, from the amount of dew he collected, he obtained 182.45 milligrams of a carbonate, probably $CaCO_3$. He believed the dew to contain an acid carbonate, as did Van Tieghem. He found also that if he first filtered the dew he got less effervescence of CO_2 when treated with H_2SO_4.

In order to test the effects of a dry atmosphere upon leaves holding dew-drops, a number of leaves were taken in early morning and placed immediately in a dry atmosphere which produced a rapid evaporation of the drops. On examination it was found that a slight deposit of a whitish substance was left upon evaporation. This result showed clearly that a saline substance had been dissolved in the dew-drop. At the time of collecting the leaves for this experiment, other plants of the same species were marked for observation later. In the case of these plants no deposit was found. This experiment was repeated six times during the summer with practically the same result. The substance contained in the dew-drops must have been largely, if not wholly, extracted from the leaves of the plants. These experiments indicate also, that under favourable circumstances, leaves resorb the saline substance contained in the dew; and there is a suggestion also that some of the dew-water may be absorbed in the process.

As the dew experiments seemed to indicate that saline substances were extracted from leaves, and also that under certain conditions these salts were resorbed, a series of experiments was arranged to test the matter from another point of view.

Guttation drops were produced upon the following plants:—Tropæolum, Maize, Tomato and Phaseolus. Five leaves of each were then placed in a moist atmosphere, and five of each in an atmosphere whose humidity was very low. When the water of the guttation drops had disappeared it was found, upon close examination, that a whitish deposit lay where the larger drops were upon the leaves in the dry atmosphere. Upon those lying in the moist chamber no deposit was found.

These drops contained, as shown by analysis, potassium carbonate, calcium carbonate and some organic substances. This analysis is corroborated in part by that of Nestler (1899) who states that he found potassium carbonate in drops produced upon leaves of Phaseolus, and on some of the *Malvaceæ*.

In order to determine whether a substance similar to that produced by immersion could be extracted in a shorter time than that employed in the foregoing experiments, a number of tests were made with growing plants. Ten different species were taken and the leaves subjected to a fine spray of distilled water for fifteen minutes. The water was then carefully collected and slowly evaporated down to dryness. In six out of the ten cases, a faint crystalline deposit was found upon evaporation. In one case, that of Nicotiana, a very considerable amount was found. This plant was one of those which showed with the distilled water, a strong alkaline reaction in a short time. When the leaves of the other three plants were tested as in the first series they also produced a deposit after a short time.

In regard to the calcareous incrustations found upon desert plants, Volkens calls attention to the fact that they occur chiefly upon desert plants which grow upon soil which was once the bottom of an inland sea, and which, therefore, contains a considerable amount of lime. It may be said that two things particularly contribute to their formation,—abundance of material, and an atmosphere periodically moist and dry. They are spread over the surfaces of leaves, according to Nestler, and also Noll, by means of hairs and corrugations, leaving no indication as to the place upon the leaf from which they came. The writer has noticed leaves of plants, other than those producing incrustations, having peculiar striations and trichomes which may function, as Nestler suggested, to transport water or solutions over the surface of the leaf (Fig. 10).

The supply of calcareous substance is furnished by the roots of plants in the form of the bicarbonate of calcium (Roux 1900). Volkens (1884) *states that this bicarbonate of calcium is the chief saline substance* contained in the guttation drop. This is in accordance with analyses made by the writer, and the view held by Van Tieghem. It is well known that one of the commonest substances found in spring water is calcium bicarbonate, and Roux states that the CO_2 given off by the roots aids in its formation. There is every reason to suppose, then, that the plant obtains its calcium chiefly from this substance. It is also well known that $CaCO_3$, in the presence of CO_2 and water, forms the soluble bicarbonate thus:—$CaCO_3 + CO_2 + H_2O = CaH_2(CO_3)_2$; but, as this compound is very unstable, it breaks down again if the conditions be seriously disturbed. These interactions may be, therefore, important in plant economy.

The function of incrustations are (Volkens, 1884):—(1) to keep up an equilibrium between absorption of the roots and transpiration of the leaves; (2) in the excretion of useless and harmful products; (3) to prevent too rapid evaporation in a dry hot climate. Pfeffer (1897) states that the function may be to induce an abundant formation of dew. Since calcium bicarbonate is a very unstable compound, breaking down into $CaCO_3$, CO_2 and H_2O, it may be, that in the formation of the deposit of $CaCO_3$, a source of supply of CO_2 is suggested. The roots take in the bicarbonate and it is found upon leaves of plants in the morning. In the early morning when photosynthesis is becoming active this bicarbonate begins to break down, resulting in a liberation of CO_2 which is then in demand by the plant. From these data the writer assigns another probable function to these incrustations, namely, that of furnishing CO_2 to the plant.

Since analyses show that the deposits from the dew-drop, the guttation drop, and the water of immersion or drenching, are similar to those in the calcareous incrustations, one may infer that the causes of formation are similar. As the process involved in the formation is one of diffusion, the loss or gain to leaves will depend upon relations existing between internal and external conditions.

In summarizing the results of these discussions and experiments, we may say that the residue obtained from the evaporation of dew-drops, guttation drops, and of the water used in drenching leaves, is practically the same. This residue is similar in chemical composition to that of the calcareous incrustations found upon certain Saxifrages and other plants. The relative proportions of the constituents, however, are different. In the calcareous incrustations, the quantity of calcium carbonate is much more pronounced than is the case with dew and guttation water. Under certain conditions guttation water and dew-drops are absorbed by leaves, leaving no deposit of saline matter on the surface of the leaf. When the evaporation is rapid a deposit is found. When the drop contains calcium bicarbonate in solution, carbon dioxide is liberated during the process of evaporation. It may be that in desert countries the calcareous incrustations, in the presence of moisture during the night, serve the purpose of retaining the CO_2 given out in respiration. Owing to lack of decomposition of vegetable matter there is a low percentage of CO_2 in the air in deserts. This might indicate an economy of some importance to the plant.

These results throw some light upon the question of water-absorption, and suggest something in regard to the nature and the cause of such absorption.

V.—DOES DISTILLED WATER BECOME ALKALINE WHEN PLACED UPON LEAVES OF PLANTS?

In Sachs' Pflanzen Physiologie (1882, p. 305) he states that if distilled water be placed upon the leaves of plants for a few minutes, it becomes alkaline, and he refers to a paper of his own, (1862, p. 259), upon "The acid, alkaline and neutral reaction of the cell-sap of plants." The subject is merely referred to in his paper, Sachs himself having made no direct investigation into this particular point. The conclusions he draws are based upon work done by Payen and Gaudichaud. These two men entered into a warm discussion, in which Payen held that an alkaline reaction is produced by the leaf, and Gaudichaud showed that the sap of plants in general is acid and rarely, if ever, alkaline. He argued further, saying that the few particular cases mentioned by Payen were irrelevant; and as no further reply was given by Payen, the matter stood thus for a considerable time. However, in looking into Payen's work (1848), one finds that he saw far more in the subject than Gaudichaud gave him credit for; and also that he had the best of the argument as Gaudichaud recognized later on. Payen gave also in connection, some analyses which are interesting. In one of these he found upon evaporating the water taken from Mesembryanthemum crystallinum, crystals of potassium oxalate. A quotation from Gaudichaud, (1848, p. 35), gives his position upon the question. "Toutes les autres plantes que j'ai observées depuis par ce moyen même Urticées se sont montrées acides dans le même éspace de temps. On sait que l'eau de ces sortes de macérations devient promptement alkaline. * * *

"Je coupai deux ou trois branches de cette singulier plante, et les plaçai dans un verre avec un peu d'eau. Le lendemain matin en poursuivant mes recherches la pensée me vint d'essayer aussi de l'eau du verre où avaient séjourné ces branches et je fus très surpris de voir le rouge passer au bleu."

Later on Gaudichaud made other experiments by placing distilled water upon leaves of many plants, and found an alkaline reaction. Two of the plants he mentioned are Trapaeolun majus and Cucurbita. He accounted for this alkalinity by saying that the alkaline substances diffused out more readily than the others. This agrees with De Saussure's results, which Gaudichaud gives, and which are already referred to in the chapter on incrustations. That alkaline substances diffuse out into the surrounding water, seemed to be quite clear to *Gaudichaud.*

In the paper, just referred to, by Sachs, he shows that there is generally an alkaline reaction in the sap in the conducting vessels (stem and roots) of the wood, while the reaction of the parenchyma is generally acid. *He says* :—

"Die beschriebenen Fälle ziegen, dass Payen's und Gaudichaud's Ansicht, als ob alkalische Säfte nur in "specifischen" Zellen einiger "exceptionellen" Pflanzen vorkamen, nicht gerechtfertigt ist, dass vielmehr die alkalischen Säfte in einer grossen Zahl unserer gemeinen Culturpflanzen neben sauren Säften vorkommen; und zwar ziegen die vorstehenden Untersuchungen, dass gerade diejenigen Säfte vorzugsweise alkalisch sind, denen wir eine hohe Wichtigkeit für das Leben der Pflanzen nicht absprechen dürfen, nämlich in den dünnwandigen Zellen, welche bei vollständig ausgebildsten Gefässbündelen krauter Pflanzentheile zwischen dem Baste und den Gefässröhren liegen. Dass gerade diese dünnwandigen Zellen die wesentlichsten Elemente der Gefässbündel darstellen, darf zunächst aus dem Umstande gefolgert werden, das dieselben in den Gefässbündelen lebenskräftiger Theile wie es scheint, niemals fehlen. Es sind offenbar diese dünnwandigen Elemente der Gefässbündel, welche auch bei solchen Familien der Gefässpflanzen schon auftreten, wo eigentliche Gefässe und Bastzellen noch mangelen, und während *in den äussersten endigungen der* Gefässbündel der Blattnerven höherer Pflanzen der Bast und die Gefässe beinahe oder ganz aufhören, bilden die Leitzellenbündel die äussersten Endigungen."

This gives the location of the substance which produces the acid and the alkaline reactions respectively. This also lays the foundation for a reasonable explanation for the phenomena chiefly under discussion in this chapter.

The nature of the substance diffusing out through the leaf tissue, to cause this alkaline reaction, is discussed in more detail in the foregoing chapter. Several phenomena developed during the course of the following experiment, which are interesting and important. On examining the recorded details of the experiments, one notices first that the time required to cause a sufficient change of colour of the litmus is an appreciable interval, and it varies widely with different plants, as might be expected. The time required to cause a distinctly alkaline reaction of the water applied to the surface, depends upon the permeability of the cell walls, especially upon that of the cutin upon the epidermal layer, upon the diffusibility of the salts extracted by the external water, and directly upon the readiness with which the acid contents of the cells make their way out and neutralize the alkaline substances taken from the tissue by diffusion. The CO_2 in the atmosphere, and in and about the leaf surface, is no unimportant factor in determining the colour of the test paper. As is shown in the preceding chapter the substance which diffuses out is largely K_2CO_3, $CaH_2(CO_3)_2$, and probably some potassium oxalate. Two of these substances, potassium carbonate and potassium oxalate, have a reaction rather strongly alkaline, while the other is slightly acid to litmus test paper. If the last-mentioned salt ($CaH_2(CO_3)_2$) predominate strongly, there will be a weakly acid reaction, as is shown in some plants. This substance, being so very unstable, breaks down (upon evaporation of the solution), into $CaCO_3$, CO_2 and H_2O, leaving as a residue the carbonate of lime. If, however, water is present and more CO_2 available for absorption into the solution, it would become gradually more and more acid, as is shown in the results of the experiment.

One very important difficulty in the way of success in demonstrating this phenomenon, is that reddened litmus paper will often become slightly blue if placed in distilled water which is allowed to evaporate down to dryness. That there might be some slight action between the water and the sodium or the potassium of the glass, is barely possible. Small quantities of ammonia in the air may have some effect. An experiment was performed to test this phenomenon. Two well-cleaned panes of glass, 160 by 210 mm, were placed face to face together, with a few drops of distilled water and a few strips of red litmus paper between. Owing to the adhesion of the water for the glass and the slow evaporation, the water remained there several days, and the colouring of the paper might be seen readily at any time without disturbing the plates. One could hardly say that atmospheric conditions had much to do, under these circumstances, with giving the water between the plates any quality, either acid or alkaline. The strips of paper all turned slightly blue, showing that the water and glass had probably something to do with the change. This change took place long before the water had evaporated, showing that the evaporating down to dryness was no important factor, though, so far as is known to the writer, this is the only reason assigned for the change.

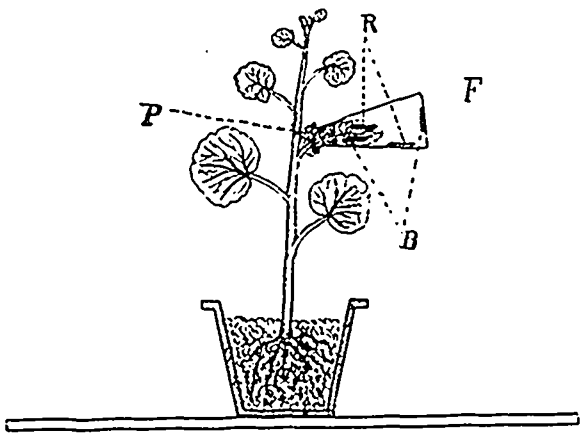

FIG. 6.

F, is a flask enclosing a leaf and kept in position by a support. P, a plug of cotton in the flask. R & B, red and blue litmus paper strips.

Experiment to test the acid or alkaline quality of distilled water which has been allowed to stand upon a living leaf for some time. Plant used, Helianthus. Plant placed under a bell-jar.

I.—*December 15th, 1900.*

3 strips red litmus paper placed on glass slide under jar and moistened, became blue in 24 hours; dry.

2 strips red litmus paper placed on the inside of jar; moist; no change.

3 strips (red) placed upon leaves touching jar; moist; turned blue.

3 strips (red) placed upon leaves not touching jar: dry; no change.

II.—*December 16th.* Observations made in 24 hours; reddened litmus paper used.

4 strips	on glass slide, moist, under jar . . .	*Reaction*,	bluish.
4 "	*touching inside surface of jar, moist.*	"	*3 red : 1 (dry) blue.*
4 "	on leaf touching jar, moist ....:	"	bluish.
4 "	in beaker of dist. water under jar...	"	red.
4 "	on slide, moist, under beaker not with plant.......	"	bluish.
4 "	on inside moist beaker inverted.....	"	bluish (dry).
4 "	on under side of leaf, moist.........	"	blue.

III.—*December 17th.* Observations made in 24 hours.

2r. 2b., under jar in beaker.	*Reaction,*	2r. and 2 faded.
1r. 1b., under jar on moist slide	"	1 bluish one blue, (dry)
3b. 4r., touching inside moist jar	"	3b. 4r.
2b. 2r., under side of leaf.	"	2b. 2 bluish.
3r., on upper side of leaf touching jar	"	3 bluish.
1r., on upper side of leaf not touching jar	"	1 bluish.
1r. 1b., under beaker in beaker	"	1r. 1r.
2r., on moist slide under beaker	"	2 bluish, (dry).
1b., under cover glass under beaker	"	blue.

IV.

	Time.	Reaction.
January 25th.—Pelargonium; plant in the open air. In all cases the litmus paper was first moistened.		
3r. on upper side of leaf	6 hours.	3 blue.
1r. on upper side of leaf as in (Fig. 6).	24 hours.	1 reddish.
February 16th. Plant under jar.		
2r. upper side of leaf	24 hours.	2 bluish.
2b. upper side of leaf	24 hours.	2 blue.
February 21st. Plant in open.		
4b. on upper side of leaf and left for	3 days.	4 blue.
February 21st. Plant under jar.		
3b. on upper side of leaf	3 days.	3 blue.
January 25th. Nicotiana; plant in open.		
3r. and 3b. on upper side of leaf	6 hours.	6 blue, very.
February 21st. Plant under jar.		
3r. and 3b. on upper side of leaf	6 hours.	6 blue.
February 21st. Chrysanthemum; plant in open.		
3r. and 3b. on upper side of leaf	6 hours.	No change.
2r. and 2b. on under side of leaf	6 hours.	No change.
February 21st. Plant under jar.		
3r. on upper side of leaf	24 hours.	No change.
January 25th. Solanum; plant in open.		
3r. and 3b. on upper side of leaf.	6 hours.	3r. and 3b.
2r. and 2b on leaf as in (Fig. 6)	24 hours.	4 reddish.
January 25th. Capsicum; plant in open.		
3r. and 3b. on upper side of leaf	6 hours.	6 blue.
3r. and 3b. on under side of leaf	6 hours.	6 blue.
February 21st. Plant under jar.		
3r. and 3b. on upper side of leaf	24 hours.	6 blue.
3r. and 3b. on upper side of leaf (Fig. 6).	6 hours.	3 bluish, 3 blue.
3r. and 3b. on upper side of leaf (Fig. 6).	24 hours.	6 reddish.

From these experiments one can see that there is a certain alkaline reaction of the water which had been left upon the leaf surface for a short time. A very dry atmosphere surrounding the leaves will cause such rapid evaporation of the water that there may be no definite reaction either way on some plants. It is not difficult to see that the time required to extract substances in solution osmotically from the leaf tissue will vary with different plants. Both the substance to be diffused and the septum through which diffusion takes place, have to do with the amount diffused in a given time. This process is in accordance with the general laws of diffusion, the solution within the cells on the one side of the septum and the water on the other. All the experiments described show that a substance is actually extracted from the leaf, the time required being different with different plants.

When the plants were placed under bell-jars to reduce in amount the evaporation from the leaf surface they were under different climatic conditions from the surrounding plants in the open. These differences, however, were not of such a nature as to interfere with the progress of the experiment, as is shown by the numerous controls. During the day time there would be, when photosynthesis is active, a diminished amount of CO_2 in the air in the jar; while during the night when photosynthesis is checked, or stopped altogether, and respiration is still going on, there would be an excess of CO_2 in the air of the jar. The action of an excess of CO_2 would be to render the water drops clinging to the sides of the jar of an acid quality.

When the water had evaporated slowly down to dryness upon a glass surface there was always a *slight* alkaline reaction to the litmus paper. The general results of the experiments with the plant Helianthus (exper. I, II, III), are that distilled water became alkaline in twenty-four hours after being placed upon leaves. The same reaction was found whether the water were placed on the upper or on the lower side of the leaf. As the plant was inside a bell-jar, as in experiment I., it was easy to have a leaf touching the moist inside surface of the jar, with a strip of test paper touching both jar and leaf in the presence of water. The strips placed clinging to the inside surface of the moist jar were in fair comparison with that touching leaf and jar, and in the latter case the portion touching the leaf showed the stronger alkaline reaction. This tends to prove that the alkaline reaction is caused by the leaf, and not wholly or in large part by the glass, as was suggested by the writer to have been possible.

Sachs shows (Bot. Zeit. 1862, p. 257) that the substances contained in the conducting vessels in the stem of the plant, in petioles and in veins of a leaf are alkaline. It is therefore possible that this alkaline substance in solution is largely in the same condition as when found in the xylem of the root. So we have in the leaf an alkaline liquid on its way towards the minute tracheids entering into whatever chemical compounds are natural to the leaf. The alkaline substance which diffuses out through the leaf surface to the distilled water is not in all likelihood *wholly* the same as that coursing upward through the conducting vessels, for there diffuses out through the leaf, potassium oxalate, a compound organic in its nature, and one which therefore has had to do with the plant metabolism. Sachs shows that the liquid in the xylem of the roots is alkaline and that this alkaline quality is maintained throughout its course into the leaf.

To sum up, one may conclude from these experiments and from those recorded in Chapters III. and IV., that a substance is extracted from leaves of plants by the application of distilled water, and that this substance gives generally an alkaline reaction. This alkaline reaction is produced largely by compounds of potassium (potassium carbonate and potassium oxalate). If distilled water extracts salts from leaves it may be that rain-water does, and this will result in a loss of substance to the leaf. If the substance be *injurious* to the plant this process might be called a *process of excretion*. The amount which diffuses out differs with different plants, and the alkaline reaction may be masked by the presence of other substances as shown above. It has been shown that, in the case of the potato plant (1895), distilled water when applied to the leaves, acts as a stimulus to growth, and the suggestion is here offered that the stimulus may be a result of the loss of injurious salts which had accumulated in the leaves, the removal of which substances would benefit the plant.

VI.—THE EFFECTS OF A NUTRIENT SOLUTION AND OF DISTILLED WATER UPON LEAVES OF PLANTS.

The experiments here described in detail were designed to extend at intervals over a period of two years, and to have the plant as nearly as possible under natural conditions. It was expected that these investigations would throw some light upon the much disputed question as to whether leaves can absorb water and solutions to the advantage of the plant. Arrangements were made to have the roots of the plant isolated, so to speak, from the atmospheric conditions surrounding the leaves, and to have the roots supplied with nothing but distilled water and air. It was thought that if no food were supplied to the roots, growth could not continue for any extended length of time. If liquid food be supplied to the leaves and a distinct growth results—that is, a growth more

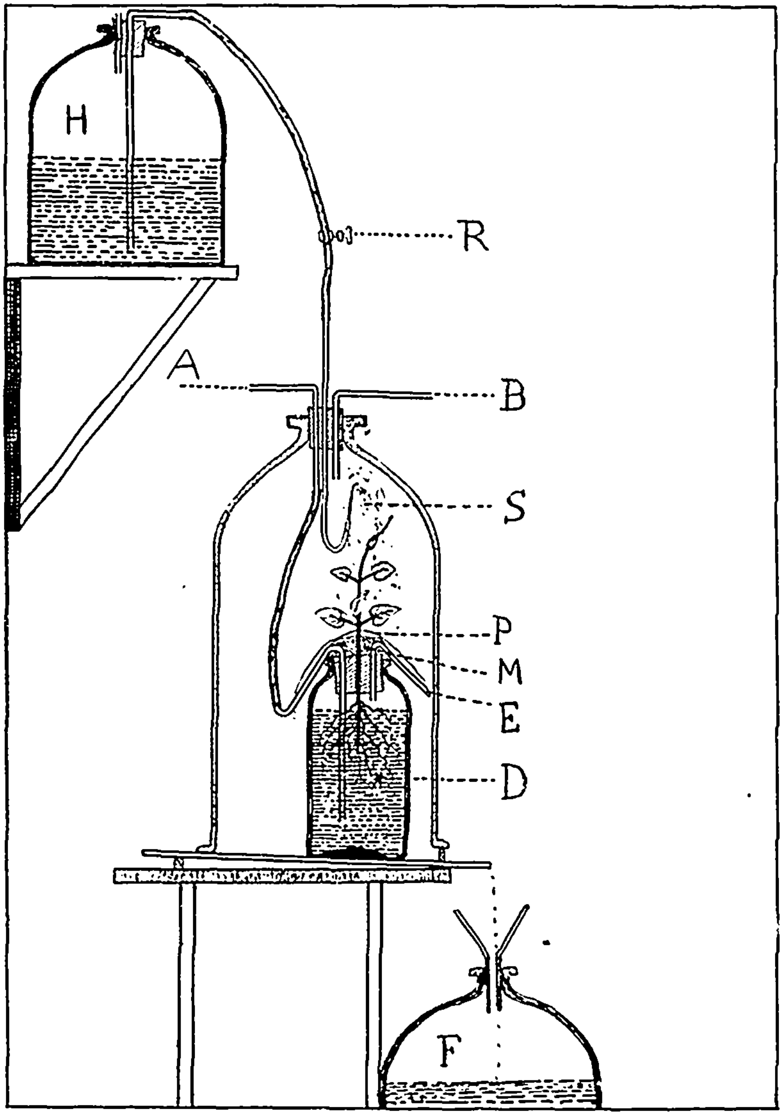

FIG. 7.

H, reservoir for nutrient solution; R, regulating tap; A, tube through which water and air are supplied to the roots; B, ventilator; P, sheet rubber; M, wax; E, exit tube; D, distilled water; S, spray; F, receiver.

pronounced than that in the case of water alone—it is deemed reasonable to conclude that some of the food solution was absorbed to the advantage of the plant. (For illustration of the method used to supply the leaves with food see Fig. 7). It was found expedient to paint the bottles in which the roots were immersed, with black bicycle enamel to protect the roots from the light.

SERIES I.

The first of the following series of experiments was begun on October 13th, 1899, and carried on at the physiological laboratory at the botanic gardens, and is the first of the series to test whether a nutrient solution can be made to support the life of a plant by applying it to the leaves in the form of a spray. The roots were placed in distilled sterilized water and the supply was kept up by means of a system of tubes arranged for the purpose. The corks of the bottles were smeared with a specially prepared soft wax, and above this was placed a piece of sheet rubber, cut so as to go round the stem of the plant in the form of a hollow cone, then cemented in this position so as to shed the liquid used as a spray, and to keep as much as possible of the spray from coming into contact with the wax. The wax served the purpose of doubly securing the liquid at the roots from contamination with the liquid used as a spray. (See Fig. 7).

Plants used—Thunbergia alata.

Plant A.—Roots in distilled water and leaves fed by a spray of nutrient solution (Fig. 7).

Plant B 1.—In distilled water but no spray.

Plant B 2.—Under same condition as B 1.

Plant B 3.—Roots in distilled water, plant under jar and moistened daily.

Plant C.—Control, in flower-pot in soil.

The records of growth in length are for the purpose of inquiring into the manner in which the growth is affected when the plant is placed under these conditions. Measurements are given in millimeters.

PLANT A.

Date.	No. of leaves.	Length of last internodes. Stem.	Branch.	Branch.	Branch.	Branch.	Increase in length.
Oct. 13.	12		..	.	..	.	..
17..	24	.			..	.	..
20..	24	.		.	..	..	..
22..	24	69	19	62	..	.	..
24	26	75	28	9	.	..	37
26..	30	6	6	37	..	..	66
27.	32	6	19	56		..	37
29..	34	6	3	37	..	..	28
31.	36	6	3	62	..	..	25
Nov. 1..	38	6	3	25	..	..	50
2.	38	6	3	12	..	..	25
5..	40	6	50	25	..	..	69
7..	42	6	28	137	..	..	166
9..	46	6	100	6	..	..	87
11..	49	6	125	6		..	69
13.	51	6	50	3	..	.	25
15.	55	..	12	25	31	25	244
16..	61	..	94	3	3	3	144
17..	61	..	100	19	12	3	69
18	63	..	19	37	19	12	87
19	65	..	50	75	37	25	225
20..	67	.	100	19	78	75	210
22.	71	.	31	50	37	3	166*
23..	73	..	56	12	62	56	125
25..	81	..	19	3	12	75	150
26.	81	..	31	25	62	75	112
27..	83	.	47	56	81	25	141
28	87	..	12	100	12	50	191
29.	89	.	31	19	37	62	125
30	91	..	56	56	62	12	112
Dec. 1..	93	..	6	81	81	31	87
2..	97	..	50	6	6	62	175
3..	101	..	12	31	31	62	112
4..	105	..	50	62	50	75	87
5	107	..	75	100	62	62	75
7.	111	.	6	50	50	100	172†

*Root is seen at 3rd node on main stem.

†Plant growing vigorously at conclusion of experiment. (55 *days*).

PLANT B. 1.

Date.	No. of leaves.	Length of last internode.	Increase in length.	Remarks.
Oct. 27..	8	19	.	
28.	8	25	6	
29..	8	50	31	
30.	8	19	44	
31..	10	12	62	
Nov. 1.	10	100	137	
2..	10	112	75	Plant wilting.
3..	10	125	0	Turgor slightly restored.
4..	10	125	0	Top dead.
5..	10	125	0	
6.	10	125	0	Dying.
7	10	125	0	Dead. (11 *days*).

PLANT B. 2.

Date.	No. of leaves.	Length of last internode.	Increase in length.	Remarks.
Oct. 27..	8	2	..	
28.	8	6	6	
29	8	19	12	
30	8	37	19	
31..	10	3	16	
Nov. 1..	10	12	41	
2..	10	19	6	Plant wilting.
3..	10	25	6	
4..	10	25	0	Top dying.
5..	10	25	0	
6..	10	25	0	Dying.
7..	10	25	0	Dead. (11 *days*).

On testing the leaves it was found that starch was present, excepting in the four most recently developed leaves, and in the terminal buds. Another plant (B. 3) was substituted on November 10th.

PLANT B. 3.

Date.	No. of leaves.	Length of last internodes.		Increase.	Remarks.
Nov. 10	4	31	.		
11	4	34	..	3	
12	4	37	..	3	
13	6	3	..	6	
14	6	9	.	6	
15	6	22		12	
16	8	3	..	19	
17	8	12	.	9	
18	8	19	..	6	
19	8	44	..	25	
20	8	62	..	19	
22	8	100	..	19	
24	10	6	12	9	
25	10	6	12	0	
26	10	6	12	0	
27	10	6	19	7	
28	10	6	19	0	
29	10	6	22	3	
30	10	6	31	9	
Dec. 1	10	6	37	6	Flower-bud developing.
2	10	6	37	0	" opening.
3	10	6	37	0	" open.
4	10	6	37	0	Flower open.
5	10	6	37	0	" pale.
6	10	6	37	0	Plant dying.
7	10	6	37	0	" dead. (27 *days*).

PLANT C.—(CONTROL, IN FLOWER-POT IN SOIL.)

Date.	No. of leaves.	Length of last internode.	Increase in length.	Total increase.	Remarks.
Oct. 17	8	19	0	.	
19	8	19	0	..	
21	8	19	0	..	
23	8	19	0	..	
24	8	6	6	..	
25	10	12	6	..	
26	10	25	12	.	
27	10	37	12	..	
28	10	56	19	..	
29	12	19	22	..	
30	12	25	6	..	
31	12	37	12	..	
Nov. 1	12	56	19	..	
2	12	12	37	..	
3	14	19	6	..	
4	14	44	25	..	

PLANT C.—*Continued.*

Date.	No. of leaves.	Length of last Internode.	Increase in length.	Total increase.	Remarks.
Nov. 5	14	75	31	.	
6	16	12	37	.	
8	16	19	6	..	
10	16	62	44	..	
12	..	.	.		Broken off; bud from 4th node recorded.
13	..	25		..	
14	.	3	28	..	
15	..	6	19	..	
16		12	19		
17	..	37	25		
18	..	62	25	.	
19	..	6	19	..	
21	..	12	6	..	
22	..	12	0		
24	..	19	3	..	
25	.	31	12	.	
26	..	44	13	..	
27	..	50	6	..	Two buds springing from near the base.
28	..	12	19	..	
29	..	..	.	..	Branches from near the base recorded and only the *total* increase in length of stem given.
30	..	..	.	24	
Dec. 1	..	..	..	38	
2	..	..	..	62	
3	..	..		12	
4	..	..		24	
5	..	..		38	
7	..	..	..	53	End of the series. (51 *days*).

It will be noticed that the plant in soil in the flower pot being transplanted from soil, remained almost at a standstill for six or seven days, when growth proceeded more or less regularly. The plants whose roots were in water suffered no such standstill in regard to growth as did the plant in the soil, although all were taken from the same propagating-box.

SERIES II.

This series of experiments was carried through in the physiological laboratory at the botanic gardens during the month of December, 1899. The records given in the table below show the daily increase in length of stem and also the increase in number of leaves. All the plants were subjected to the same conditions of light, and as nearly as possible, to the same conditions of temperature, but owing to the fact that some of the plants were under bell jars, the condition of temperature, as well as of moisture could not be kept exactly the same.

Plant used, Helianthus (Sunflower).

Apparatus was arranged as in Fig. 7 for plants 1 and 2 in the same bell-jar. The spray was a nutrient solution and the roots were in distilled water.

Plants 3 and 4 were arranged as in 1 and 2, excepting that the spray was of distilled water.

Plants 5 and 6 were in nutrient solution, as in the ordinary water culture, but under a jar with ventilation at the top and bottom.

Plants 7 and 8 were under a bell jar with ventilation at the top, and the inside was kept moist by means of flat dishes of water; roots were in distilled water. Numbers 9 and 10 were in soil and were kept under a jar. Numbers 11, 12, 13, 14 were in soil in an ordinary flower-pot in the room.

PLANT.	DATE.										
	Dec. 10.	Dec. 14.	Dec. 17.	Dec. 21.	Dec. 25.	Dec. 28.	Jan. 1.	Total.	Increase.	Av. increase in No. of leaves for the set.	Av. length increase for the set.
PLANT 1.											
No. of leaves	8	8	8	8	8	10	12	12	4	....	....
Length of stem	162	200	200	219	219	237	245	245	83	...	....
PLANT 2.											
No. of leaves	8	10	10	10	12	14	18	18	10	7	...
Length of stem	206	248	248	256	284	284	300	300	94	....	86
PLANT 3.											
No. of leaves	6	8	8	10	12	12	12	12	6	...	....
Length of stem	159	194	225	256	300	300	328	328	169	....	....
PLANT 4.											
No. of leaves	8	8	10	10	10	10	10	10	2	4	....
Length of stem	181	206	256	256	272	272	281	281	100	..	134
PLANT 5.											
No. of leaves	6	8	8	8	8	10	10	10	4	....	....
Length of stem	147	169	182	197	219	244	250	250	103	....	....
PLANT 6.											
No. of leaves	6	6	8	8	8	10	10	10	4	4	....
Length of stem	131	162	162	169	206	209	222	222	91	...	97
PLANT 7.											
No. of leaves	6	6	8	8	8	8	8	8	2	....	...
Length of stem	162	225	256	256	291	300	312	312	150	...	..
PLANT 8.											
No. of leaves	8	8	8	8	8	8	8	8	0	1	....
Length of stem	150	181	181	181	181	200	203	203	53	....	102

PLANT.	DATE. Dec. 10.	Dec. 12.	Dec. 17.	Dec. 21.	Dec. 25.	Dec. 28.	Jan. 1.	Total.	Increase.	Av. increase in No. of leaves for the set.	Av. length increase for the set.
PLANT 9.											
No. of leaves	8	8	8	10	12	12	14	14	6	....	....
Length of stem	225	262	303	312	387	406	469	469	244	....	....
PLANT 10.											
No. of leaves	8	8	10	12	12	12	16	16	8	7	....
Length of stem	219	281	291	316	337	337	387	387	168	..	206
PLANT 11.											
No. of leaves	8	10	10	10	12	12	14	14	6	....	....
Length of stem	237	284	325	352	381	387	500	500	267	...	....
PLANT 12.											
No. of leaves	6	8	8	10	10	12	12	12	6	...	....
Length of stem	194	253	269	319	363	375	431	431	237	...	....
PLANT 13.											
No. of leaves	8	8	8	10	10	12	12	12	4	.. .	....
Length of stem	219	285	322	381	381	412	462	462	243	....	....
PLANT 14.											
No. of leaves	8	8	8	10	12	12	12	12	4	5	....
Length of stem	137	170	212	269	272	325	365	356	219	....	214

Plants 1-8 were each carefully weighed before being placed in the bottles, with a view to ascertain by weight the increase in growth, if any, but it was found during the course of the experiment that it would be impracticable to employ this method to determine growth throughout a series of experiments continued for so long a time as here contemplated, because some of the plants lost many of their leaves. As soon as a leaf dropped it began to absorb of the solution, as detached leaves do, and consequently quantitative determinations of ash increase might lead to error.

On December 21st plant 1 had developed an aerial root about 16 mm. in length, and on 23rd this had increased in length to 34 mm. On December 21st plant 4 showed three small roots just coming forth from the stem at the second internode, and on 23rd these roots had grown to a length of about 6 mm. On December 25th one of these had grown to a length of 19 mm., but on 28th had withered. The root that developed on No. 1 was dead on December 31st.

On December 30th, observations were made as to the general appearance of the plants, and it was found that the leaves of 1 and 2 showed a tendency to curl, and had the appearance of plants grown in too rich soil. The leaves were much crowded towards the top and they showed a good green colour. Plant 3 seemed to be dying and the uppermost leaves were becoming very pale. It may be that death was being brought about by fungi which attacked a dead leaf that clung to the stem and decomposed there. The stem of plant 4 had become pale and the upper leaves had become a pale yellow and begun to roll in from the tips, not curling at the edges as in 1 and 2. The leaves of plants 5 and 6 curled similarly to 1 and 2, but had a much more stunted appearance. The plants were now removed from the jar and they did better after being removed. These plants do not seem to take kindly to water cultures. Plants 7 and 8, leaves flat and thin, becoming very pale; stems thin and bending. Plants 9 and 10, growing well, and have the appearance of 11, 12, 13, 14.

The difficulty with these plants seemed to be that they could not well endure a moist atmosphere, and they had a tendency to send out aerial roots. Of course, in the case of No's 1 and 2 this would spoil the experiment, as the roots would, or could, then do the absorbing. In nearly every case, however, the atmosphere at some time became too dry for the roots, and so they died down. The spraying, in the case of 1, 2, 3, 4, lasted continuously for about thirteen hours, then a rest was given for at least twelve hours, nearly always much more than twelve hours. The roots were aerated regularly by means of a hand pump through the tube left for this purpose in the bottle. Distilled water was fed regularly to the roots through the tube just mentioned.

Notwithstanding the fact that these plants were not well adapted to this experiment, there are some conclusions of more or less importance to be drawn, and which bear upon the subject under discussion. The average increase in length of stem of 1 and 2 is less than that of 3 and 4, as is also the case with 5 and 6. In both cases the nutrient solution seemed to retard the growth in length of the stem. The average increase in length of stem of 3 and 4 is greater than that of 1 and 2, though the number of leaves is greater in 1 and 2. In the case of 7 and 8 a small increase in length of stem and in number of leaves was found.

The following conclusions, applicable to this plant, may fairly be drawn from the experiment, though due allowance must be made for slight exigencies :—

(1). A spray of water seemed to stimulate growth for a time.

(2). The general effect of placing the plant under a bell jar is to retard growth of stem but promote growth of leaves.

(3). Plants deprived of all food matter, except that contained in the air and in pure water, will grow rather rapidly for a time but will gradually die, the leaves first turning yellow.

(4). Plants grown in a moist atmosphere tend to send out roots at the internodes as well as at the nodes.

(5). A nutrient solution fed in the form of a spray to a plant seems to affect the plant in a way similar to that of a nutrient solution applied to the roots, as in the ordinary water culture, and therefore it may be assumed that some, at least, of the solution had been absorbed* and had been used in the general vital processes of the plant. Though the plant, fed with a solution applied to the *leaves* in the form of a spray, did not show a healthy or vigourous growth, yet the same may be said of the plant whose *roots* were supplied with the solution.

On the completion of the experiments, January 7th, the liquid medium in which the roots dipped was examined, and it was found that in the case of 1 and 2, none of the liquid spray had made its way down into the water about the roots. The liquid, however, showed an acid reaction in all cases. It was found further that those plants growing in distilled water, 7 and 8, had a much more extensive growth of roots than 5 and 6, those in the nutrient solution.

SERIES III.

The following series of experiments was arranged and conducted in the basement of the University Museum where the atmosphere was exceedingly dry at that season of the year, but the temperature was fairly constant, ranging from 60 to 70 degrees F. The plants supplied by a spray were arranged as shown in Fig. 7, while the others were placed under bell jars with ventilators. These were aerated daily, as were also the roots of the plants, and this aeration was accomplished by forcing a stream of air into the liquid surrounding the roots. The capacity of the bell jars was twenty-four liters.

The number of leaves was recorded regularly, and measurements

* Absorption by the leaves is indicated also by the experiments in Chapter X.

were made upon the last three internodes in particular, and recorded, and also upon the whole plant as nearly as possible, so as to give the increase in growth from time to time. The measurements are in all cases given in millimeters.

Plant 1 A.—Thunbergia alata, roots in distilled sterilized water and fed with a spray of nutrient solution.

Plant 1 B.—Fagopyrum esculentum (buckwheat), under the same conditions as 1 A.

Plant 1 C.—Ipomaea purpurea (morning-glory), under same conditions as 1 B., and substituted for it.

Plant 2 A.—Thunbergia alata, roots in distilled water and plant kept under a jar frequently moistened and ventilated, no spraying.

Plant 2 B.—Fagopyrum, under same conditions as 2 A.

Plant 2 C.—Thunbergia, substituted for 2 A. and kept under same conditions.

Plant 3 A.—Thunbergia alata, roots in a nutrient solution, formula given on p. 238; atmospheric conditions same as 2 A.

Plant 3 B.—Fagopyrum, same as 3 A.

Plant 4 A.—Thunbergia alata, roots in distilled sterilized water and under the same conditions as 1 A., excepting that the liquid used for spraying was distilled water instead of a nutrient solution.

Plant 4 B.—Fagopyrum, under same conditions as 4 A.

PLANT 1. A.—OBSERVATIONS.

Date, 1900.	No. of leaves.	Length of last internodes. m.m.	m.m.	m.m.	Total length. m.m.	Increase. m.m.	Remarks.
Feb. 9	8	22	31	6	78	....	
11	8	22	37	19	97	19	
12	8	22	44	37	122	25	
13	8	25	44	56	144	22	
15	10	25	44	87	175	31	
16	10	44	100	12	200	25	
17	10	44	100	22	209	9	
18	10	44	100	31	219	10	
19	12	112	44	3	247	28	
21	12	119	62	3	283	36	
24	12	119	125	25	350	67	
25	12	119	137	50	387	37	
28	12	119	137	100	437	50	One bud is seen at 5th node.
Mar. 2	14	137	119	6	467	25	
5	14	137	125	19	519	47	
8	14	137	125	22	522	3	
12	14	137	125	25	525	3	Bud noted on 28th is a flower bud. There is a second flower-bud.

Stem referred to above, died down, and a branch is recorded below.

Mar. 16	4	31	31	3	66	....	
19	4	31	37	6	75	9	
21	4	31	37	12	81	6	
24	4	31	44	37	112	31	Second flower-bud broken accidentally.
26	6	44	56	3	134	22	
31	6	44	62	19	156	22	
April 4	6	44	62	28	166	10	
8	6	44	62	28	166	0	Flower-bud developing naturally.

Another branch developed which is recorded below; the one recorded above had ceased to grow. The flower mentioned on February 28th dropped off.

April 23	6	31	44	6	81	....
28	8	47	44	6	109	28
May 5	8	47	44	6	109	0
7	8	47	44	6	109	0
11	8	50	47	6	116	7
15	8	50	47	6	116	0

Another branch developed.

May 18	2	....	19	3	22	....	
20	4	....	19	9	28	5	
23	4	19	16	3	37	9	
25	4	19	22	3	44	6	
27	4	19	25	3	47	3	
June 6	4	19	28	6	53	6	End of experiment; plant living. (118 *days*).

PLANT 1 B.—OBSERVATIONS.

Date, 1900.	No. of leaves.	Length of last internodes.			Total length.	Increase.	Remarks.
		m.m.	m.m.	m.m.	m.m.	m.m.	
Feb. 9	3	....	100	12	112	....	
11	3	....	100	16	116	4	
12	3	....	100	16	116	0	
13	4	....	100	25	125	9	
15	4	....	100	28	128	3	
16	4	100	31	3	134	6	
17	4	100	37	3	141	7	
18	4	100	44	3	147	6	
19	4	100	44	6	150	3	
21	4	106	44	9	159	9	
24	4	106	44	9	159	0	
25	4	106	44	9	159	0	Chlorotic.
27	4	106	44	9	159	0	Very chlorotic.
28	....	....	....	....	....	....	Dead ; killed apparently by fungi. (19 *days*).

PLANT 1 C. SUBSTITUTED.

Date, 1900.	No. of leaves.	m.m.	m.m.	m.m.	Total length.	Increase.	Remarks.
Mar. 8	4	19	75	37	144	....	
12	4	50	37	31	206	62	
16	5	50	37	25	275	19	
19	5	50	37	37	237	12	
21	5	50	50	44	256	19	
24	5	50	50	44	256	0	Dying down from top and attacked by fungi.
26	5	50	50	44	256	0	
31	....	....	....	....	....	....	Plant taken from the jar, carefully cleaned and replaced.
April 4	....	....	....	....	....	....	PLANT 1 C. living but attacked by aphides.
8	....	....	....	....	....	....	" beginning to thrive again.
23	....	....	....	....	....	....	" thriving vigourously.
28	....	....	....	....	....	....	" thriving well and a small branch growing from near base.
May 7	....	22	19	3	66	....	
11	....	129	3	109	43	....	
15	....	19	37	19	175	66	Growing very rapidly.
18	....	37	50	19	178	3	
20	....	37	62	37	209	31	
23	...	75	62	19	278	69	
25	....	69	22	3	291	4	
June 6	....	75	31	19	322	31	Plant healthy. (90 *days*).

PLANT 2 A.—OBSERVATIONS.

Date, 1900.	No. of leaves.	m.m.	m.m.	m.m.	Total length.	Increase.	Remarks.
Feb. 9	4	0	22	22	44	....	
11	4	22	22	6	50	6	
12	4	22	25	6	53	3	
13	5	22	25	12	59	6	
15	6	25	25	3	75	16	
19	6	25	25	3	75	16	Leaves losing colour.
24	6	25	25	3	75	16	Leaves dropping.
Mar. 2	6	25	25	3	75	16	
5	6	25	25	3	75	16	Plant dead. (24 *days*)

PLANT 2 A.—*Continued.*

New plant substituted—same species.

Date. 1900.	No. of leaves.	Length of last internodes.			Total length.	Increase.	Remarks.
		m.m.	m.m.	m m.	m.m.	m.m.	
Mar. 8	5	12	31	12	67	....	
12......	6	12	31	31	87	25	
16......	5	37	31	19	112	25	
19......	5	37	37	19	119	7	
21	6	37	37	19	119	0	
24.. ...	6	37	37	19	119	0	Two lateral branches starting.
26.....	6	37	37	19	119	0	Plant dying from top.
31	7	37	37	19	119	0	Leaves turning yellow.
April 4......	7	37	37	19	119	0	Leaves dropping.
8......	4	37	37	19	119	0	
23......	4	37	37	19	119	0	Plant dead. (46 *days*).

PLANT 2 B.—OBSERVATIONS.

Feb. 9......	3	0	100	12	112	....	
11......	4	0	100	12	112	0	
12......	4	25	100	16	116	4	
13......	4	100	34	6	125	9	
15......	4	100	34	6	141	16	
16......	4	100	37	12	159	9	
17......	4	100	37	16	153	3	
18......	4	44	19	3	166	13	
19......	4	44	19	3	169	3	
21......	4	44	22	16	184	15	
24......	5	34	25	12	212	38	
25	6	34	34	19	225	13	
28......	7	34	34	22	228	3	
Mar. 2......	6	37	37	25	231	3	
5......	7	37	31	6	244	13	
12... ..	7	37	37	9	256	12	
16......	8	37	37	19	266	10	
19......	8	37	19	3	269	3	
21......	8	37	19	3	269	0	
26......	8	37	19	3	269	0	Losing colour and dying from top.
31......	8	37	19	3	269	0	*Apparently dying.*
April 4......	8	37	19	3	269	0	Losing turgor and leaves dropping.
8....	8	37	19	3	269	0	Dying.
23......	8	37	19	3	269	0	Dead. (73 *days*).

PLANT 3 A.

Date, 1900.	No. of leaves.	Length of last internodes.			Total length.	Increase.	Remarks.
		m.m.	m.m.	m.m.	m.m.	m.m.	
Feb. 9.....	6	....	19	6	25	....	
11	6	....	19	12	31	6	
12......	6	....	19	12	35	4	
13.....	6	....	19	12	35	0	
15......	6	...	19	12	35	0	
16	6	....	19	12	35	0	
17......	4	...	19	12	35	0	
18	4	19	12	3	34	3	
19......	4	19	12	3	34	3	
24.. ...	4	19	12	3	44	9	
25......	4	19	12	3	44	9	
28......	4	19	12	3	44	0	
Mar.	4	19	12	3	44	0	
5......	4	19	12	3	44	0	
12......	6	12	16	3	50	3	
16......	6	16	37	9	69	16	
21......	5	12	37	16	75	6	
26......	4	12	37	16	75	0	
31.....	4	12	37	16	75	0	Top dead; a branch springing from base.
April 4.....	4	12	37	16	75	0	" "
8......	4	12	37	16	75	0	Growth confined to branch.
BRANCH.							
Apr. 28......	4	....	19	12	....	....	Plant not dead but seems stunted, and growth so slow that no further observations are taken. (68 *days*).

PLANT 3 B.

Date, 1900.	No. of leaves.	Length of last internodes.			Total length.	Increase.	Remarks.
		m.m.	m.m.	m.m.	m.m.	m.m.	
Feb. 9......	3	0	62	6	69	....	
11	4	0	62	12	75	6	
12......	4	0	75	19	94	19	
13......	4	0	87	22	109	15	
15......	4	0	87	25	112	3	
16......	4	0	87	37	125	13	
17	4	87	37	3	128	3	
18......	4	87	44	9	141	13	
19......	4	87	44	12	144	3	
21.....	4	44	25	3	159	15	
24......	4	44	50	3	184	25	
25......	4	44	50	19	200	16	
28	5	44	50	25	206	6	
Mar. 2......	5	44	50	37	219	13	
5.....	5	50	44	3	228	9	
12......	5	50	50	37	269	41	
16......	5	50	50	37	269	0	and lateral branch.. 12
21... ..	5	50	50	37	269	0	" " 16
26......	4	50	50	37	269	0	" " 19
31......	4	50	50	37	269	0	" " 25
April 4......	5	....	....	....	....	..	Growing very slowly; flowers all dropping.
28......	5	....	....	....	....	....	Growing very slowly; seems to have spent its energy in flowering. (78 *days*).

PLANT 4 A.

Date, 1900.	No. of leaves.	Length of last internodes. m.m.	m.m.	m.m.	Total length. m.m.	Increase. m.m.	Remarks.
Feb. 9	7	22	22	3	47	....	
11	7	22	37	3	62	15	
12	7	22	44	6	72	10	
13	7	25	50	16	91	19	
15	6	25	50	37	112	21	
16	6	25	50	50	125	13	
17	6	25	50	53	128	3	
18	8	56	75	3	159	31	
19	8	56	81	3	166	7	
24	5	56	87	9	178	6	
25	5	56	87	16	184	6	
28	4	56	87	19	187	3	
Mar. 2	4	56	87	25	206	19	
5	4	56	87	25	206	0	Leaves turning white.
10	4	56	87	31	212	6	
12	2	56	87	31	212	0	Almost dead, excepting a lateral branch near the base.
BRANCH.							
Mar. 16	2	....	....	19	....	....	
19	2	....	....	22	....	....	
21	2	....	....	22	....	....	
26	2	....	....	22	....	....	
31	2	....	.	22	....	....	
April 4	0	....	....	....	....	....	Dead. (54 *days*).

PLANT 4 B.

Date, 1900.	No. of leaves.	m.m.	m.m.	m.m.	Total length. m.m.	Increase. m.m.	Remarks.
Feb. 9	3	....	87	12	100	....	
11	4	....	87	37	125	25	
12	4	87	44	12	144	19	
13	4	87	50	16	153	9	
15	4	87	50	19	156	3	
16	4	87	50	22	159	3	Commencing to flower.
17	5	25	12	6	200	41	
18	6	25	22	6	209	9	
19	6	25	22	6	212	3	
21	6	25	22	6	212	0	
24	6	25	22	6	212	0	
25	6	25	22	6	212	0	
Mar. 2	6	25	22	6	212	0	Lateral bud developing.. 19
5	5	25	22	6	212	0	" " 19
10	4	25	22	6	212	0	" " 19
12	4	25	22	6	212	0	
16	4	25	22	6	212	0	Dying down.
19	4	25	22	6	212	0	Branch dies.
21	4	25	22	6	212	0	
26	3	25	22	6	212	0	
31	2	25	22	6	212	0	
April 4	2	25	22	6	212	0	Dead. (54 *days*).

SERIES IV.

The following series of experiments was carried on in the basement of the University Museum, and was set up on December 21st, after the manner shown in Fig. 7.

All the plants used were of the species Thunbergia alata.

Plant A. In a spray of nutrient solution, roots in distilled sterilized water, Fig. 7.

Plant B. Same as A.

Plant C. Plant under bell-jar, roots in distilled sterilized water, no spray.

Plant F. Same as C.

Plant E. Plant under bell-jar, roots in a nutrient solution half the concentration of that given on page 238, no spray.

Plant D. Same as E.

Plant G. Plant with roots in distilled sterilized water, spray of distilled water, Fig. 7.

Plant H. Same as G.

A.

Date.	No. of leaves.	Length of internodes.						Remarks.
Dec. 21	4	25	7					Poorest plant and not very green.
24	6	30	9					
27	6	30	12	5				One cotyledon yellow.
31	4	30	12	8				Cotyledons dropped.
Jan. 3	6	30	16	15				
7	6	30	16	35	4			
10	6	30	15	40	12			
14	8	30	15	40	25	2		
18	8				40	10		
24	8				65	220		
29	7				68	20		One leaf dropped.

A. 1.

Date.	No. of leaves.	Length of internodes.						Remarks.
Feb. 1								Plant removed; broken by accident; strong one substituted.
2	11	65	3					
5	11	75	10					
11	13	75	40	3				
25	17	75	70	90	20			Two leaves dropped.
Mar. 10	10	75	70	90	95	80		Three well marked flower buds.
18	8	75	70	90	95	85		Flower opening.

A.—41 *days*: A. 1.—46 *days*, *plus*, very healthy at the close of the experiment.

B.

Date.	No. of leaves.	Length of internodes.						Remarks.
Dec. 21	6	25	6					Plant small and not healthy looking
24	6	25	9					
27	6	25	9	2				
31	4	28	9	3				Cotyledons dropped.
Jan. 3	4	28	9	5				
7	6	28	9	7				
10	5	28	9	7				One leaf dropped.
14								Died down seemingly.
15								Revived.
18								Bent over and apparently dying.
19	Taken out and replaced by another which had been kept in soil in case of accident. (29 *days*).							
19	6	10	25	3				
24	6	10	25	10				
29	8	10	25	30	5			
Feb. 5	8	10	25	45	12			
11	6			45	15			Two leaves dropped.
25	4				50	3		Four leaves dropped.
Mar. 10	2							Broken down by accident.
18								Dead. (58 *days*).

F.

Date.	No. of leaves.	Length of internodes.						Remarks.
Dec. 21	4	20	4					Medium in quality.
24	4	21	4					
27	6	21	3					
31	6	21	30	8				
Jan. 3	6	21	32	18				
7	7	21	35	30				One cotyledon dropped.
10	6	21	35	50	12			Two cotyledons dropped.
14	6	21	35	55	35			Lower leaves chlorotic.
18	6							Lower leaves gone.
24	6			60	60			
28								Broken off at lowest internode.
	BRANCH RECORDED.							
Feb. 5	5	12						*One leaf dropped.*
11	3	12	2					Leaves turning yellow.
25	4	12	8					
Mar. 10	2	12	10					Leaves yellow.
18	2	12	12					Leaves yellow. (87 *days, plus*).

C.

Date.	No. of leaves.	Length of internodes.						Remarks.
Dec. 21	4	28	15					
24	6	30	18					
27	6	30	28	10				Two cotyledons dropped.
31	4	30	28	30				
Jan. 3	6	30	28	55	12			
7	6	30	28	60	25			
10	6	30	28	60	70			
14	7	30	28	60	100	20		Two lower leaves chlorotic.
18	6	30	28	65	110	45		
24						50		
29						60		
	BRANCH RECORDED.							
Feb. 5	4	2						Leaves turning yellow.
11	3							
25	4	5	8					Chlorotic.
Mar. 4	2	5	8					"
18	4	5	8	8				" (87 *days, plus*).

E.

Date.	No. of leaves.	Length of internodes.						Remarks.
Dec. 21	4	40	5					
24	4	40	12					
27	6	40	30	3				
31								Plant wilted down.
	SUBSTITUTE.							
Feb. 1	8	100	3					
5	8	110	15					
11	8	110	45					
25	12	120	55					
	BRANCH RECORDED.							
11	12	8						
25	15	25	20					
Mar. 10	15	30	40	110	120	10		
18	15	30	50	125	175	145	15	

E.—41 days; substitute (46 *days, plus*).

D.

Date.	No. of leaves.	Length of internodes.						Remarks.
Dec. 21	6	40	18	...	...	...	...	
24	6	40	22	...	...	...	...	
27	6	40	25	8	...	...	...	
31	5	40	25	25	...	...	...	One cotyledon dropped.
Jan. 3	6	40	25	35	5	...	...	
7	6	40	25	40	8	...	...	
10	6	40	25	40	10	...	...	
14	4	40	25	40	12	...	...	Lower leaves wilting.
23	4	...	...	...	12	...	...	
24	4	...	...	...	15	...	...	
29	6	...	...	...	25	...	...	
Feb. 5	6	...	...	...	25	...	...	
11	8	...	...	...	28	...	...	
	BRANCH RECORDED.							
11	8	3	...	...	...	...	...	
25	10	3	15	...	...	...	...	
	3	3	...	...	...	...	...	
Mar. 10	10	3	15	20	...	...	...	
		3	15	...	...	...	...	
18	12	3	15	20	30	...	...	
		3	25	...	...	...	...	(87 *days*).

G.

Dec. 21	6	20	6	...	...	...	...	Best plant in the series.
24	6	20	13	5	...	...		
27	6	20	18	8	...	...	...	
31	6	20	18	20	...	...	...	Two cotyledons dropped.
Jan. 3	6	20	18	40	3	...	...	
7	6	20	18	50	25	...	...	
10	8	20	18	50	50	5	...	
14	8	20	18	50	60	25	...	
18	10	...	...	...	...	80	10	
24	10	...	...	...	...	100	20	
29	8	...	...	...	...	100	25	Branch at first node.
Feb. 11	9	12	3	...	...	...	...	
25	4	10	15	3	...	...	...	
Mar. 20	4	10	15	30	...	...	...	Slightly chlorotic.
18	2	10	15	30	...	...	...	Chlorotic. (87 *days*).

H.

Date.	No. of leaves.	Length of internodes.						Remarks.
Dec. 21......	4	18	6	....	....	....	....	
24.....	6	18	15	....	....	....	....	
27	6	18	15	5	....	....	..	
31	4	18	18	10	....	....	....	Cotyledons dropped.
Jan. 3......	6	18	18	25	....	....	....	
7......	6	18	18	45	5	....	...	
10	6	....	....	50	10	....	....	
14......	6	....	....	50	25	...	.. .	
18.. ...	7	....	....	....	50	10	....	
24.....	7	....	....	....	55	18	....	
29......	7	....	....	....	55	20	....	Branch at first node.
	BRANCH RECORDED.							
Feb. 5......	8	30	5	....	....	....	....	
11......	4	35	10	. ..	....	....	. ..	
25.....	4	35	15	....	....	....	....	
Mar. 10......	3	35	20	....	....	..	....	
18......	....	....	....	....	....	...	...	Dead. (85 *days*).

From these experiments certain conclusions may be drawn, an investigation into which would throw some light, not only upon the absorption of non-poisonous dilute solutions, but also upon the question of water-absorption. The plants best suited to this foliage culture are those whose leaves are adapted to moist conditions, and those whose roots are fibrous and numerous. Those having tap-roots will draw upon the food stored in the tap-root, defeating, to some extent, the results of the experiments. If plants can utilize food solutions applied to their leaf surfaces, it may be that rain-water, after a period of dry weather more or less prolonged, falling upon leaves, aids directly in nourishing the plants. Galloway and Woods have shown that lime-water used as a spray acts as a food, or at least produces a growth distinctly above the normal. It is now known that the bordeaux mixture causes an increase in growth by supplying food, or by action in the nature of a stimulus.

The nutrient solution applied to the leaves produced a substantial increase in growth, indicating that the solution was absorbed, or that it acted as a stimulus, or both. The conclusions in regard to growth are based upon :—(1) large increase in number of leaves and in total leaf area, (2) increase in length of stem, (3) the production of flowers, coupled with a general appearance which can scarcely be described in words and figures. In the case of the plant Helianthus, the solution used seemed to be too strong when applied to the roots as well as when applied to the leaves. The effects, though in a measure injurious, were similar, making it seem probable that the solution was absorbed.

The effect of water used as a spray was to stimulate growth for a time, then to produce a chlorotic unhealthy appearance. In the case of the buckwheat plant, the characteristic reddish colour of the stem was maintained where the nutrient solution was applied to the leaves, as well as when applied to the roots. Where the spray was of water the stems became pale. These experiments being carried on through such an extended period of time give strength to the conclusions reached. It will be noticed in a few cases that accidents happened to the plants, owing to frequent manipulation of the apparatus necessary to carry on the work. This was unavoidable.

To sum up we may say, that a nutrient solution when applied to the leaves affected the plants as did the solution when applied to the roots, that the nutrient solution produced a substantial growth, and that water used as a spray stimulated growth for a time.

In order to ascertain more fully the effect of the nutrient solution applied to the leaves in this way, it was thought that an estimation of the ash content would throw some light upon the matter.

The following experiment was designed to determine the effect upon the content of ash by feeding a plant with a nutrient solution applied to the leaves in the form of a spray (Fig. 7). Eight plants of the same species (Justicia speciosa) were selected so as to have them as nearly as possible uniform in size and quality. They were divided into two groups of four each, the division being made so as to have by estimation the same amount of ash in each group. This was of course only an approximation, but it was made in such a way as to leave error, if error there was, on the safe side. The selection of plants was not made by the writer.

Group I.—M, N, O, P; Group II.—A, B, G, H.

The plants of Group I. were at once dried and then analyzed to ascertain the content of ash. Those of Group II. were fed, as described above, for seventeen days, when they also were dried, weighed and analyzed in a similar way. The plants in both cases were dried first in air, and then for two days in a desiccator for dry weight calculations.

The following tables show the results of the experiment; weight given in grams, length of stem in centimeters :—

I.

Plant.	Leaves.	Length of stem.	Weight dry.	Weight of ash.	Per cent. of ash to dry weight.
M	8	14	.2631	.0045	16.91
N......	8	15	.3900	.0610	15.64
O...............	6	12	.1719	.0281	16.34
P.............. .. .	8	11	.3930	.0653	16.61
	30	52	1.2180	.1589	

Average per cent. of ash to dry weight 16.37.

II. a.

A..................	6	10	....	.	..
B.......	6	12	...	.	. . .
G	8	14	..	.	..
H	8	11	...		..
	28	47	...	....	...

II. b.

A......	8	11	.3281	.0592	18.04
B.....	8	14	.3667	.0663	18.08
G....	12	22	.5722	.1005	17.56
H	10	14	.3575	.0640	17.90
	38	61	1.6243	.2900	. ..

Average per cent. of ash to dry weight, 17.89.

Gain per cent. in		number of leaves	35.7
"	"	length of stem..	29.7
"	"	dry weight................	33.37
"	"	ash...........	82.5

The plants fed with the nutrient solution *contained 1.52 per cent. more ash*, in proportion to dry weight, than did those which were not fed.

The important point brought out in this experiment is, that each plant of Group II. (those fed with a nutrient solution in the form of a spray), contained a higher per cent. of ash in proportion to dry weight than did those of Group I. This is the more striking because it does not depend upon approximations, as do the comparisons in weight with Group I. Since it is impossible to calculate the amount of ash in a living plant in order to ascertain if that plant makes any increase, it is necessary in all such investigations to base results upon estimates with similar plants grown under similar conditions.

The results of this experiment support the conclusions arrived at in regard to the effect of nutrient solutions applied to leaves in the form of a spray. There is not only a visible increase in number of leaves and in length of stem, but also a substantial increase in dry weight and in weight of ash. Since the actual content of ash in proportion to dry weight is increased, there can remain no doubt that the leaves had absorbed some of the substance applied in the form of a spray.

VII.—THE EFFECTS OF STRONG SOLUTIONS APPLIED TO THE CUT ENDS OF THE PETIOLES OF FOLIAGE LEAVES.

It was necessary first to determine whether solutions when applied to the cut ends of the petioles of leaves ascended through the blades. It was found by chemical analysis that solutions did ascend through the blade of the leaf even to the margin. This having been proved, it was then possible to investigate the effects of solutions entering leaves in this way. The leaves were placed in solutions as shown in Fig. 8, and the records of the experiments are self-explanatory.

For the first series of experiments leaves of the following plants were chosen:—Malva, Primula, Nicotiana, Ranunculus and Dicentra.

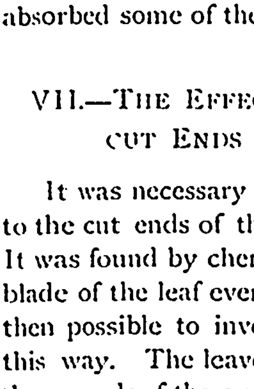

FIG. 8.

S., solution used; A., cardboard cover to prevent too rapid evaporation.

In twenty-four hours after setting up the experiment, solutions (HCl) and (H_2SO_4) produced a decolorization of the leaf tissue from the base of the leaves outwards in all the leaves, especially so in the leaves of Primula and Nicotiana. This decolorization, in some cases was slightly more extensive in the region of the large veins, but had when small the shape of a semicircle whose centre was at the junction of the petiole and the blade of the leaf. Solution (NH_4OH) had caused a blackening of the tissue in the part of the blade nearest the petiole; and had produced a deepening of the green colour out towards the margin. Solution ($NaHCO_3$) had caused a "frozen" appearance between the main veins, extending from the margin inwards, especially so in the case of Nicotiana.

On October 15th, seventy-two hours after the leaves had been placed in the solutions, observations were made upon all the leaves and records taken.

$FeSO_4$ *m/16, veins blackening generally but in the case of the Dicentra there was a blackening up the centre.

$ZnSO_4$ m/4, Malva dry, Dicentra whitish up the centre, and the others limp with a freckled appearance.

$HgCl_2$ m/16, leaves all dead ; salt ascending except in Dicentra, brown from the base outwards along the chief veins.

$CuSO_4$ m/16, all dead, with the apparent exception of Dicentra, which seems to be living ; Ranunculus is darkened all over ; Malva dried with a deep green margin.

$Ba(NO_3)_2$ m/4, Malva crisp from the margin inwards, especially between the chief veins ; Dicentra dry along margin.

KCl m/2, Malva dried and salt had crept well out along the veins, Dicentra wilting at the margin.

Na_2CO_3 m/4, Malva dried and discoloured outward from a yellowish green to dark ; Ranunculus darkened on the veins, with the dark colour spreading ; Dicentra dry at the margin.

HCl m/4, all brownish from the base outward, the region next the margin is green and apparently living.

H_2SO_4 m/4, similar effect to that produced by HCl, but rather more extensive decolorization, especially so in Ranunculus.

KOH m/4, dark from the base outward with all the leaves resembling the effect produced by Na_2CO_3.

NaOH m/4, same effect as KOH.

NH_4NO_3, m/2, all slightly wilted, and some have a frozen appearance near the margin.

$NaHCO_3$ m/4, all wilted dry and Ranunculus darkened.

NH_4OH 5%, all wilted and dead ; Malva very dry.

* "m" is a solution made by dissolving the mol. wt. in grams of the substance in a liter of water, thus $FeSO_4$ m/16 means 152 grams in 16 liters of water.

Glycerine m/2, all fresh, Nicotiana spotted.

Gr. sugar m/2, all fresh.

Ca. sugar m/2, all fresh.

$MgCl_2$ m/2, similar to KCl.

NaCl m/2, similar to that of KCl.

It was found that in ten to twelve hours after taking the leaves from the solutions some of them underwent other changes worthy of note. The part of the blade of the leaf turned yellowish-brown by the acids had changed to a bluish colour, showing that very probably the tissue was undergoing further changes, resulting in a product having an alkaline reaction.

Judging from their effects. these substances may be classified as follows :—

Acids .... HCl, H_2SO_4.
Alkalies .... KOH, NaOH.
Decomposable alkalies.......... Na_2CO_3, NH_4OH.
Poisons......................... $CuSO_4$, $HgCl_2$, $Pb\bar{A}_2$, $FeSO_4$, $ZnSO_4$.
Osmotically active substances..$MgCl_2$, KCl, NH_4NO_3, etc.

In a second series of experiments the arrangement was as shown in Fig. 8. and continued for three days, when the leaves were taken from the solutions, and observations made upon their conditions then and afterwards. The acids, in a measure, acted as did the alkalies, showing that these substances alike penetrate readily the walls of the cells in all directions, and do not follow the veins. Acids and alkalies to some extent dissolve the cellulose, and so make a way for themselves readily in all directions.

LEAF OF PRIMULA STELLATA, PLACED AS IN FIG. 8.

I.

Strength of Solution, m/4 ; set up November 9th.

Solution.	Died in.	Remarks.
NaCl..........	16 days	Salt ascended.
$Ba(NO_3)_2$......	1 day	
$KClO_3$........	2 days	
KCl...........	18 days	Salt ascended.
$MgCl_2$.........	8 days	
KNO_3..........	10 days	Salt ascended.
Na_2CO_3.....	4 days	Like that of NaOH.

I.—*Continued.*

Solution.	Died in.	Remarks.
$ZnSO_4$	2 days	Depressed spots.
KI	3 days	
KBr	7 days	
HCl	3 days	Petiole and base of leaf very red.
H_2SO_4	2 days	Like that of HCl.
NaOH	3 days	Petiole and base blue.
KOH	2 days	Stronger than that of NaOH.
NH_4OH 2.5%	2 hrs.	Killed by gas, not by solution.
$CaCl_2$	4 days	
c. sugar	5 days	
g. sugar	4 days	Sugar decomposed and leaf killed probably by an [acid.
Glycer.	4 days	Became freckled.
$NaHCO_3$	4 days	Salt ascended.
NH_4NO_3	6 days	Bluish, due to a decomposition NH_4NO_3.
K_3PO_4	1 day	Seem to be very poisonous.

II.

Strength of Solution, m/8: November 21st.

NaCl	11 days	
$Ba(NO_3)_2$	2 days	Crisp.
$KClO_3$	3 days	Veins lighter.
$CuSO_4$	1 day	Limp.
KCl	15 days	Salt ascending.
$MgCl_2$	9 days	Base blue.
KNO_3	15 days	Water in intercellular spaces as if frozen.
Na_2CO_3	6 days	Base blue.
$ZnSO_4$	2 days	Frozen appearance.
KI	2 days	Acted between the veins first.
KBr	9 days	Freckled.
$FeCl_3$	2 days	Veins not blackened.
$Pb\bar{A}_2$	2 days	
$HgCl_2$	2 days	
HCl	3 days	Base and petiole red.
H_2SO_4	3 days	Same as for H_2SO_4.
NaOH	6 days	Base blue.
KOH	5 days	Similar to NaOH.
NH_4OH	1 day	(1.75% strength), base blackened.
$CaCl_2$	7 days	
$FeSO_4$	2 days	Veins blackened.
g. sugar	6 days	
$NaHCO_3$	5 days	Salt ascending.
NH_4NO_3	7 days	
K_3PO_4	1 day	
c. sugar	14 days	
Glycer.	16 days	

III.

Strength of Solution, m/16; December 1st.

Solution.	Died in.	Remarks.
NaCl	27 days	Salt ascended, turned yellow.
$Ba(NO_3)_2$	2 days	Wilted first between the veins.
$KClO_3$	8 days	Wilted from the margin.
$CuSO_4$	1 day	Limp.
KCl	18 days	Margin bluish.
$MgCl_2$	8 days	
KNO_3	36 days	Salt ascended.
Na_2CO_3	5 days	Salt ascended, base blue.
$ZnSO_4$	4 days	Bluish between veins, light green above.
KI	6 days	Margin crisp.
KBr	7 days	Margin crisp.
$FeCl_3$	5 days	Limp, veins not blackened.
$Pb\bar{A}_2$	1 day	Bluish.
$HgCl_2$	1 day	Died from the base outward.
HCl	2 days	Petiole and base red.
H_2SO_4	2 days	Same as HCl.
NaOH	10 days	Base blue.
KOH	8 days	Same as NaOH.
NH_4OH	7 days	(.625%) base blackened.
$CaCl_2$	35 days	Spotted bluish at margin.
$FeSO_4$	2 days	Veins blackened
c. sugar	14 days	Turned yellow.
g. sugar	8 days	Killed by an organic acid (probably $C_3H_6O_3$.
glycer.	14 days	Did not turn yellow.
$NaHCO_3$	10 days	Salt ascended.
NH_4NO_3	14 days	Did not turn yellow.
K_3PO_4	2 days	Limp.

IV.

Strength of Solution, m/32: December 12th.

NaCl	41 days plus	Fairly fresh.
$Ba(NO_3)_2$	2 days	Blue.
$KClO_3$	16 days	Glazed looking, veins light green.
$CuSO_4$	1 day	Limp.
KCl	33 days	
$MgCl_2$	16 days	Turned yellow.
KNO_3	36 days	Wilted.
Na_2CO_3	9 days	Salt ascended, bluish spots.
$ZnSO_4$	5 days	Blue spots on back.
KI	8 days	Crisp margin.
KBr	41 days	Salt ascended.
$FeCl_3$	8 days	Wilted from margin.
$Pb\bar{A}_2$	2 days	Veins dark towards the margin, blue.
$HgCl_2$	4 days	Yellow up the veins.
HCl	3 days	Petiole red.
H_2SO_4	3 days	
NaOH	18 days	Salt ascended.
KOH	11 days	Salt ascending.
NH_4OH	1 day	(.3125%) base blackened.

IV.—*Continued.*

Solution.	Died in.	Remarks.
$CaCl_2$	41 days plus	
$FeSO_4$	2 days	Veins darkened, blade blue.
c. sugar..........	14 days	Turned yellow.
g. sugar..........	15 days	Solution acid.
glycer..........	24 days	
$NaHCO_3$..........	17 days	Salt ascended.
NH_4NO_3	14 days	Wilted from margin.
K_3PO_4.	2 days	Died from margin.

V.

Strength of Solution, m/64: January 5th.

NaCl..........	54 days plus	
$Ba(NO_3)_2$	3 days	Bluish.
$KClO_3$	4 days	
$CuSO_4$..........	1 day	Very limp.
KCl	27 days	Spotted yellow, salt ascended.
$MgCl_2$..........	14 days	Turned yellow.
KNO_3	30 days	Turned yellow.
Na_2CO_3..........	36 days	Limp.
$ZnSO_4$	3 days	Freckled on upper side, spotted blue on back.
KI..........	5 days	Base bluish.
$FeCl_3$	4 days	Veins not blackened.
$Pb\bar{A}_2$	2 days	Blade stiff, not limp, back blue.
$HgCl_2$..........	5 days	Petiole blue.
HCl	5 days	Petiole red.
H_2SO_4..........	4 days	Petiole and base red.
NaOH	14 days	Very limp second day, turgor restored on third day.
KOH..........	11 days	Very limp second day, turgor restored on third day.
NH_4OH	1 day	(.3125%) base blackened.
$CaCl_2$	54 days	
$FeSO_4$	5 days	Veins blackened.
c. sugar..........	12 days	Wilted, not yellow.
g. sugar..........	10 days	Solution reddened.
glycer..........	54 days plus	
$NaHCO_3$.	14 days	Gradually wilted down.
NH_4NO_3	17 days	
K_3PO_4..........	6 days	Died from margin.
KBr..........	47 days	Turned yellow.

VI.

Strength of Solution, m/128: January 22nd.

NaCl	44 days plus	Salt ascending.
$Ba(NO_3)_2$	5 days	Spotted.
$KClO_3$	4 days	Crisp margin.
$CuSO_4$..........	1 day	Limp.
KCl	44 days plus	Salt ascending.
$MgCl_2$	30 days	Turned yellow as it wilted.
KNO_3	44 days plus	
Na_2CO_3..........	30 days	Crisp margin, turned yellow as it died.
$ZnSO_4$	13 days	Back of leaf blue.
KI	14 days	Margin blue.

VI.—*Continued.*

Solution.	Died in.	Remarks.
KBr	44 days plus	Salt ascending.
$FeCl_3$	4 days	Margin, blue, veins not blackened.
$Pb\bar{A}_2$	14 days	Petiole blue.
$HgCl_2$	4 days	Base most affected, petiole blue.
HCl	4 days	Petiole red.
H_2SO_4	4 days	Petiole red.
NaOH	44 days plus	Salt ascending.
KOH.	29 days	Salt ascending.
NH_4OH	34 days	Much wilted second day, but recovered afterwards [(.15625%).
$CaCl_2$	44 days	
$FeSO_4$	4 days	Veins blackened.
c. sugar	13 days	Petiole decomposing.
g. sugar	12 days	Petiole decomposing.
glycer.	44 days plus	
$NaHCO_3$	34 days	Became yellow from margin.
NH_4NO_3	32 days	Yellow margin.
K_3PO_4	5 days	

Summary of records of experiments I., II., III., IV., V., VI. The figures in the vertical columns denote the time required (in days) to kill the leaf. The letter "p" after a number indicates that the leaf was living and fresh at the termination of the experiment.

Solution.	m/4	m/8	m/16	m/32	m/64	m/128
NaCl	16	11	27	41p	64p	44p
KCl	18	15	18	33	27	44p
KNO_3	10	15	36	36	30	44p
$CaCl_2$	4	7	35	41p	54p	44p
$MgCl_2$	8	9	8	16	14	30
Na_2CO_3	4	6	5	9	36	30
KBr	7	9	7	41	47	44p
$KClO_3$	2	3	8	16	4	4
KI	3	2	6	8	5	14
NaOH	3	6	10	18	14	44p
KOH	2	5	8	11	11	29
glycerin	4	16	14	24	54p	44p
$FeCl_3$	—	2	5	8	4	4
$FeSO_4$	—	2	2	2	5	4
K_3PO_4	1	1	2	2	6	5
$CuSO_4$	—	1	1	1	1	1
$NaHCO_3$	4	5	10	17	14	34
NH_4NO_3	6	7	14	14	17	32
$Ba(NO_3)_2$	1	2	2	2	3	5
$Pb\bar{A}_2$	—	2	1	2	2	14
$HgCl_2$	—	2	1	4	5	4
HCl	3	3	2	3	5	4
H_2SO_4	2	3	2	3	4	4
c. sugar	5	14	14	14	12	13
g. sugar	4	7	8	15	10	12
$ZnSO_4$	2	2	4	5	3	13

Experiments with solutions applied to the cut ends of the petioles of leaves (Fig. 8). May and June.

I.—LEAF OF PRIMULA OBCONICA.

Solution.	Strength.	Time to kill.	Remarks.
*1	m/4	5 days	Wilted from margin.
2	"	10 days plus	
3	"	9 days	Wilting.
4	"	9 days	Wilting.
5	"	6 days	Large veins turning white.
6	"	5 days	Veins blackening from base.
7	m/400	8 days	Spotted.
8	m/4	2 days	Very crisp.
9	m/400	10 days plus	Very healthy looking.
10	—	10 days plus	
11	—	10 days plus	

II.—LEAF OF CUCURBITA.

1	m/4	10 days	Margin became crisp.
2	"	9 days	
3	"	7 days	Trichomes much swollen.
4	"	6 days	Covered with crystals.
5	"	9 days	Turned dark brown.
6	m/50	3 days	Veins black.
7	m/400	6 days	Veins turned yellow.
8	m/4	2 days	Coated over with crystals.
9	m/400	10 days plus	Very green but glossy.
10	—	10 days plus	Turning yellow at margin.
11	—	10 days plus	Turning yellow at margin.

III.—LEAF OF TRAPAEOLUM.

1	m/4	1 day	Soft.
2	"	1 day	Dry.
3	"	1 day	Dry.
4	"	1 day	Soft.
5	"	1 day	Soft.
6	m/50	1 day	Dry.
7	m/400	1 day	Dry.
8	m/4	2 days	
9	m/400	10 days plus	Very fresh looking.
10	—	9 days	Wilted from margin.
11	—	2 days	Crisp.

*1. NH_4NO_3; 2. KCl; 3. $MgCl_2$; 4. KNO_3; 5. $NaHCO_3$; 6. $FeSO_4$; 7. $HgCl_2$; 8. $Ba(NO_3)_2$; 9. $Pb\bar{A}_2$; 10. H_2O dist.; 11. H_2O tap.

IV.—LEAF OF LUPINE.

Solution.	Strength.	Time to kill.	Remarks.
1	m/4	5 days	Had a tendency to curl.
2	"	4 days	Same as 1.
3	"	5 days	
4	"	5 days	Tendency to curl.
5	"	5 days	Much curled.
6	m/50	2 days	Veins black.
7	m/400	1 day	Veins yellowish.
8	m/4	2 days	Salt on surface.
9	m/400	10 days plus	Very fresh looking.
10	—	8 days	Dried spotted yellow.
11	—	7 days	Spotted.

V.—LEAF OF PRIMULA OBCONICA.

1	m/8	10 days	Spotted and "frozen" appearance.
2	m/8	10 days plus	Wilting at the margin.
3	m/8	10 days plus	Spotting.
4	m/8	10 days plus	Quite fresh.
5	m/8	7 days	Spotted, then all yellow.
6	m/100	3 days	Veins blackened.
7	m/400	5 days	Sick looking in two days.
8	m/8	3 days	Wilting second day.
9	m/400	10 days plus	Very fresh.
10	—	10 days plus	Fresh.
11	—	10 days plus	Fresh.

VI.—LEAF OF CUCURBITA.

1	m/8	3 days	"Frozen" appearance.
2	m/8	3 days	Crisp at margin.
3	m/8	2 days	Spotting.
4	m/8	3 days	Salt ascending.
5	m/8	3 days	Freckled appearance.
6	m/100	2 days	Veins blackening.
7	m/400	2 days	Veins becoming yellow.
8	m/8	1 day	Salt ascending.
9	m/400	10 days plus	Very fresh.
10	—	6 days	Yellow at margin.
11	—	5 days	Yellow at margin.

VII.—LEAF OF CUCURBITA.

*191	m/8	3 days plus	Salt on the upper surface.
74	m/8	3 days plus	Salt upon the upper surface.
19	m/8	2 days	Wilted second day.
73	m/8	2 days	Died in spots.
72	m/8	3 days plus	Quite fresh.
100	m/8	3 days plus	Fresh, salt not all dissolved.
76	m/256	1 day	Veins brown.

*191. Neut. sol.; 74. K_3PO_4; 19. $KClO_3$; 73. $ZnSO_4$; 72. Na_2HPO_4; 100. C[illegible]O_4; 76. $CuSO_4$ 160. K_2O; 70. KI; 71. Na_2CO_3; 111. KBr; 75. Na $\bar{A}$; 10. H_2O dist.; 11. H_2O tap.

VII. LEAF OF CUCURBITA.—*Continued.*

Solution.	Strength.	Time to kill.	Remarks.
160	m/8	2 days	Poisoned look, salt ascended.
70	m/8	2 days	Died in spots.
71	m/8	2 days	Very limp.
111	m/8	3 days plus	Very fresh.
75	m/8	3 days plus	Salt ascending on upper side.
10	—	3 days plus	Fresh.
11	—	3 days plus	Fresh.

VIII.—LEAF OF LUPINE.

191	m/8	3 days plus	Fresh.
74	m/8	2 days	Dead from the margin.
19	m/8	2 days	Light green, veins yellow.
73	m/8	3 days	Wilted second day.
72	m/8	3 days	Light green.
100	m/8	3 days plus	Salt not all dissolved.
76	m/256	1 day	Lighter green.
160	m/8	3 days plus	Almost dead.
70	m/8	2 days	Veins green.
71	m/8	3 days	Brown at margin.
111	m/8	3 days	Fresh.
75	m/8	3 days	Veins green.
10	—	3 days plus	Fresh.
11	—	3 days plus	Fresh.

IX.—LEAF OF PRIMULA OBCONICA.

191	m/8	3 days plus	Fresh.
74	m/8	3 days plus	Fresh.
73	m/8	2 days	Spotted.
76	m/256	1 day	Very limp.
160	m/8	2 days	Poisoned looking.
70	m/8	3 days	Dead in spots.
	All others	3 days plus)	

VII. *a.—Leaf of Acer.*

1	m/4	3 days	Colour lighter green, wilting from margin.
2	m/4	3 days plus	Almost dead, wilting from margin.
3	m/4	3 days plus	Almost dead, tendency to spot.
4	m/4	3 days	Freckled between veins and with yellowish spots.
5	m/4	3 days	Veins darkened, dried from the margin, black near the petiole.
6	m/50	2 days	Wilting in twenty-four hours, petiole and veins blackened, blade deeper green.
7	m/400	4 days plus	Slightly wilting fourth day, petiole dying.
8	m/4	1 day	Frozen appearance between veins.
9	m/400	5 days plus	This leaf remained fresh much longer than any of the others.
*10	—	5 days	Wilted.
*11	—	5 days	Wilted.

* Numbers ten and eleven died in five days while number nine remained fresh until May 28th, eleven days longer.

VIII. *b.—Leaf of Ampelopsis.*

Solution.	Strength.	Time to kill.	Remarks.
*1	m/4	4 days	Veins darkening, brown in streaks.
2	m/4	4 days plus	Dead and crisp at the margin.
3	m/4	4 days	Blade spotted.
4	m/4	3 days	Blade spotting, wilting and limp second day, drying up fourth day.
5	m/4	4 days	Base brown, margin green, petiole and veins darkening.
6	m/50	2 days	Margin black.
7	m/400	4 days plus	Blade wilting some, petiole dying, margin black, veins dying near base of leaf.
8	m/4	1 day	Frozen appearance between veins, veins decolourized.
9	m/400	4 days plus	Slightly wilted.
10	---	4 days	Wilting on second day.
11	---	5 days plus	Fresh.

* In the cases in which the leaf died it became blackened after death.

Certain solutions seemed to produce, after a few days, a translucent appearance in the region between the main veins. It appeared as though the intercellular spaces in this part of the leaf were injected with water. On examination it was found that the cells in this region were plasmolyzed. Then, from these considerations, namely that the cells were plasmolyzed, that water appeared to be in the intercellular spaces, and that solutions of considerable concentration were known to ascend through the blade, it may be concluded that the cells in this region were killed by an osmotic action, causing a loss of water to the cell.

It was noticed that normal solutions of H_2SO_4 and of HCl had practically the same toxic power, as might be expected, since they are chemically equivalent and contain the same amount of replaceable atoms of hydrogen. This result does not accord with the results obtained by Kahlenberg and True (1896, p. 92), who showed that 1/6400 gram-equivalent solution of H_2SO_4 was as Toxic to Lupine radicles as 1/3200 gram-equivalent solution of HCl. Judging from their results and conclusions, one might infer that they regarded a gram-equivalent per liter solution of H_2SO_4 to contain *twice* as many ions as a gram-equivalent solution of HCl which, however, is not the case according to Mohr,* Talbot† and others.

From the experiments here recorded it may be concluded that certain salts kill the leaf by osmotic action, while others produce death by chemical action. The latter may be classed as poisons and the

* Titrimethode, p. 36.

† Quantitative chem. anal., 1900, p. 65.

former as non-poisons. Among the poisons, $CuSO_4$ was the most deadly. With dilute solutions it always rendered the leaf quickly limp, commencing at the margins. With strong solutions there seemed to be a complete "paralysis," the whole leaf becoming wilted in a very short time. With $HgCl_2$ the action took place from the base outwards, showing that the solution made its way out laterally from the vein only with great difficulty, while the $CuSO_4$ seemed to penetrate the whole leaf rapidly, causing a wilted condition but no discolouring.

The experiments with the sugars are of little importance, because of the fact that a fermentation took place quickly, and the solution became a solution of an organic acid, resulting from a decomposition of the sugar. The grape sugar, as might be expected, was much more susceptible to fermentation than was the cane sugar.

Certain of the salts, notably $ZnSO_4$, produced a depression of the surface in spots, due to a decrease in the turgor at that point, generally without that "water-logged" appearance so common in cases where a leaf is being killed by osmotic action.

The cause of the "water-logged" appearance seen in the case of certain non-poisonous, but strongly osmotic substances, is due to the fact that these salts in solution upon reaching the thin walled parenchyma cells in the leaf, draw water osmotically from the cells into the intercellular spaces, at first in the region between the main veins. In some cases this is noticed at the margin of the leaf, but the drying action of the air upon the water drawn into the intercellula spaces, causes the leaf to become crisp and dry along its margin.

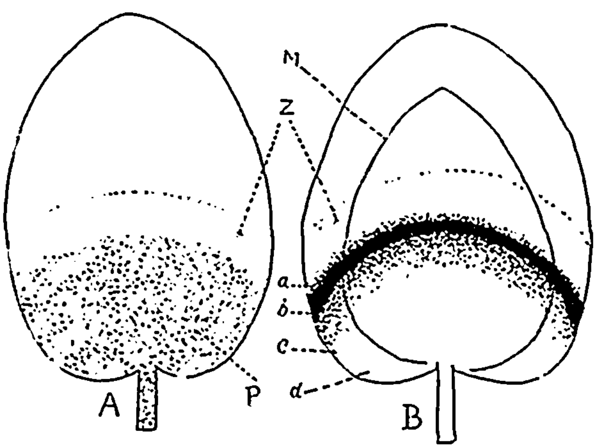

FIG. 9.

A. filter paper cut in the form of a leaf, it is saturated with ferric chloride, and then placed in a solution of potassium ferrocyanide: P. a precipitate; Z. a zone of water: B. saturated with potassium sulphocyanide, and then placed in a solution of ferric chloride: a. dilute solution; b. strong solution; c. partially soluble in excess; d. wholly soluble in excess; M. margin of area if a living leaf be used.

The salts ascend readily into the leaf and penetrate the whole blade, as is proved by testing the leaf for the salt taken up by the petiole. The cells of the leaves having the "water-logged" appearance are plasmolyzed, showing that water has been extracted osmotically by the salt. This phenomenon is mentioned by Vines (p. 40).

Certain solutions will, therefore, if applied to the cut ends of the petioles, kill the leaves by extracting water from the cells. This effect is not so rapid as might be expected, because the solution which ascends the petiole and enters the leaf, is not of the same concentration as that supplied in the test-tube. This fact is not as yet generally known to botanists, because in the experiment to demonstrate the rate of ascent of sap in plants, a solution of a lithium salt is taken, and the distance of ascent is determined at any given time by the height of the lithium salt. It is known that the experiment with eosin is not accurate, for the reason that the water ascends faster than the eosin. What is true of eosin is true of lithium, and probably of any other solution, as may be demonstrated as follows :—Saturate a piece of filter paper with a solution of potass-sulpho-cyanide, allow it to dry, then place one end of the paper in a solution of ferric chloride. As the iron solution ascends, the height of the solution is indicated by the deep brown-red colour, formed where the salts meet, in consequence of the chemical action between them. A zone of water may be seen to advance ahead of the substance in solution by the translucent effect which it produces upon the paper. The difference between the height of solution and the height of this zone of water at any given time is considerable, as is the case with eosin and other coloured solutions. In the case of lithium it can not be seen because the solution is colourless, but it acts as other salts do, as has been shown by experiment (Fig. 9).

In Detmer and Moor (p. 233) it is stated that the lithium ascends as *high* as the water does in which it is dissolved. This is not opposed to the ground taken by the writer, namely, that lithium in solution does not ascend as rapidly as the water. This has been proved by the writer by cutting the strip of absorbent paper *just below* the point reached by the water *while the water is ascending* and *before* it has reached its maximum height. This portion of absorbent paper contains no lithium. Sachs' view was that a decomposition of the lithium must result if the water ascended higher than the lithium salt, for he says (p. 236): – "The lithium solution possesses, as I convinced myself with the aid of the paper strips previously mentioned, the advantageous property of ascending without being *decomposed*."

The present view of the lithium test for the rate of ascent of water is based chiefly upon work done in 1877 by Sachs' (1878, p. 165). He shows that in all coloured solutions used, water ascends faster than the substance in solution ; he cites sixteen solutions in which it is said the water is known to rise more rapidly than does the substance in solution, and he states that three substances, colourless in solution, ascend *as high as the water*. Lithium nitrate is one of the latter. It should be stated that Sachs' experiments were chiefly for the purpose of determining whether solutions ascended on the surface of the cell walls (by capillarity), or in the substance of the wall (by imbibition). Lithium, he said, ascended by capillarity and reached a point as *high* as the water and so there was no decomposition. Sachs' results, therefore, are not contradictory to those of the writer.

It is shown by using such solutions as potassium ferro-cyanide and ferric chloride, or mercuric chloride and potassium iodide, or any pair of solutions which produce a precipitate soluble in excess of either solution, that the solution loses in concentration as it ascends.

The solutions used to demonstrate the fact that water ascends *more rapidly* than the substance in solution were :—

Potassium ferro-cyanide and ferrous sulphate.

Potassium sulpho-cyanide and ferric chloride.

Potassium iodide and mercuric chloride.

Potassium iodide and lead acetate.

Copper sulphate and potassium ferro-cyanide.

Silver nitrate and hydrogen sulphide solution.

Silver nitrate and potassium iodide.

Salicylate of soda and ferric chloride.

To test the rate of ascent of water by the rate of ascent of lithium in solution will lead to error, as has been proved by actual experiment, and as is inferred from experiments with other solutions which produce a precipitate (see Fig. 9).

A leaf whose petiole is in a solution does not absorb the solution in quite the same way as does a filter paper. The solution in the case of living leaves extends over the leaf so that the area affected is symmetrical to the whole leaf (Fig. 9 B, and Photo. 1-6). With the filter paper the solution extends equally in all directions without any regard to the outline, commencing at what represents the base of the leaf (Fig. 9).

Where the solution was not of such a nature as that of strong acids or alkalies, but where it followed the veins, it was found that the distances from the base of the leaf to the extreme point of discolourization along each vein was proportional to the total length of the vein, causing the solution to reach the margin of the leaf at all points about the same time (Photos. 1, 2, 3).

Experiments to test the effects of water upon certain leaves when *applied to the cut ends of the petioles. Primula obconica.*

Leaves A, B, C, D, E with petioles in distilled water (Fig. 8).

Leaves F, G, H, I, J with petioles in tap water.

Weight. October 5th.	Weight. November 12th.	Difference.		Conditions.
A . . 1.5625	1.48	.0825	Loss	Fresh.
B . . .9375	.976	.0385	*Gain*	Fresh.
C.... 1.30	1.314	.014	*Gain*	Fresh.
D... 1.30	.875	.425	Loss	Yellow and wilted.
E ... 1.75	1.245	.170	*Gain*	Fresh.
F ... 1.625	1.097	.0755	Loss	Yellow and wilted.
G.... .975	.705	.270	Loss	Yellow and wilted.
H... .9375	.916	.0385	*Gain*	Fresh.
I.... .9125	.766	.1465	Loss	Wilting.
J.. . .925	.979	.054	*Gain*	Fresh.
November 12th.	December 3rd.			
A ... 1.48	1.4245	.0555	Loss	Fresh.
B . .976	.9109	.0651	Loss	Fresh.
C.... 1.314	1.2829	.0311	Loss	Fresh.
D	....	....	....	Not weighed; as the leaf was dead.
E. 1.245	1.1935	.0515	Loss	Fresh.
F ... 1.097	.933	.161	Loss	Wilted.
G	....	....	....	Not weighed; leaf dead.
H ... .916	.9845	.0685	*Gain*	Fresh.
I.... .766	.7209	.0451	Loss	Fresh.
J.... .979	.9569	.0221	Loss	Fresh.

Examined on December 15th for starch.

A.—Plenty of starch all through the blade, especially between veins.

B.—Starch in veins from base outwards.

C.—*Starch in veins; none at margin;* leaf commencing to wilt.

D.—No starch.

E.—Considerable starch in mid-veins; some elsewhere.

F.—Abundant starch.

G.—No starch; leaf was yellow and dead.

H.—Starch abundant in distal part of blade; lobes of base yellow.

I.—Considerable starch.

J.—Slightest trace of starch near one part of margin.

During this experiment and from others used as controls in the solution experiments, a few very remarkable phenomena developed. It would appear as though these leaves had gone on living and performing all the functions natural to them, although detached from the plant, and some of them had actually increased in weight. Very many leaves under such conditions develop roots from the petiole, but it was not so with these. In only one case did a leaf of Primula develop roots, and this one was standing in water along with a leaf petiole of Impatiens which developed an extensive root system. When the leaves were gathered for the above experiment, they were immediately placed in paraffin paper to render the loss by evaporation as small as possible during the interval between gathering and placing in water.

Those leaves which, during the experiments, had begun to turn yellow had lost considerably in weight and showed little or no starch. One leaf (not referred to in the above table) which had been gathered on May 31st, remained apparently alive and fresh till October. On October 15th it was becoming yellow, but showed on examination considerable starch in its mid-veins. It had developed no roots. One fair conclusion from these experiments is that these detached leaves function* as if upon the plant, though they have no roots to supply food. The petioles of these leaves were always surrounded with water for from one to two inches above the surface of the liquid in the vessel, the trichomes raising the water by capillary action.

The leaf of Primula stellata lends itself readily to experiments such as those described in this chapter, because it will live on for months without sending out roots, if the petiole be kept in water; and the lower surface being reddish, acid and alkaline reactions are clearly marked.

These results may be summarized as follows:—

Some solutions kill the cell by extracting water osmotically from it, thus hastening its drying out. Other solutions affect the cell contents without causing plasmolysis.

Ferrous sulphate produces a blue colour which is shown on the cell wall. This colour appears black when in the veins of leaves. This blue colour is not produced by *ferric* iron, showing that it is not due to the presence of tannin.

The rate of ascent of solution through the leaf blade varies as the length of vein.

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* They produce starch, retain their turgor, and keep the chloroplasts in a normal condition.

Solutions do not ascend through the blade of the leaf as they do through filter paper (Photos. 1-6, and Fig. 9).

The lithium test for the rate of ascent of water is not accurate for filter paper, and may not be therefore, for plants.

Detached leaves may carry on some of their normal functions for a long period of time.

VIII.—ON THE EFFECT OF A SOLUTION APPLIED TO THE LEAF SURFACE.

This introduces one of the most important phases of the subject, and one towards which the attention of the fruit-grower and the farmer has been directed for the last decade or more. Since the protecting of plants from the ravages of fungi and of insects has been attempted by means of spraying with liquids of a more or less poisonous character, the attention of many, especially of those in experiment stations, has been turned towards the increase or decrease in crop, owing to the application of the poison, in solution, to the leaf of the plant. Some experiments have been carried on, notably at the Agricultural Experimental Station, Ottawa, 1900, with a view to the extermination of weeds by spraying. The experiments performed by the writer, and here described, show, as has been shown elsewhere, that leaves of plants are affected differently by the same solution. What one leaf will endure will kill another; and taking advantage of this fact, plants susceptible to the solution may be destroyed. It has recently been learned that the common field grains, such as wheat, barley and oats, are well adapted to the shedding of drops applied in the form of a spray, because of the chemical nature of the surface, because of the shape of the leaf and of its natural position with regard to the stem.

Probably the most troublesome weed now in many parts of the northern United States and Canada, is the wild mustard (Brassica sinapistrim, Boiss.); and the means just referred to have been successfully used towards its extermination. A spray of a solution of $CuSO_4$ and of $FeSO_4$ have been used with singular effect, and a certain strength of solution was found which would kill the mustard and not materially injure the grain crop. At Ottawa it was found that the solution of $FeSO_4$ of 10% strength produced some "scorching" of the barley, but stripped the mustard of its leaves and "scorched" the stem to some extent, but did not completely kill it. The 2% $CuSO_4$ solution produced only a slight injury to the barley crop but completely killed

PHOTO. 1.—Acer rubrum ; $FeSO_4$, m/56 ; three days in solution ; veins blackened. Veins blackened to points equally distant from the margin. Area affected symmetrical to whole leaf.

PHOTO. 2.—Primula obconica ; $FeSO_4$; m/56 ; blackening of the veins not complete. E, utmost limit of the darkening of the veins.

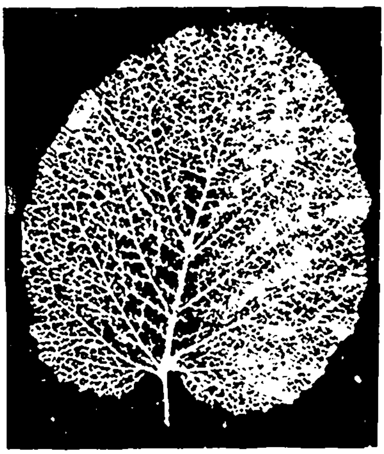


PHOTO. 3.—Primula obconica ; $FeSO_4$: m/56 ; complete blackening of the veins even to the very minute terminations. Almost no diffusion of the salt away from the veins.

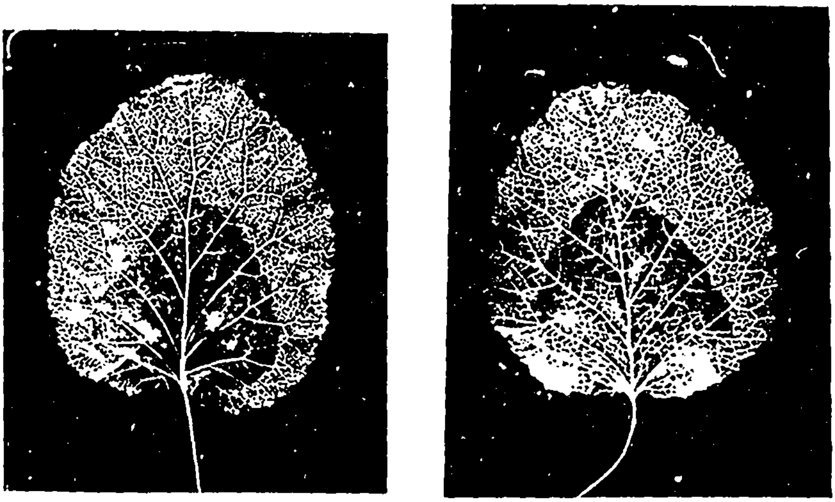


PHOTO. 4.—Primula obconica; HCl; m/4; two days; shows clearly the edge of the wave which is entirely independent of the veins.

PHOTO. 5.—Primula obconica; H_2SO_4; m/4; two days. The edge of the wave follows in a measure the contour of the leaf.

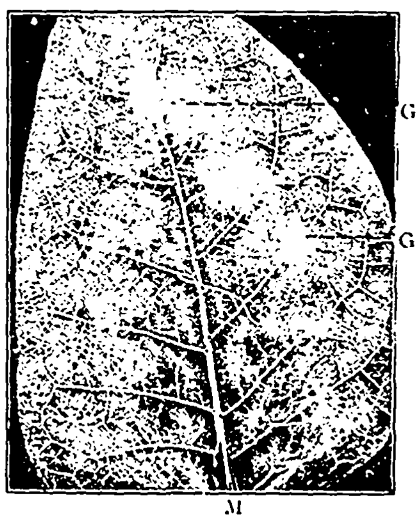


PHOTO. 6.—Nicotiana tabacum; H_2SO_4; m/4; three days; yellow striped centre, bounded by a green stripe shown at G, beyond which is a brown surface. Xylem (m) laid bare by the acid.

the mustard. This method of weed extermination has been carried on successfully, it is said, in England and France, but in matters pertaining to the farm there is usually very little, if any (Experi. Station Bulletins ref. Chapter II.), literature pertaining to the subject. The amount of liquid used per acre at Ottawa was of $CuSO_4$ solution fifty gallons, made up of two pounds of $CuSO_4$ to ten gallons water No observations seem to have been made as to the actual effect upon the crop, though it is inferred that the barley crop did not suffer materially.

The experiments just referred to, together with those performed by the writer (tobacco spotting) leave no room for doubt whatever that solutions are absorbed by plants. The most important part, however, of this very interesting subject, as has been observed by several writers, to whom reference has been made in Chapter II., is the fact that these solutions which will kill one plant may actually *promote growth* in another. No experiments were performed by the writer with this end in view.

The main objects of the following experiments were to ascertain whether solutions are absorbed by leaves (the test employed by Boussingault was adopted), and to determine the physiological effect.

SERIES I.

Effect of solutions applied to leaf surfaces in the form of drops. July, 1900, leaf Ampelopsis; solution applied to lower side. Column 1, solution used; 2, absorbed*; 3, dry, moist or crystals; 4, dark ring; 5, colour of spot; 6, less apparent effect on the lower surface of the leaf. The strength of the solution used, excepting the nutrient solution and the copper sulphate, was m/4. The copper sulphate was m/56.

1	2	3	4	5	6
$MgCl_2$	Nearly all.	Moist.	Yes.	Yellow.	Less.
$ZnSO_4$	Not all.	Dry.	Slightly.	Yellow.	Less.
Na_2CO_3 ..	No.	Crystals.	No.	Black.	Less, decidedly.
KBr	No.	Crystals.	Yes.	Yellow.	Most decidedly.
$NaHCO_3$....	No.	Crystals.	No.	None.	Neither.
Na $\bar{A}$....	Nearly all.	Moist.	Yes.	Brown.	Less.
K_3PO_4.	Half.	Crystals.	Yes.	Brown.	Less, slightly.
CuSO.	All.	....	Yes.	Brown.	No difference.
Nut. sol......	All.	....	....	.. ...	....
$KClO_3$..	No.	Crystals.	Yes.	Yellow.	Less, decidedly.
KI	No.	Crystals.	Yes.	Yellow.	Little difference.

* Absorbed if no deposit remained after evaporation.

The leaves were in the open air without protection against too rapid transpiration, and in consequence there was a greater amount of crystalline residue than might otherwise have been expected. Those substances recorded as moist were so twenty-four hours after the drop was placed upon the leaf, and they remained so for a longer time, though no further record was made. The fact that a darker ring occurred was noted particularly because of the peculiar formation of the crystalline deposit formed as the drop evaporates.

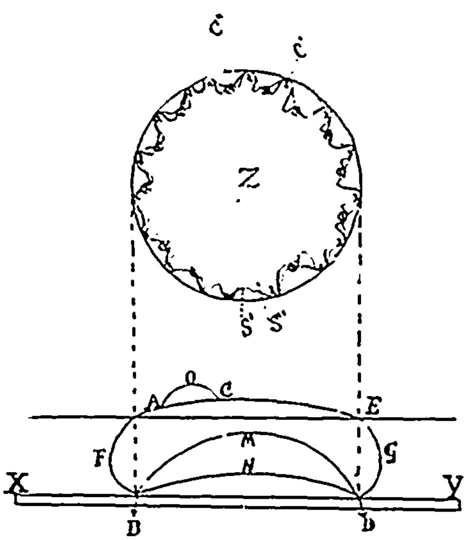


FIG 10.

XY is a section of a glass slide upon which is a drop of solution BCD, which takes the form roughly of a flattened spheroid touching the glass in the form of a circle with two points on the circumference, as B and D. As the drop evaporates it assumes roughly the form BMD and BND, the points B and D remaining, and the circle of crystals forms roughly as shown in S' S'', C' C''. The curve BFA being sharper than the curve CE, there will be more rapid evaporation and consequently crystals will form first at B and D, where they remain forming the ring. Owing to cohesion and tendency to crystallize, the first crystals formed attract solution until almost all evaporates. Z, ground plan of drop.

Boussingault and Schlössing noticed this ring of crystals, and Boussingault noticed also that in some cases of more dilute solutions, a darker green ring was produced on the leaf by the drop of solution. No attempt was made by Boussingault or any one else to explain this, so it was thought well to make the point clear, although it belongs properly to physics.

When a solution is applied to a leaf surface in the form of a drop, the salt upon rapid evaporation of the water, *forms* itself in a visible ring, which results in an *unusually strong* action upon the leaf tissue immediately under this ring of crystals. This ring formation is not confined to leaves, but is true of crystalline substances in general. If a drop of a salt solution be placed upon a clean glass slide and allowed to evaporate, it is found that there is a ring of salt at, or near, the edge of the original drop, while inside the ring there are very minute crystals evenly spread over the surface.

Let XY (see Fig. 10) represent a glass slide, and BCD a section of a drop of solution. Because of the internal cohesion of the particles of the liquid, these tend to form a sphere, but this tendency being in part overcome by the attraction between it and the glass, and of gravitation, it assumes the form of a flattened spheroid, something like the form shown in the diagram. The curves BFA and DGE being sharper than any other curves on the surface of the drop, there will be a greater surface exposure to the air in proportion to the mass of liquid in the immediate vicinity, and consequently a greater evaporation and condensation of solution. There will clearly be less evaporation from the surface AC than from the surface AOC; and if AOC be a similar curve to a part of BFA, there would be less evaporation from AC than from the part referred to of BFA. Now it follows, as diffusion through liquids is very slow that the first crystals will form at B and D. These crystals are now no longer floating, but take up a fixed position—from their weight—upon the glass, and remain there. As evaporation proceeds, the distance from C to the plate becomes less and less, while the distance BD along the plate remains almost constant; BCD becomes BMD and BND. This is due to the fact that the crystal in growing attracts other particles towards it to build it up, and as it cannot now move, the particles move to it; and also because the substance of the crystal, having a strong affinity for water—otherwise it would not dissolve readily—attracts water towards it, because of a physical affinity now called capillarity, and which some term surface tension. If a drop, half evaporated, be placed under the microscope this may be easily observed, and it will then be noticed that the margin of the area of contact between the drop and the glass is only very roughly the circumference of a circle, because the crystals first formed, (not being formed all at the same time), will be distributed irregularly, the first farthest from the centre. The place of the first crystals laid down will determine the position of the ring of salt found after evaporation has been completed (represented by C' and C'' in diagram). The prominence of the ring will depend upon several things,—affinity of the substance for the solvent, crystal-forming power, and the diffusing power of the substance in solution, etc., which it is not necessary to discuss here.

Though the solution was applied to the lower surface of the leaf, there was an effect more plainly visible upon the upper surface, showing that the solutions had acted especially on the cell contents and upon the chlorophyll granules. The substances were conveyed through the spongy tissue in the lower portion, to the palisade tissue where the chlorophyll is most abundant. The ring, in several instances, was well marked upon the upper, as well as upon the lower surface. Those substances remaining moist, did so because of their strong hygroscopic properties.

When $CuSO_4$ is applied in solutions more dilute, as in strength m/640, one finds it also producing a ring. This is easily recognized by applying the solution to the under surface of a leaf of Primula stellata (Hort.), which has a red colour. When the drop has remained for some hours upon the leaf, one can see by the colour where the tissue has been killed. The red colour disappears, and there appears a blue ring where the tissue has shrunken below the general leaf surface.

Strong acids and alkalies do not produce this ring because these substances dissolve a way regularly through the tissue, permeating in all directions, as is the case when these substances are applied to the cut ends of the petioles. (See photographs 4, 5, 6).

SERIES II.

Experiments with solutions of $CaH_2(CO_3)_2$ and $Ca(OH)_2$ upon leaves of Begonia, Primula obconica, Primula stellata, Pelargonium and Heliotropium.

When drops of each of these solutions were placed upon the upper surface of these leaves, and allowed to evaporate in the open air, there was a slight residue in each case; but if the leaf were placed in a flask (Fig. 6), or if a detached leaf were placed under a beaker to prevent too rapid evaporation, the salts entirely disappeared. (The object of this experiment was to test the effect of the soluble carbonate upon the surface of the leaf). It took between two and three days to absorb completely the drop of solution. If the drop became dry in less than twenty-four hours there was a residue, showing that the loss by evaporation was too rapid. Though the $Ca(OH)_2$ solution left upon evaporation a small amount of crystalline matter, this was undoubtedly not the hydroxide of lime but the carbonate, produced by the action of CO_2 upon the evaporating solution of the hydroxide. The deposit of $CaCO_3$ then upon the leaf vanished upon the application of more water, and especially so if the leaf were kept in a moist chamber as shown in Fig. 6. An interesting fact to notice, was that if a leaf holding upon it the residue from a drop of the solution of the bicarbonate which had been allowed to evaporate rapidly, were placed as in Fig. 6, this white residue vanished after a time. This was due to the moisture in the air in the flask acting just as the water did upon the residue, causing it to become again, in the presence of CO_2, a solution of the bicarbonate, which was then in this condition absorbed. This proves that a part of the calcareous substances found upon the leaves of some plants, may be, upon occasion, in the presence of moisture and CO_2, resorbed by the plant.

From these experiments, and from others not recorded, the conclusions may be drawn that, while a solution applied in the form of a fairly large drop may be harmful, applied as a fine spray it may not be so; that it is the upper surface especially that shows the "scorching," no matter whether the solution be applied to the lower or to the upper surface of the leaf; and that calcium carbonate may be absorbed in the presence of moisture and carbonic acid gas.

SERIES III.

On the action of strong solutions upon Spirogyra.

$CuSO_4$, m S, one and three-fourths hours, no plasmolysis, chlorophyll band broken up and of a lighter green colour, spiral form lost, protoplasm very granular, and excepting these granules it seemed to be dissolving, membrane not visible.*

$HgCl_2$, m S, one and a-half hours, no plasmolysis, chloroplast yellow and has lost its form, protoplasm full of dark granular bodies each having a bright red center.

$Pb\bar{A}_2$, m S, two hours, no plasmolysis, protoplasm full of very fine granules which are not dark, chloroplast shrunken but still spiral.

$FeSO_4$, m S, one and a-half hours, no plasmolysis, chloroplast yellowish, broken up into fragments each retaining a pyrenoid, the walls between any two cells constricted and of a beautiful deep blue colour, the other walls of the cells of a faint blue tinge giving the whole a blue cast.

HCl, m S, one and three-fourths hours, no plasmolysis, chloroplast yellow, protoplasm dissolving, no granules, band has kept its form and is very conspicuous.

$NaOH$, m S, two hours, no plasmolysis, chloroplast of a light yellow colour and dissolving, protoplasm dissolving.

NH_4OH, 5%, one and three-fourths hours, no plasmolysis, chloroplast in pieces and dissolving, general colour light yellow and the cells swollen.

* Nageli (1893, p. 151) states that copper in very strong solution causes extreme plasmolysis; and that weaker solutions cause a chemical poisonous action with a breaking up of the chlorophyll bands. The strong solutions used by Nageli are therefore much stronger than m S.

In all cases the protoplasmic membrane was dissolved, or had not been separated from the cell wall; the strands had disappeared.

The object of this experiment was to discover, if possible, the action of poisonous solutions upon Spirogyra. In the case of $CuSO_4$, $HgCl_2$ and $Pb\bar{A}_2$ there was a peculiar formation of small dense particles in the protoplasmic substance, showing that some chemical change had taken place, resulting in a precipitate; or in an action upon globules, colourless by nature, within the protoplasm. These substances either dissolved the protoplasmic membrane, or passed through it without any apparent obstruction, as no plasmolysis occurred. These dark particles were especially large and dark with the $HgCl_2$ solution, a result which in the case of a mass of cells would produce a darkening of the general colour. Such a change took place in the case of leaves which were acted upon by this solution applied to the cut ends of the petioles. The darkening in the case of the $FeSO_4$ solution was entirely different, being due to the action of the iron solution upon the walls of the cells, producing a blue colour which appears black in mass. This was shown particularly where the cells of the filaments were joined. This dark colour was shown in the leaves whose petioles had been dipped in a solution of $FeSO_4$, the veins becoming dark even to their minute extremities. (See photographs 1, 2, 3). The HCl penetrated the cell wall quickly and dissolved the protoplasm. NaOH and NH_4OH quickly penetrated the cell walls, dissolved the protoplasm and broke down the chlorophyll band.

Poisonous solutions applied to the upper side of a leaf compared with the same solutions applied to the lower side.

SERIES IV.

Detached leaf of *Primula stellata*; petiole in water; time twenty-four hours; solution strength m 640.

$Pb\bar{A}_2$ upper	Residue slight	No effect visible.
lower	Residue slight	No effect visible.
$CuSO_4$ upper	Residue slight	No effect visible.
lower	Residue none	Red colour destroyed in a ring.
$Ba(NO_3)_2$ upper ..	Residue slight	No effect visible.
lower ...	Residue none	No effect visible.
$HgCl_2$ upper	Residue none	No effect visible.
lower	Residue none	Red colour destroyed in a ring.

It was found that the solutions applied to the lower side were absorbed more quickly.

These experiments show that the leaves of this plant are more sensitive to these solutions when they are applied to the lower surface.

When drops of these solutions were placed upon leaves of Bouvardia, there were distinct spots "scorched" upon the leaves, but when a filter paper was saturated with some of the solution and folded flat upon the leaf, upper and lower side being covered, there was no visible effect. This seemed very peculiar, more especially as the paper was saturated three times upon three successive days, enough of the solution being applied to kill several leaves if placed upon them in drops. This may have been due to the fact that the filter paper* held the solution mechanically in its tissue by capillary action, and as the water evaporated, the salt was retained in the paper; little, if any, could have entered the leaf.

When the solution of $CuSO_4$, and solutions of those substances, which produced dark green rings at the margins of the drops, were applied in sufficiently low concentration to cause no "scorching" of the leaf, but yet strong enough to bring about after some time this darkening of the green colour (see also Griffon, An. Sc. Nat. 8, 1-2, 1899), the action was probably in the nature of a stimulus to growth, and produced a better development of chlorophyll and of protoplasm in the region where the tissue appeared dark to the naked eye. (See Fig. 12). The explanation of this is given in the chapter on "Tobacco Leaf Spot."

The yellow spots and marginal stains noticed by Smith upon the leaves of plants (1872), were due to the poisonous substances held in solution by water clinging to the leaf, either in the form of drops, or held by capillary action on the edge of the leaf. The poisonous substances came, as Smith showed, in the form of fumes, from the neighbouring chemical works. How exceedingly sensitive plants are to these noxious vapours and fumes, is shown in the following statement of Smith:—"When the air has so much acid that two to three grains are found in a gallon of rain water, or forty pints in a million, there is no hope for vegetation in a climate such as we have in the northern part of the country."

In discussing the question of the application of solutions to leaves

* This is in accordance with the common method of purifying distilled water from compounds of copper, etc., by placing pure filter paper in the water.

of plants, one must examine into the condition of the 'eaf surface, because this surface might exert a mechanical influence upon the solution. Plants whose leaves are coated with an oily or waxy substance will shed the liquid applied, while other plants which apparently shed the drops, actually spread the liquid over the veins by the capillary action of the hairs and striations which occur on the grooves of the epidermis over the veins. This *is plainly shown when a* harmless solution of considerable strength is used; for after the evaporation of the water the dry salt is clearly seen. Some plants, such as Primula sinensis, have striations radiating from the large trichomes, which would aid in conveying liquid which happened to be brought near the base, up the trichome to a surface less cutinized. (Fig. 5, st.).

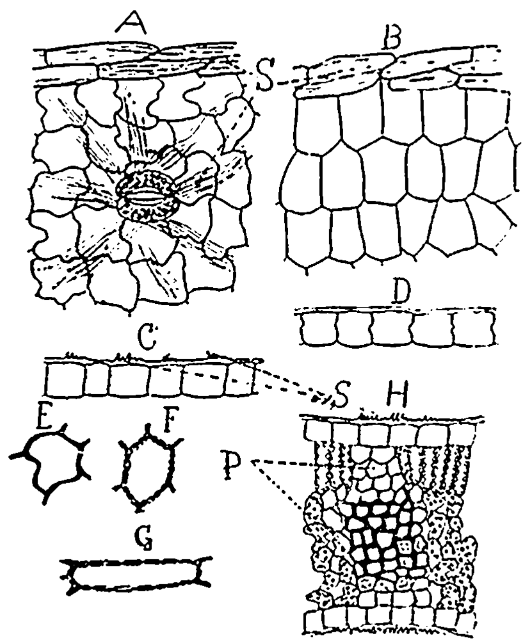


FIG. 11.

A, epidermis, lower surface, showing striations; B, epidermis, upper surface; C, section through epidermal cells, lower surface; D, upper surface, epidermal cells; E, epidermal cell, lower surface; F, epidermal cell, upper surface showing "pits"; G, epidermal cell over vein; H, section through leaf through one of the smaller veins, P, thin-walled parenchyma; S, striations.

The leaf of Ampelopsis has peculiar striations (Fig. 11, H.S.), radiating irregularly from the stomata. Striations are found on both sides of the leaf over the veins. Decrock (An. Sc. Nat. 8, 13, 1, p. 61, 1901) noticed similar striations upon several plants of the Primulaceæ. Corrugations have been observed by *Henslow* and *Stahl*, though *Stahl* assigned to them a far different function from that assigned by Henslow. E. L. Gregory (1886) concluded from experiments performed with many plants having hair coverings upon the leaves, that the basal cells of the hairs were best fitted for the absorption of water.

An interesting instance of the absorption of salts by the leaves of plants is given by Boehm (1875, p. 287), reviewed in Bot. Jahrsber, f. 1875, s. 860.

"Nach einer früheren Untersuchung . . . . . . 'gehen Keimpflanzen der Feuerbohne in distillertem Wasser sehr bald zu Grunde, während dieselben bei Zusatz von Kalksalzen sich vollkommen normal entwickeln. Es sollte nun geprüft werden, ob die Aufnahme des zur Entwickelung nothwendigen Kalksalzes auch durch die Blätter der Feuerbohne geschehen kann. In distillirtem Wasser gezogene Keimpflanzen wurden zu diesem Zwecke täglich drei mal während je 15 minuten mit ihrem obern Ende in distillirtem Wasser mit 2 pro mille Kalksalz eingetaucht. Diese Pflanzen erhielten sich so la ig frisch, bis die cotyledonen eingeschrumpft und bei dem Versuchen im Dunkeln sämmtliche Stärke aus dem Stengel verschwunden war, während Controlpflanzen, die nicht in die Kalklosung getaucht wurden, frühzeitig abstarben.'"

This supports the conclusions made by the writer, both in regard to the absorption of water by developing buds and living undetached leaves.

In regard to the question of the absorption of dilute solutions of poisonous substances there is something to be said. It has generally been held that the copper of the bordeaux mixture is not absorbed by the leaves of plants, but by two special experiments, the writer has been able to prove that $CuSO_4$, m/640, or when applied in a more dilute form, is absorbed. Of course $CuSO_4$ is not the compound of copper in the bordeaux mixture, although it is in this form before mixing, still the experiment with $CuSO_4$ will apply to the $Cu(OH)_2$, or whatever soluble copper compound may result from the combination of the substances in the mixture.

If a drop of a dilute solution (m/640) of $CuSO_4$ be placed on the under side of a leaf of Primula stellata, and left for twenty-four hours, no trace of the $CuSO_4$ is found upon the surface, but there is a discolouring, to some extent, of the natural tissue of the leaf. Similar experiments with other salts were performed by Boussingault and by Schlössing, and they concluded that if no salt was visible upon the leaf surface, total absorption took place.

If one were to spot rather freely a similar leaf with a solution of $CuSO_4$, m/640, for four or five successive days, then wash quickly the surface with distilled water, dry, incinerate carefully, collect the ash and dissolve as in qualitative mineral analysis; and if, after getting rid of the surplus acid and evaporating down to a small quantity, this solution be placed in a small test-tube, and in the solution a clean, bright iron wire, in a couple of hours afterwards there will be a coating of metallic copper upon the iron wire even if there be but a small trace of copper present Piano wire will do for this experiment. Chuard and Porchet (1900, p 71), state that copper was not found present in the leaves of grapes which had been sprayed with the bordeaux mixture. They state further that the effect of copper upon growth has been exaggerated, but admit that the sugar content of the grape is increased. The deeper green colour of the leaves, they claim, is not due to an increase in the amount of chlorophyll. This statement is not consistent with experiments performed by the writer, nor with those of Griffon (1900, p. 1). A certain stimulus there is, which results in an increase in the size of the chloroplasts, especially in the palisade tissue, and which is referred to in the explanation of the green ring produced by certain solutions applied to the leaves. This green colour may be due in part to a movement of the chloroplasts as noticed by Stahl in the case of other stimuli.

A long series of experiments was performed by Galloway and Woods (1895), to investigate the effects of bordeaux mixture upon the growth of potatoes. They used the substances contained in the bordeaux mixture separately and in various combinations in order to determine which constituent had to do with the stimulus to growth, or whether it was due to the effect produced upon the soil by the solution They show clearly that, while the bordeaux mixture applied to the leaves undoubtedly increases the growth, it is not the copper compound alone that causes the increase. The lime is found to be a very important factor, and they show that spraying with lime-water causes a large increase in leaf surface, showing that the lime-water is very probably absorbed directly by the leaves and utilized there. The spraying of the soil with lime-water caused some increase, but not so much as the spraying of the leaves.

The writer has shown (Chapter IV.) that $Ca(OH)_2$ in water (lime-water), is absorbed by leaves, and that this substance very probably exerts an active influence upon CO_2 of respiration, retaining it for resorption by the plant.

The experiments of Galloway and Woods show that a spray of water, while not increasing or decreasing the growth of the leaves, produces a decided *decrease* in the gross weight of tubers produced. This may be due to the loss of substances sustained by the leaves due to the drenching with water. (See experiments, Chapters III. and IV.). The experiments just referred to, corroborated by those of De Saussure, Gaudichaud and Sachs, leave no room for doubt that a very considerable amount of inorganic alkaline salts is extracted from leaves by the application of pure water to the leaf surfaces. This may in some cases prove of advantage to the plant, but it also might under certain circumstances prove a decided disadvantage resulting from the too great loss of useful mineral nutrient substances.

Regarding the absorption by leaves of iron in solution, it is easy to speak with certainty; for, if one secure a plant, chlorotic (from lack of iron in the culture medium), but otherwise in good condition, and place a few drops of a dilute solution of Ferric chloride (m/640) carefully upon a leaf, in twenty-four hours afterwards a green circular area is seen where the drop was applied. Thunbergia alata was the only plant upon which a sufficient chlorosis was obtained to demonstrate clearly this phenomenon. The green area spread over the whole leaf in three days to such an extent that the deep green of the leaf was uniform. Plants chlorotic from starvation, as were some of those referred to in the experiments in Chapter VI., will not become green by the application of an iron salt solution. This fact of the utilization of iron applied to the surface of a chlorotic leaf is referred to by Sachs (1887, p. 285). This same result was obtained some years ago in the case of a Maize plant, by Miss Minns at the physiological laboratory, Botany Garden of Harvard University. Definite information regarding this experiment the writer has not been able to obtain.

Summarizing the results of the experiments here described we may conclude that:—

(1) Salts in solution are absorbed through both surfaces of leaves of plants whether the leaves be detached or not if the surrounding atmosphere be favourable. Absorption generally takes place more readily when the solution is applied to the lower surface.

(2) Dilute solutions applied in drops stimulate the leaf tissue in a ring, whereas if the solutions are concentrated the entire area covered by the drop is affected.

(3) The effects produced by poisonous solutions upon Spirogyra aid in explaining the effects of similar solutions upon foliage leaves.

TOBACCO-LEAF "SPOT."

Tobacco leaves, under certain conditions which are as yet but little known, become somewhat mottled or spotted at a certain period in the growth of the plant, and these spots remain throughout the entire process of curing, and come out on the dried leaf to be used for the wrapper of the cigar. It is generally supposed that leaves having these spots are also characterized by their superior flavour and burning qualities, both of which are valued very highly by those who use tobacco. So important has this become in the marketing of the tobacco leaves that "spotting" has been attempted by means of caustic alkalies, such as carbonate of soda, caustic potash and caustic soda. While this artificial spotting may be only an outward imitation of the natural leaf, yet there are many evidences of its affecting the quality of the leaf from the smoker's standpoint, as will be explained later on. Attempts have been made by some of the smaller tobacco dealers to "spot" the tobacco by means of acids and other chemical irritants, thereby producing a leaf in imitation, to some extent, of the Sumatra leaf, and an article which is more saleable, but which doubtless possesses properties which would render it inferior to the leaf of the same tobacco plant which was not spotted. The only spotting under particular examination, however, is that of the natural Sumatra leaf and of that produced by caustic alkalies.

The real Sumatra leaf when nearly ripe has a peculiar mottled appearance which the leaf retains, more or less, throughout the curing process, and which indicates to the consumer a superior quality. It has been asserted by some who have investigated the cultivation of the Sumatra tobacco that the spot is due to the contact of wood ashes with the leaves during their growth. The plants which produce the best quality of Sumatra cigar wrapper are grown upon recently cleared and burned land. The jungles which contain a large amount of underbrush are made ready for cultivation by fire. The consequence of this is that there is mixed with the top soil a very considerable amount of ash, which, during the course of the summer, is blown by the wind upon the leaves, and which produces certain effects which result in the leaves having this spotted appearance. It is also stated in proof of this, that after two or three years cultivation of this recently cleared land, the tobacco plant does not become spotted to any great extent during its growth; and the leaves are of a thicker and more gummy nature, and are less valuable as a cigar wrapper. If these statements just repeated regarding the cause of the spotting of the Sumatra leaf be true, then it opens up the way to produce it artificially, and that too at little expense. It is well known that ordinary wood ashes contain a high percentage of caustic alkalies, especially caustic potash and caustic soda (if water be added), and that these substances do affect the leaves of plants, causing them to resemble, in outward appearance at least, the leaf grown upon the newly cleared ground in Sumatra.

The Sumatra tobacco when planted early in the year is generally without spots, but when planted late it spots freely. It is grown in Florida quite extensively and becomes spotted similar to the real Sumatra leaf, and in texture and general appearance resembles it closely. It is also cultivated in Cuba.

This tobacco, whether grown in the East Indies, Florida or Cuba, has another rather desirable quality, namely, that of a good "burn." This quality is especially wished for in the wrapper of a cigar. When once ignited it burns away quite steadily without producing flame, and more rapidly than the ordinary tobacco leaf which is used for filling purposes. This can be proved experimentally by placing two or more leaves in similar positions, then by igniting them and comparing the areas burned in a given time. When compared with the bright Virginia wrapper, the writer found that there was little or no difference between them, when the average was taken of a large number of cases. The Virginia leaf was not spotted, but was a thin bright yellow leaf containing apparently very little of this gummy substance generally found in the darker coloured leaves used for filling the body of the cigar.

This quality of burning steadily and rapidly is a desirable one in a cigar wrapper for reasons which the smoker readily understands, and which we need not enter upon here; and it follows that any investigation which results in developing this quality in a plant naturally, or in producing it in a leaf artificially, would be important both from a scientific and from an economic standpoint. The spotted leaf has this quality to a very high degree, and all very thin well-cured leaves possess it also to a considerable extent.

It was shown by Nessler in 1867 that when different kinds of paper, leaves, etc., were impregnated with certain substances the burning quality was affected,—that phosphates and chlorides were detrimental to, and that potassium nitrate aided in the burning.

Adolph Mayer, writing upon combustibility, shows that potassium carbonate was favourable to burning, and that chlorine compounds were unfavourable. If leaves lack potash they have a "poor burn." He shows also that these qualities may be produced in two ways, (1) by using certain fertilizers, chiefly Chili saltpetre, (2) by impregnating the cured leaf with this substance. By saturating tobacco having a "poor burn" with a solution of potassium nitrate or potassium acetate he caused the leaf to have what he called a "good burn." He also found that when Chili saltpetre was used abundantly as a fertilizer for the tobacco crop, a spotting was often produced in the cured leaf, because, as he states, the leaves cured more slowly and unevenly; and that when the leaves were simply dried instead of cured, a greenish mottled appearance was liable to result.

In Griffon's researches (1900, p. 1), he proves that nitrates in the soil and in nutrient solutions add greenness to the leaves of plants, and that salts of copper in minute quantities augment the dimensions of the chloroplasts and the intensity of the colour, though it may kill the roots. Sodium chloride is uniformly unfavourable, and an excess of lime causes a paleness and a consequent lessening of assimilatory power. The palisade tissue, chiefly, is affected (by the abnormal conditions), both as to the dimensions of the chloroplasts and the cells themselves, and in the colouration of the chloroplast. The writer has found, when decoctions are made of the leaves of several kinds of cured tobacco, by steeping them in distilled water for ten or twelve hours, that these decoctions, to a litmus indicator, show a decided acid reaction in most cases. The litmus paper used was purposely made slightly alkaline in order to insure evenness in quality of the paper and to emphasize strongly the experiment. One can secure litmus paper of an even quality by steeping the paper to be used, in distilled water to which a very few drops of ammonia have been added. The Virginia leaf changed the colour of the deep blue litmus paper in *two* minutes, the Sumatra leaf taking *five* minutes, the artificially spotted leaf *ten* minutes and the leaf artificially spotted then dried, not cured, taking three and a-half hours.

Mr. A. J. Ewart has shown (1896), that plants tend to neutralize both acids and alkalies, and that so long as the substance in which he placed the leaves remained alkaline, the chlorophyll was of a darker green colour. Twenty-four hours produced less effect than sixteen. He experimented with Elodea and Utricularia in a solution of ammonium carbonate (one tenth of one per cent. strength) in water. Darwin, in 1872, noticed that a precipitate in the cell-sap was produced on treatment with dilute alkalies. This shows that the alkali penetrates both the cell-wall and the lining of the protoplasm; only after prolonged exposure were the cells killed. This precipitate consists of tannin and other substances excreted by the ammonium carbonate.

Among the tobacco growers of America there are recognized two diseases, or two forms of the same disease, of the tobacco plant, the "calico" and the "mottled head." "Mottled head" is a condition in which only the uppermost leaves are affected, and where the spotting occurs at a somewhat later stage in the life of the plant. When the plants are affected early in life, the middle and the lower leaves have the characteristic appearance. This is known as "calico." About fifteen years ago there was observed a peculiar mottled condition of the tobacco plant in Holland. Dr. Mayer made some investigations upon this condition and gave to it the name "Mosaic Disease." He concluded that the disease was a bacterial one, but his investigations were not carried on far enough to warrant his conclusion. He proved that a sound plant might be inoculated with infected sap; but that one plant could not infect a neighbouring plant.

In some early works giving a general description of the tobacco plant, we find that one character given is that the plant on reaching its maturity in a natural condition is quite likely to have light coloured spots on its leaves. These spots were in no sense looked upon as a disease, or as being at all hurtful to the plant. The leaves of the suckers from healthy plants or stumps are often found spotted (Sturgis, 1898), and this would tend to show that this feature was not so much a disease as a condition of the plant depending upon soil and atmospheric conditions, or was philogenetic in its nature. It has also been shown by Otto Carl Butterweck that one means the farmer has of knowing when the tobacco is ready to cut is that the leaves begin to turn lighter green, and light coloured spots appear upon them. This is doubtless the time when the plant ceases to draw nourishment from the air and soil and is now concentrating its nourishment that was scattered through all parts. According to Dunal on Solanaceæ (1852), some species of this genus, Nicotiana, have peculiar grey-spotted, or a dirty green colour naturally; and one species of the genus has its specific name from this character.

About the time that Dr. Mayer was carrying on his investigations in Holland, *a disease was described which occurred in South Eastern* Russia which resembled very closely the "calico" of America. Some examination was made in detail as to the nature of the disease, as it was called, and the conclusions reached were that the cause was not due to bacteria nor to enzymes, and was therefore in no sense what might be termed an organic disease, but entirely physiological in its nature. It was proved by experiment (Sturgis, 1898) that the lower leaves of a tobacco plant will become spotted when the plant is beginning to starve because of a lack of water; and it occurs similarly when a period of excessive humidity is followed by hot sunshine, which results in a very rapid transpiration. It was, moreover, asserted by some, that spots were produced by drops of water adhering to the leaves and acting as lenses, and in direct sunlight actually burning the leaf. This is probably not true, as tobacco is not one of those plants to whose leaves the water adheres in drops; besides we are unable to bring this about by artificial means upon this plant. Others state that particles of sand, dust, etc., will, when adhering to the leaf, cause a "speck" to be produced as a result of the contact and the irritation brought about by the particle. This is quite probably not correct unless the particle adhering acts chemically upon the leaf cutin and the cells and their contents. It may be that where the land was fertilized freely with ashes, lime, or other rather strongly alkaline substances there is a modicum of truth in the statement; and indeed this would tend to confirm the assertion that the spotting of the Sumatra leaf is due to wood ashes brought into actual contact with the leaves by means of the wind.

A few years ago Marchal described a disease of the tobacco, similar to "calico." He concluded that it was a bacterial disease, as he saw in the spots a bacillus which he was able to grow upon pure culture media, and in turn to inoculate healthy plants with the pure culture. Others have found since Marchal's investigations were made that the mottling is due to a sort of enzymitic action. Now it is obvious that these so *called diseases*, "*mottled-head*," "*Mosaic disease*," "*calico*" etc., are distinguishable in a general way from the "Tobacco Spot" which is so universally admired in a cigar wrapper; and that so far as investigations have been made upon the subject up to this time, it may be regarded that "Tobacco Spot" is a physiological condition, while the others mentioned are produced by fungi or by enzymes.

This naturally leads up to the producing of the spotted leaf by artificial means. There are various methods employed by the small, but not too scrupulous tobacco dealers to produce an imitation of the Sumatra leaf, as has been already mentioned, but these will not be dealt with here as they have, so far as the writer can learn, no scientific bearing upon the subject under discussion. There is a method, however, of producing a spotted leaf by means of strongly alkaline substances, applied with a sprayer to the leaves, a few days before they are harvested. This process has been investigated in some detail by the writer, and it is found that certain effects are produced upon the leaves, which render them more desirable as a cigar wrapper, for two reasons:—(1) They burn more rapidly and are less liable to become extinguished than similar leaves not so treated. (2) The leaf when cured has a more silky appearance, and is slightly thinner. As to this latter it should be mentioned that a very limited number of leaves were compared, and so too much stress should not be placed upon it. With regard to the former it is found, by experiment with different kinds of leaves, that when saturated with caustic potash, caustic soda or carbonate of soda, then dried and ignited, they will burn more evenly and readily than leaves not so treated. It is the same, but to a much more noticeable degree, with filter paper, writing paper and other kinds of paper. Leaves vary much in the capability of being affected in this way, probably due to differences in chemical constituents of the substances contained in the different plants. Both paper and leaves, when not saturated with the alkali, have a tendency, more or less marked, to burst into flame when ignited; while if first treated, and then dried and ignited, they burn and glow steadily without producing flame.

The next question that naturally arises, is:—Do plants when growing absorb through their leaves any of the alkali which is applied to the leaf surfaces? Certain experiments with the object of answering this question, were performed at the Botanic Gardens, and elsewhere, July, August and September (1899), in order to ascertain whether leaves did absorb substances and transport them to other parts of the plant. Species of the following genera were operated on:—Solanum, Nicotiana, Aralia, Ampelopsis, Fraxinus, Pelargonium and Helenium. The following solutions were used:—Caustic soda in strengths of 1, 2½, 5, 10, 20 per cent.; and sodium carbonate in strengths of 5, 10, 20 per cent. It was found that caustic soda at 10 and 20 per cent. was too strong, producing holes in the leaves after a few days. The strength of solution required to produce a spot similar in appearance to the artificial tobacco spot, differed considerably among the several plants tried, but the ten per cent. sodium carbonate solution seemed to be the most generally successful. Twenty per cent. sodium bicarbonate was used in the Nicotiana, but it was not sufficiently strong to produce a spot and so no further attempt was made with this substance. To each solution was added about one per cent. by weight of lithium nitrate, for the purpose of utilizing the flame test in determining whether the alkali was absorbed and transported to other parts of the plant. It was found in all leaves that were tested by means of the flame and the spectroscope, that the lithia had penetrated to other parts of the same leaf, and also down to the extreme end of the petiole. Lithia was not found in other leaves of the plant, but it is inferred that the strength of the solution of lithia was too low and that the instruments were not sufficiently accurate or delicate to recognize it in such minute quantities, rather than there was no transportation of lithia to other parts of the plant. Lithia was found in few cases in the stem below the leaf, and in a very few cases above the leaf node. Of course it might be objected that the fact of the lithia being found transported did not prove that the caustic soda was conveyed with it. This is a fair objection, because the caustic soda might easily be all decomposed in acting chemically upon the cutin, cell walls and cell contents. However, it is thought fair to assume that at least a certain amount of the caustic soda or the sodium carbonate, as the case may be, would accompany the lithia through the plant tissue. Some of the caustic may be decomposed, as has been proved by the writer in the case of the beautiful liquid colouring matter in the epidermal cells of the red leaves of *Ampelopsis* in the late autumn. Caustic soda turns the red liquid a deep blue, but this blue rapidly disappears giving place to a greenish colour which soon changes to a yellow. When an acid is now applied, there is no reddening of the liquid, showing that some chemical change has gone on upon the liquid contents by the action of the alkali.

In all the leaves spotted artificially it was found that no spots or mottling appeared except those spots plainly visible when the leaves were lying upon a dark surface; while in all the Sumatra leaves available it was found upon examination with transmitted light that the leaves were all mottled with darker coloured patches, spots and dots, not visible by reflected light. This might suggest the notion that the

Sumatra leaves examined were affected also with a disease similar to the "Mosaic disease," and to "calico."

Now as to the internal effect of the spraying with caustic, the writer has found that the tissue undergoes some changes of importance in the vicinity of the spot. (See Fig. 12, section perpendicular to the leaf surface). It appears that the caustic alkali kills the chloroplast and the protoplasm in the cells where the spot becomes whitish; and that on the darker green ring bordering the light spot, the cells become larger and the chlorophyll bodies more numerous, especially in the palisade cells. There they are found very abundantly along the sides of the palisade cells, which have increased in length very considerably. The guard cells in the ring are well filled with protoplasm and chloroplasts, more so than in the ordinary guard cells of the leaf (see illustrations in Fig. 13). The stomata in the ring present therefore a different appearance in surface view from both the spot and the ordinary tissue. We notice also that the leaf is much thicker and denser in this ring, and that the chloroplasts are larger and more numerous. In the spongy parenchyma there is some enlargement due to the expanded cells and to the increased area of intercellular spaces. In the spot itself the protoplasm was dead, exceedingly pale, and much shrunken. It is quite possible that there is a stimulus to growth produced by the caustic solution used. If this be the case it would increase the activity of the protoplasm in the ring immediately surrounding the part that was dead, and consequently produce more numerous and larger chloroplasts. It has been shown by Griffon, Ewart, Mayer and others, that potassium nitrate and potassium carbonate affected the chloroplasts in some way resulting in increased dimensions and in general in a deeper green colour of the leaves. Griffon shows, too, that it is only the palisade cells that are affected. The writer has found that in the case of Nicotiana and Ampelopsis both

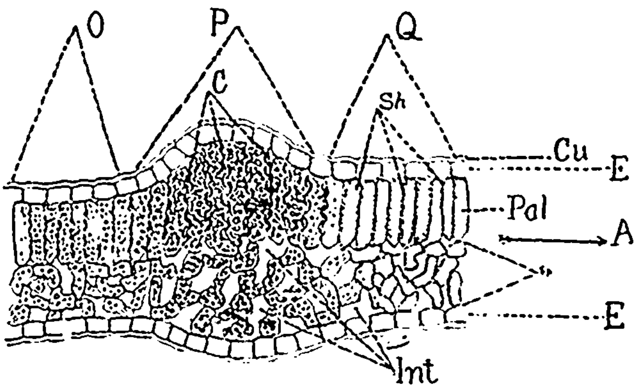


FIG. 12.

Section through tobacco leaf "spot." O, natural condition. P, ring; Q. dead part of spot; C, chloroplasts; Int., intercellular spaces; A, towards centre of spot.

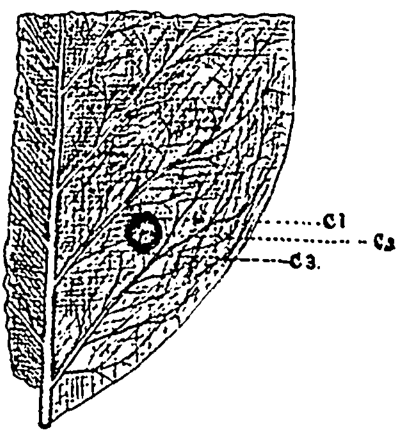
palisade tissue and spongy parenchyma are affected,—including the guard cells of the stomata, in a manner which is quite noticeable and important (Fig. 13). Outside of the green ring is seen one slightly lighter in colour. This is probably due to the fact that an extra supply of nourishment is now required by the enlarged and more active cells in the green ring, and these cells outside the ring are drawn upon to furnish this supply.

FIG. 13.

Surface view of guard cell of tobacco leaf. A, from area P, Fig. 12; B, natural condition; C, from area Q, Fig. 12.

In experimenting upon Chilomonas, an infusoria, W. E. Garry, (1899, p. 291) shows that when certain solutions are allowed to diffuse gradually toward the colony, a ring of the animals appears. This ring formed by the crowding of the animals, gradually widens, and with some solutions, after a time, recedes. This would tend to show that the ring is formed of animals, not only those driven away by the irritating liquid but also of those attracted towards it. In fact H. S. Jennings goes so far as to state that Paramecia are negative to strong acids and positive to weak acids. Whether this offers any explanation to the condition of the leaf around the spot it is not easy to say. At all events the phenomena are similar and in both cases exceedingly remarkable.

The diagrams here given are self explanatory, and are intended to illustrate the general appearance of the spot upon the leaf several days after the application of the alkali to the surface, to show the effect upon the stomata and upon the general tissue of the leaf. The spot does not at first appear light coloured but rather of a rusty brown, gradually becoming lighter. It was also quite noticeable that the thickness of the leaf was somewhat less in the case of cured tobacco leaves, some distance away from the spot than it was in the centre of the spot.



IG. 14.

Tobacco leaf showing spot. C1, deep green ring; C2, dead area; C3, tissue from region of O. Fig. 12.

Summary of the results of the investigation :—

There are four causes (in a measure quite distinct), which produce the spotted condition of the tobacco leaf, due to :—

(1) Fungi, (Cercospora, Macrosporium), Bacteria, Enzymes.

(2) Conditions of soil, moisture, temperature, fertilizers, etc.

(3) The recurrence of a philogenetic condition. (This is but a suggestion).

(4) Local applications of chemical irritants.

With regard to the last (4) the important points may be enumerated. The alkali kills the tissue in direct contact with the irritant; it stimulates to abnormal development the tissue immediately around the spot; the cells outside of the stimulated area are drawn upon more than ordinarily and are consequently poorer in protoplasm and chlorophyll than that of the tissue in the ring, and in the tissue of the ordinary part of the leaf.

The deductions to be made from this are, that plant growth may be stimulated by local applications to leaves, that leaves can transport the absorbed substance, and consequently the texture of the leaf may be modified by artificial means.

IX.—SOME OF THE EFFECTS OF SEA-WATER ON THE AIR.

The question as to whether the inorganic salts in solution in sea-water ever pass off into the air, in the neighbourhood of the sea, in any measurable quantity, has so far never received much attention from scientific men, but it has long been suspected by many people that sea-water does, in some way or other, enter the air, but little has as yet been done in a scientific way to ascertain the nature of the process, if any, by which the sea salt and other inorganic substances may leave the solution and permeate the surrounding atmosphere. It is obvious that, upon the occasion of storms and winds, the sea spray is blown into the air, and if the air be below the saturation point, as it generally is, much of the water evaporates while suspended in the air, and in consequence, minute particles of salts are left floating in the atmosphere, and later are blown about and deposited upon the surface of the sea, or upon the land and the leaves of plants within a reasonably short distance of the sea shore. Leaving this condition altogether aside, it is still an open question whether the salt may be taken up into the air without the aid of wind or spray and afterwards deposited upon substances that have a physical contactile affinity for the salts;

and with many of these substances with which these salts come into contact, form chemical compounds of a more or less stable nature. With this object in view, from the standpoint of vegetable physiology, it was thought advisable here to ascertain in an indirect way whether it be possible for substances in aqueous solutions to leave the solution, not with the liquid as a liquid, or as a vapour in the state in which the particles are so large as to refract and reflect light and therefore render it visible; but to leave the solution with the solvent water, or in small particles that are in the layer immediately upon the surface of the water, at the same moment the water particles become taken up by the air.

A series of experiments was arranged, as shown in Fig. 15.

Four kinds of iron were obtained:—(1) Chemically pure iron (98.8%); (2) Fine soft iron wire; (3) Coarse, common iron wire; (4) Piano wire. Each of these specimens of wire was cut up into three approximately equal portions, and one from each specimen was placed under a bell-jar in a watch glass perfectly clean. Under the jar was a crystallizing dish filled with sea-water in one case, salt water in the second case, and pure water in the third. Each jar then had under it four different kinds of iron, and excepting for the liquid used, all conditions were as nearly as possible the same. The specimens of iron were all weighed with the nicest accuracy upon commencing the experiment, and they were in clean watch glasses in order to be able to see if any of the solution happened to be precipitated in any way, or come in contact with the metal while the solution was in the air in the form of a liquid or spray. A liquid containing even the faintest trace of a salt in solution will leave plain evidence of the salt if the smallest part of a drop be allowed to evaporate from the surface of a well-cleaned glass. The surface of the watch glass was very large in comparison with the specimen upon it, and it is fair to conclude that if no salt settled in any way upon the glass none came in contact with the iron in the same way. The jars were each placed upon four glass plates laid

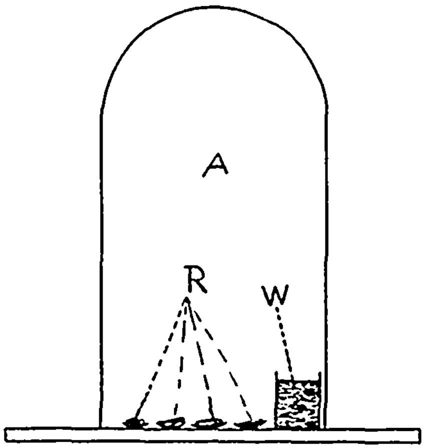


FIG. 15.
R, samples of iron; W, liquid used.

about half an inch apart, leaving an open ventilating canal in the form of a cross, in order to secure some ventilation and yet to have no direct current of air within the jar Each jar was removed every two days and sprayed upon the inside from a wash-bottle having a fine nozzle. This spray was of a liquid corresponding to that in the receptacle under the jar:—(1) Sea-water; (2) Salt water; (3) Distilled water. The spraying was done at some distance from the specimens, and in no case was there enough of the spray to cause drops to run down and off the side of the bell-jar. The object of this was to secure a moist atmosphere and to aerate fully.

There was one very peculiar phenomenon which developed during the experiment and one which is worthy of note. The jar containing the sea water did not become dry on the inside, even after four or five days, while the others dried completely (during the course of the first experiment) in twenty-four hours or less, consequently the jar containing the sea-water was not sprayed as often as the others, although it was the intention, when the experiment was arranged, to spray them all regularly. Why did the jar containing the sea-water remain moist,—the water clinging in small drops—while the others dried so readily? This phenomenon raises one of the most interesting questions relating to atmospheric conditions, and the effect upon plant and animal life. The experimental work belongs rather to physics and chemistry than to botany, so it will be deemed sufficient to merely answer the question leaving the details to the realm of physics where it belongs. Experiments were performed with some solutions, simple and compound, by placing a drop upon a leaf and leaving it undisturbed for several hours, and in some cases for several days, for the purpose of finding out whether the solution was absorbed by the leaf. During the performance of this experiment, among other things observed was that certain solutions did not seem to evaporate for some days, while others became dry in from one to six hours. Some solutions remained upon the leaf, having the appearance of a drop of water, for a remarkably long time. The same was then tried with glass plates, instead of leaves, and it was found that similar results were obtained—the same solutions remaining moist. A comparison was then made between glass and leaves and results obtained which showed that the moist condition was kept up longer by those drops which were on the leaves. Certain salts are very hygroscopic in their nature, *e.g.*, magnesium chloride, sodium acetate, etc., and it was these salts which remained longer moist,—retaining not only their necessary water of crystallization, but also enough besides to keep the whole in a liquid form. Certain mixed solutions exhibit this property to a greater degree than a solution containing only a single salt, but of equal concentration. It is thus, probably, with this complicated solution known as sea-water.

After the conclusion of the experiment described above, owing to some rather peculiar results as shown by the figures in the tables of weights given, it was thought advisable to continue the experiment for some time longer and to add another,—a fourth specimen of iron. This was a piece of piano wire, bright and clean. The other specimens, being now rusted, were cleaned with emery paper,—the rust being removed in this way—and after being carefully weighed were again placed under the jars. An interesting phenomenon had developed, in consequence, probably, of the change in humidity of the room in which the experiment was conducted, due to the increased firing necessary to heat the building. (The experiments were carried on in the basement of the university museum where during autumn there is considerable humidity in the atmosphere and where, when extra heating is required, the atmosphere in the basement becomes very dry).

Samples A, B, C, were of coarse iron wire, well cleaned.

Samples D, E, F, were of finer soft iron wire, well cleaned.

Samples G, H, I, were of 98.8% pure iron wire, well cleaned.

Samples O, P, Q, were of fine piano wire.

Samples A, E, H, O, under jar No. 1 (sea-water).

Samples B, F, I, P, under jar No. 2 (salt solution).

Samples C, D, G, Q, under jar No. 3 (distilled water).

The weighings are given in grams.

TABLE I.

Specimen.	Weight.		Gain.	Gain %.	Time, *14 days*.
	Oct. 29th.	Nov. 12th.			
A....	8.1000	8.1128	0.0128	0.1580	
E.	1.9446	1.9480	0.0034	0.1748	
H	0.5710	0.5809	0.0099	1.7340	
B......	7.2891	7.2950	0.0059	0.0807	
F.....	1.9315	1.9336	0.0021	0.1087	
I	0.5230	0.5300	0.0070	1.3380	
C..	7.6096	7.6128	0.0032	0.0420	
D................	1.8845	1.8856	0.0011	0.0583	
G	0.6764	0.6810	0.0046	0.6800	

TABLE I. a.

Specimen.	Weight. Nov. 12th.	Nov. 26th.	Gain.	Gain .	Time, 14 days.
A	8.1128	8.1145	0.0017	0.0209	
E	1.9480	1.9499	0.0019	0.0975	
H	0.5809	0.5839	0.0030	0.5760	
B	7.2950	7.2950	0	0	
F	1.9336	1.9350	0.0014	0.0718	
I	0.5300	0.5305	0.0005	0.0943	
C	7.6128	7.6159	0.0031	0.0407	
D	1.8856	1.8888	0.0032	0.1690	
G	0.6810	0.6859	0.0049	0.7190	

TABLE II.

	Nov. 27th.	Dec. 13th.			
A	8.0589	8.0642	0.0053	0.0657	*16 days.*
E	1.8471	1.8491	0.0020	0.1082	
H	0.5409	0.5450	0.0041	0.7580	
O	2.6095	2.60995	0.00045	0.0 72	
B	7.1251	7.1247	0	0	
F	1.9101	1.9101	0	0	
I	0.5093	0.5093	0	0	
P	2.5559	2.5559	0	0	
C	7.7426	7.7426	0	0	
D	1.8586	1.8591	0.0005	0.0269	
G	0.6581	0.6608	0.0027	0.4100	
Q	2.56455	2.5646	0.00005	0.0019	

TABLE II. a.

	Dec. 13th.	Jan. 4th.			
A	8.0642	8.0661	0.0019	0.0235	*22 days.*
E	1.8491	1.8510	0.0019	0.1027	
H	0.5450	0.5453	0.0003	0.0550	
O	2.60995	2.60996	0.00001	0.0003	
B	7.1247	7.1247	0	0	
F	1.9101	1.9105	0.0004	0.0209	
I	0.5093	0.5093	0	0	
P	2.5559	2.5559	0	0	
C	7.7426	7.7456	0.0030	0.0387	
D	1.8591	1.8613	0.0022	0.1183	
G	0.6608	0.6619	0.0011	0.16 [illegible]	
Q	2.5646	2.5649	0.0003	0.0117	

As indicated in these tables there are some rather peculiar phenomena, some of which are not easy to explain. Experiment I. a. was simply a continuation of I., as the specimens were weighed and returned to the jars without being cleaned of the accumulated rust. The same is true of II. a.

In both cases where the specimens were put in, well-cleaned of rust, those in the atmosphere under the influence of sea-water had made the largest proportional increase in weight, showing that the sea-water affected the atmosphere, which in turn caused an addition in weight of the iron due to oxidation. In jar No. 2, in which was the salt solution, there was found a greater percentage increase than in that of the distilled water. This, it was expected, would show that salt and water would always produce an increase in weight over that of the distilled water, and that the substances in solution had to do with the increased accumulation of rust, but in all the subsequent weighings this was reversed,—that of the salt and water showing little or no increase in weight. This seemed to upset any preconceived notions, or any conclusions that might be drawn from the first experiment, but when one takes into consideration other atmospheric conditions there is an explanation which may be fairly reasonable. This peculiar phenomenon, as was mentioned before, was associated with the difference in atmospheric humidity in the room where the experiments were performed. Almost all through the course of the first experiment the humidity was from seventy to eighty, and temperature fifty-five to sixty degrees F., while during all the other experiments it was at thirty-five to forty and temperature sixty-five to seventy. At first, when the humidity was about seventy-five, the jars remained moist for about twenty to twenty-four hours, whereas in the later experiments the moisture disappeared in five to six hours in jars two and three.

At first it was thought sodium chloride and other salts *might* pass into the air, but these experiments point rather to another conclusion, namely, that the salts affected the formation of iron oxide, only where it contributed to the atmospheric humidity, and that sodium chloride actually protected the iron from rust by absorbing water vapour from the air and thus reducing still further its humidity. The reason why the sea-water salts did not produce the same effect as the common salt solution was because of its extraordinary hygroscopic properties maintaining an atmosphere with more moisture than would be the case with a sodium chloride solution. It should be mentioned that during the latter part of the experiment the inside of jar No. 2 was covered with salt crystals, due to the residue of solution sprayed upon the inside; and there had been placed inside the jar at the commencement of the experiment a watch glass containing dry salt. Besides this, the salt from the solution in the crystallizing dish had crept up round the margin of the dish, and there had collected in considerable quantity, but only on the half of the margin on the side towards the source of light. No attempt is made to explain this last mentioned phenomenon. The greater increase per cent. of one sample of iron in jar three as compared with the same in jar one in experiments I. a. and II. a. is due to the fact that the specimen in jar one had been fairly well coated with rust from experiments I. and II.; and so the iron having the smallest amount of rust upon it at the commencement of the experiments I. a. and II. a., made, as might be expected, the greatest gain in the succeeding experiments.

From these experiments we might conclude :—

(1) That sea-water causes the atmosphere to produce rust upon iron to a greater extent than does fresh water.

(2) That the presence of salt (NaCl) causes an accumulation of rust upon iron when the humidity is high—about seventy to eighty—but when the humidity is low—about thirty-five to forty-five—it prevents rust formation.

(3) That sea-water affecting the atmosphere in maritime localities may also affect vegetation.

The only investigations of importance relating to the question of chlorides in the atmosphere were carried on at Rothampstead, England, by Lawes and Gilbert (1883), and by Dr. Frankland (1881). Their determinations were made by analyzing the water from rain-falls, and, in the case of Lawes and Gilbert, the experiments extended over a period of six years, 1877-83. The results obtained by these men did not fall into any very regular series and several points were left by them unexplained. Quoting from Lawes and Gilbert:—"In the account given in the earlier results of this investigation it was pointed out that the winter rain-fall was far richer in chlorine than the summer rain-fall; we are now able to take a step further, and show the general character with respect to chlorine of each month of the year. The minimum amount of chlorine occurs in the rain of July. In August and September there is a distinct but not a very large increase in quantity. In October and November a great rise occurs, the quantity of chlorine contained in the air being three times as large as during the preceding months. After the peric.. of maximum there is a fall, but the chlorine remains high throughout the winter months, the diminution towards the summer period not commencing till April. The rain of March has yielded the highest proportion of chlorine per million of water, but this is partially due to the small rain-fall of this month. Rather more than two-thirds of the annual supply of chlorine is contributed by the winter months." And they say further in explanation:—"It would appear that in summer the supply of chlorine is very limited, for a large increase in the rain-fall is attended with but little rise in the quantity of chlorine brought down per acre. In winter, on the other hand, the supply of chlorides in the atmosphere is so constantly renewed, that an increased rain-fall results in a considerable addition to the supply per acre. The rather wide irregularities in the composition of the groups of rain-fall for the whole year, are principally due to the different proportion of summer and winter months which enters into the various groups.

"The large excess of chlorides found in winter rain is probably due in a great measure to the chlorides volatilized during the combustion of fuel; the excess in question is too uniform to be dependent chiefly on the action of strong winds blowing from the sea; it is also remarked in calm months as well as in stormy weather. Exceptionally high results are, however, probably due to storms. When we turn to the nice gradations observed among the winter months, it is difficult not to believe that the temperature of the air has some influence on the results. In the more rarified atmosphere of summer, gaseous diffusion will probably be more active, while the power of transporting minute solid particles will be diminished.

"It is difficult to ascertain the influence which the direction of the wind has had on the composition of a monthly rain-fall; a partial study has been made of the data at our disposal, but with no definite result."

From this it would seem that no satisfactory explanation was then known for the small amount of chlorides in the air in summer in comparison with the winter months, and if we except the volatilizing of sodium chloride by combustion, and the spray of the sea, there is no explanation given for the chlorides being in the air at all. Both of these, however, do not account for it; but from the light of the experiments of Lawes and Gilbert, and of those described in this paper, the conclusion is suggested that the leaves of plants may absorb sodium chloride in solution from the atmosphere, resulting in a decrease in the amount during summer. If it were not for plants, therefore, there would be a greater amount in the atmosphere in the summer than in the winter; and when vegetation is checked in October and November, and leaves have fallen, one would expect the largest amount when the temperature was still comparatively high and the leaves incapable of absorbing much of the chlorides. This is, however, only a suggestion.

In Griffon's researches (1899) it is shown that leaves of plants in the vicinity of the sea differ in assimilating power from those of the same species inland. He shows that for a given unit of area of leaf surface there is less assimilation in the leaf of a plant grown near the sea than of one inland. Whether this is due to salts in the soil or to salts in the air Griffon does not say. This may in part be due to salt water in the soil, but possibly not wholly so, as the chief differences are to be found in the leaf rather than in other parts of the plant.

In the work of Smith (1872), there are many and extensive collections of tabulated results of analyses of rain-water in northern Europe. The principal analyses were made of the rain-fall of England and Scotland, and minute details are given. He shows that chlorides and sulphates, as well as many other substances, are found in the air, and states that the amount of chlorides depends upon two things:—(1) the proximity to the sea; (2) the combustion of fuel in factories. He concludes, however, that the presence of chlorides was not wholly due to spray, for he says:—"The common salt from the sea is not spray, or at least not spray purely; if it were so there would be the relative amount of sulphates to chlorides which we find in sea-water." It has been observed that salt is often found on windows far from the sea when a violent wind is blowing. Now the question naturally arises, did the salt reach the glass as an aqueous solution (in small drops) or as dry particles? If it were carried in the form of small drops that would be simply as rain or mist; but such, however, is not the case as there is neither rain nor mist, but simply a strong wind blowing from the sea. If it were in the form of dry particles one would scarcely expect it to stick to the dry pane of glass. How then was the salt conveyed from the sea? It was this question that the writer attempted to answer by the experiments described at the beginning of this chapter. Though some rather important phenomena were developed in the course of the experiments, yet little light was thrown upon the above mentioned question. That chlorides and sulphates and other inorganic salts are in the air in rather considerable and constant quantities is what mainly concerns us here.

Smith gives :—

London, 1869,	chlorides	1.2 grams;	sulphates	16.45 grams	per million.
Glasgow, "	"	8.97 "	"	70.19 "	" "

Ad. Bobierre (Smith, 1872), gives :—

Nantes, ammonia	1.997	grams per cubic meter.
salt	13.9	" " "

M. Bobinet (Smith, 1872), gives :—

Paris, calcium sulphate 20 grams per million.

According to Smith the sulphates found in the air are alkaline sulphates, and these sulphates are largely the product of organic decomposition. On a complete analysis he found that a hectare of land at Caen received in rain-fall in one year :—

$NaCl$	37.5	kilograms.
KCl	8.2	"
$MgCl_2$	2.5	"
$CaCl_2$	1.8	"
Na_2SO_4	8.4	"
K_2SO_4	8.0	"
$MgSO_4$	6.2	"
$CaSO_4$	5.9	"

and besides these he found ammonium salts, iron oxide, and oxide of manganese and nitric acid.

From this it may be seen that rain-water is an excellent nutrient solution in a very dilute form and it is extremely probable that some of the food substances of the plant are obtained directly from this source.

One important conclusion may be drawn from the experiments described in this chapter. Since growth of plants is dependent for energy upon destructive metabolism, and since destructive metabolism is (for aerobic plants) dependent upon the absorption of free oxygen (Vines, p. 332), it follows that because oxidation of iron is hastened in an atmosphere under the influence of sea-water, growth may be hastened by a similar chemical process. What applies to the destructive metabolism of plants applies in a large measure to the same process in animal life.

X.—ON THE EFFECTS OF WATER AND NUTRIENT SOLUTIONS UPON DEVELOPING BUDS OF WILLOW TWIGS.

In order to investigate in some detail the question as to whether nutrient solutions affected the budding and the general commencement of growth of twigs of a plant belonging to the genus Salix, and as to the *manner* in which they affected growth, a series of experiments was performed during the months of March and April, 1900. Apparatus was arranged as indicated in Fig. 16.* The twigs were taken at a season of the year best suited to the purpose, the internal conditions of the plant being then of such a nature as to produce immediate active growth if subjected to right conditions of temperature and of moisture. The twigs were, as nearly as may be, of uniform size and quality. As will be referred to, a comparison was also made between the effects of distilled water and of tap water upon the development of roots and buds. Willow twigs, being of such a hardy nature, and having the capability of sending forth adventitious buds and roots, even under rather unfavourable circumstances, and each small part of the twig being in itself, so to speak, the embryo of a new plant, they lend themselves readily to experiments designed for various ends. The main purpose of the experiments here described was to find out whether the bud, as it is developing, absorbs water or solutions, and whether it is affected by the liquid in which it is immersed. This is the main point. The other results recorded are subordinate to this, so far as this paper is concerned, and will consequently receive less attention, but they may not be subordinate from the standpoint of scientific interest.

Three twigs were placed as in Fig. 16, A B, with both ends in liquid, the first, (a), with both ends in distilled water, the second, (b), with distilled water in the lower vessel and a nutrient solution in the upper, the third, (c), with nutrient solution in the lower and distilled water in the upper vessel. Each twig had two undeveloped buds in each jar of liquid, and several others outside the jars. The lower jar in each case was wrapped with dark paper to exclude most of the light. The upper jars were of transparent glass and had no wrapper. The twigs were all inserted alike in having the top, or smaller end, uppermost. The upper and the lower liquids were renewed from time to time as occasion required; and in the case of (b), there was a complete

* These diagrams are for the purpose of illustrating accurately the whole conditions under which the experiments were conducted.

change necessary occasionally, owing to the very rapid growth of algae in the solution, which, if not removed, might in a short time become a hot-bed of bacteria injurious to the young buds upon the twig.

Observations were made and results recorded upon five different times during the course of the experiment which lasted over a period of forty-three days.

On March 19th, five days after the apparatus was set up, it was found that upon (a) there were growing buds between the two vessels

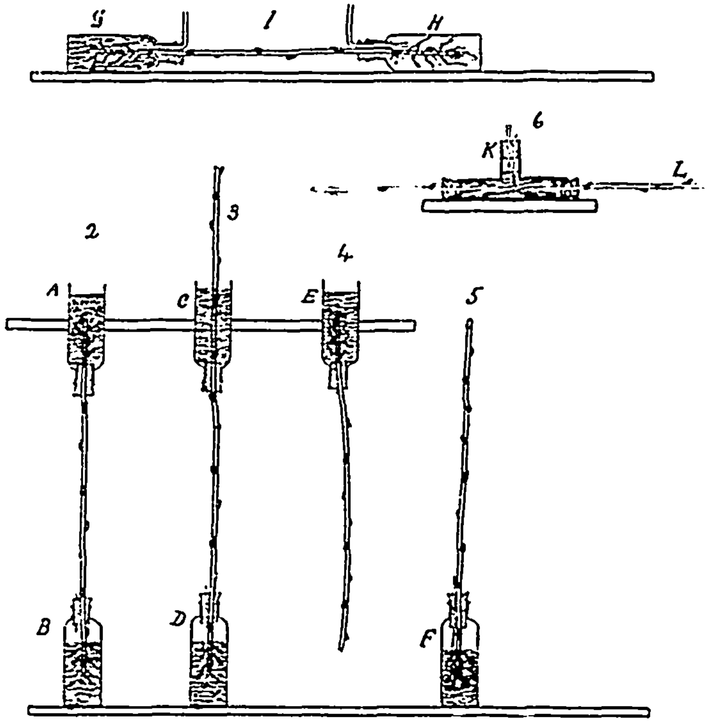


FIG. 16.

G and H contain water or solution as required. A, C, E, bottles with bottoms removed and upturned to hold liquid, cork being made so as to prevent liquid from running out. K, is a large "T" tube filled with water through which a twig passes.

but none in either liquid. Twig (b) had one growing bud *in* the upper liquid but no others growing. Twig (c) had none at all.

On March 26th, twig (a) had no growing buds in the upper liquid but had very healthy buds between the jars; twig (b) had growing buds between the jars and the two in the upper solution were also growing; (c) had growing buds between the jars but none in the upper liquid.

On April 8th, (a) had no buds in the upper liquid while (b) and (c) had.

On April 23rd, twig (a) had roots in the upper liquid but no growing buds; (b) had leaves between the jars, the lower ones especially drying up; those in the upper liquid were living and fresh; (c) had roots in the upper liquid, and one of the buds was developing, seemingly at the expense of the other.

April 26th, (a), roots but no buds developed in the upper liquid; (b), no roots developed in the upper liquid but the leaves were flourishing; (c) had roots and one green branch in the upper liquid.

On April 26th, all were taken from the liquids and the root systems compared. It was found that no buds developed in the solution in the lower jar; the roots of (a) were the most healthy looking and the most flourishing in every way; (b) was second, and (c) was much the poorest in development and had a miserable looking root system in comparison with the other two.

From these experiments we may conclude, (1) that a nutrient solution, such as that used here (in comparison with pure or tap water), does not favour the development of a healthy root system of this plant. It would not be safe, perhaps, to make this conclusion upon two or three experiments alone, but in every case of similar and of different experiments there was no exception to this. On young roots, water, in every case, seemed more favourable to the development of a healthy and extensive root system. (2) Leaves can live and develop in water and in a nutrient solution. (3) The development of roots and leaves is not, as is often stated, confined to the poles,—the one system at the one pole, the other at the other,—certain conditions of moisture supply having an important bearing upon their development. An important point to note, and one which will be discussed later, is that the nutrient solution in some way or other affected injuriously, after a time, the leaves on the plant, other than those immersed in it, and that the solution (as in b) affected the root system. This point is the stronger when compared with other similar experiments.

Coincident in time with the experiment just described was one set up as shown in Fig. 16, CD, in which we have (d) with distilled water in both the upper and the lower vessels; (e) with distilled water in the lower vessel and nutrient solution in the upper (two buds in the liquids in each case).

March 19th, we found small buds developed, *(all)* above the upper liquid in (d); in (e) no buds developed yet.

March 26th, (d), all the buds above the upper liquid were developed; (e) small buds developed in the upper solution which was somewhat green owing to a growth of algae which seemed to thrive vigorously in the solution used.

April 8th, (d), both buds developing in the upper solution and some above but none below; (e) both buds in the upper solution growing, several above and one below were growing.

April 23rd, (d), leaves all living above the upper solution; (e), leaves all dried above the upper solution and below it, but not in the upper liquid.

The one important difference between this experiment and the preceding one is that there was no development of roots in the upper liquid, and almost no development of leaves between the jars where there was a vigorous growth of leaves in Series I.

At the conclusion of the experiment, upon examining the root systems of the twigs, it was found that (d) had a healthier root system than (e). This must have been due to the difference of conditions, which were, that there was a nutrient solution in the upper jar in the one case, and water in the other, the nutrient solution above, having *apparently* entered through the buds and penetrated as far as the roots.

Series III. was arranged on the same date as the others, and according to the plan shown in Fig. 16, 5; (f) was in a nutrient solution; (g) in distilled water; and (h) in tap water. (Two buds in each liquid, and several others besides).

March 19th, the roots of (f) were most numerous but short, and the buds of all three twigs were commencing to develop; little if any difference between (g) and (h).

April 8th, the tips of the buds of (f) were dead, while the buds of the others were living.

April 23rd, the leaves of (f) were all withered and the twig appeared dead. Both the others were living. The root systems were compared and it was found that the roots of (f) were rather numerous but stunted and of a yellowish brown colour, while those of the others were long, whitish and healthy-looking. When these results are correlated with those of the preceding it is found that, in a measure at least, they confirm certain conclusions previously stated.

Series IV., shown in Fig. 16, 4, was set up at the same time as the others and consisted of three jars with twigs as shown in the diagram, having in the jar in (i) tap water, and having the "butt" end of the twig in the jar. In (j) there was distilled water in the jar but the twig was placed with the "top" end in the water. In (k) the "butt" end was in the solution, (nutrient).

March 19th, (i) had five healthy roots (one of which was about an inch long), growing equally from all sides of the twig and nearly perpendicularly to its axis. Twig (j) had sent out four short roots and (k) two roots, one of which was about three mm. long.

April 8th (i) seemed to be thriving excellently both as to roots and buds. Twig (j) had a very poor growth; (k) had a few roots in the liquid but they were short and the tips were darkened; a couple of buds were developing near the tip of the twig.

April 23rd, (i) flourishing nicely; (j) not dead but exceedingly slow in growth both as to roots and buds; (k) buds become darkened and seemed to be drying up, the roots were discoloured and of a stunted growth. We note the difference in growth between (i) and (j) when moisture and polarity are contending forces; also the effect again of the nutrient solution upon the growth of both the roots and the buds.

Series V., Fig. 16, 1, in the diagram shows the arrangement of the apparatus. Two sets were arranged—(l) and (m), all the jars being wrapped about with black paper and no observations were made of the ends of the twigs until the close of the experiment on April 23rd. In (l) there was distilled water in both jars; in (m) nutrient solution in both jars. Before the close of the experiment it was observed that both twigs had considerable growth, but that in the case of (m) the leaves had a tendency to curl and to turn black, wilt and die, though the plant was certainly living at the close of the experiment. Upon examining the ends of the twigs on April 23rd it was found that (l) had many roots at the butt of the twig, some of them 75 to 100 mm. in length, that it had ten roots at the "top" and one green bud. Two of the roots at the "top" were each 60 mm. long. The roots at the "butt" of (m) were short and stunted, none being over 25 mm. long. The tips of these roots were brown in colour. It had developed two roots at the "top," and also one bud. These roots, strange to say, were longer than those in the jar at the "butt" of the twig.

To test if water might enter through the bark an experiment was arranged as shown in Fig. 16, 6, and left from March 14th to April 23rd (forty days). One internode of the twig was kept in water, while both adjacent nodes and the free ends were in the air. Absolutely no growth occurred and the twig dried and shrivelled up at both ends. The middle which was constantly in water shrivelled up considerably.

From all these sets of experiments, varied as they are, some rather important general conclusions may fairly be drawn. The nutrient solution when applied to developing buds of the willow seemed to affect the development of the roots of the twig in the same way as when applied to the place of origin of the roots. It also affected developing buds, other than those immersed in it in the same way as they were affected when the roots were in the liquid. All these results point towards absorption of the liquid by the developing bud.

Water was in all cases more favourable to growth than was the nutrient solution; and distilled water was more favourable than tap water.

XI.—SUMMARY OF RESULTS AND CONCLUSIONS.

Wilted leaves, whether detached from the plant or not, will absorb water, if immersed, or if water be applied to the surface in the form of a spray. Weighing a leaf or a branch to estimate the amount of water absorbed, will be deceptive, because a certain amount of substance is extracted by the water; and unless this substance be taken into consideration in the weighing, a loss instead of a gain *may* result, and yet an absorption of a considerable amount may have taken place.

Special parts of leaves of certain plants seem to be adapted to the purpose of absorption as shown by the surface of the epidermal cells over the veins, at the base of the trichomes, and in other regions. Trichomes in some cases are particularly susceptible to the action of water and of solutions applied to them. Striations and hairs or trichomes aid exceedingly in spreading liquids over the regions which seem to be adapted to absorption; and trichomes prevent a rapid evaporation of the liquid so spread, by retaining air. Absorption of water may take place also through the surface of the petiole.

Guttation drops and dew-drops contain substances in solution which are generally resorbed by the plant. Carbonates as incrustations may serve to store up, in the presence of moisture, CO_2 at night, and utilize the same as the bicarbonate is reduced to the carbonate in the day time. Incrustations may be, therefore, not only an adaptation to retain water in desert countries, but also to utilize to the full the loss of CO_2 caused by respiration. $CaCO_3$, though insoluble in water, may be absorbed if water and CO_2 be present.

Distilled water becomes alkaline, generally, if allowed to remain upon leaves of plants for a shorter or longer period of time.

Certain plants adapted to a moist climate may be made to take in all the food necessary for growth through the leaves. Distilled water used as a spray acts for a time as a stimulus to growth. It may be that it acts as a means of drawing from the plant surplus alkaline salts which, if formed in too large quantity in the cells, might become harmful. Calcium and sodium compounds, and also potassium oxalate have been extracted from leaves by distilled water. Rain water may act as a stimulus in this way.

Solutions if applied to the surfaces of detached leaves, or to leaves upon the plant are generally absorbed as shown by the increased content of ash. Solutions, so applied, often stimulate a certain portion of the tissue to an abnormal development. The ring produced upon a leaf by the application of a drop of solution, is the result of the peculiar action of the evaporating drop.

Solutions applied to the cut ends of the petioles of leaves are generally conveyed to the minute terminations of the tracheids, where they kill the tissue in one of two ways:—(1) by drawing water osmotically from the cells into the intercellular spaces, producing a translucent appearance of the tissue; (2) by chemical action,—upon the walls of the cells, (b) upon the protoplasmic membrane, (c) upon the protoplasm as a whole. The first determinable reaction after death is alkaline, even though the tissue be killed by an acid. Some leaves will remain green and fresh longer in a dilute solution of the poison lead acetate, than they will in either distilled or tap water. This applies to leaves which ordinarily wilt away in water in a fortnight or so.

Certain substances in solution ascend through the blade of a leaf, at rates which vary as the lengths of the different veins of this leaf, and the area of the part affected is symmetrical to the area of the whole leaf.

The lithium test gives rise to error because the water ascends faster than the lithium, and because the rate of ascent in the same leaf, varies as the length of the vein.

A detached leaf is a living thing which may continue its functions, to some extent, for several months after being detached from the plant.

The food required by woody branches of Salix in the early growth of spring is water. A nutrient solution at this stage proved harmful. Water and nutrient solutions are not absorbed through the bark but affect the developing bud and young leaves in a manner which seems to indicate absorption through the buds.

Since sea-water affects the atmosphere in such a way as to produce an accumulation of rust upon iron, greater than that produced in an atmosphere under the influence of pure water, it is reasonable to conclude that the atmosphere in the neighbourhood of the sea may affect plants, because physiological processes are associated, in large measure, with chemical processes.

The best thanks of the writer are due to Professor Goodale for opportunity and much kindly assistance and encouragement in regard to this paper, to Professor Sharples for material and help in the work on the "spotting" of the Tobacco leaf, and to Mr. Robert Cameron, foreman of the Botanic Gardens, for material cheerfully furnished at all seasons.

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THE WINDWARD ISLANDS OF THE WEST INDIES.

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(Read 2nd November, 1901).

CONTENTS.

INTRODUCTION AND HOW TO REACH THE ISLANDS.

THE West Indies have had a long and thrilling history, including even the small Windward Islands, that separate the Caribbean Sea from the Atlantic Ocean. These lesser Antilles were formerly a source of great commercial wealth. They have been the birth place of many distinguished families, and the scenes of actions of world-wide importance. But most of these things and their literature are more than half a century old. The small amount of scattered knowledge concerning their physical features scarcely amounted to more than a statement that they were volcanic islands or coral rocks. It was even most difficult to get information as to the facilities of travelling about among the islands, especially the smaller ones. Although some popular books of travel have been written, the best account of the features of the islands is that of Élisée Reclus.* But the different islands have varied and most interesting geological and geographical phenomena. It was for the study of these that I visited the Windward Chain in 1896-'97; for previously, I had discovered in the West Indian region the evidence of the great changes of level of land and sea in late

* "The Earth and Its Inhabitants." Vol. II., pp. 431-486. (Appletons, 1893).

geological times, which was published several years ago.* The results of my investigations of the geology of the Windward Islands have only in part been completed, and that portion has recently been published by the Geological Society of London.† The final studies have not yet been made. The object of the present paper

Map of the Windward Chain of Islands.

is to describe the physical geography of the region and the changes it has undergone.

* "Terrestrial Submergence Southeast of the American Continent." Abs. Bull. Geol. Soc. Am. Vol. V. (1893). pp. 19-22, with map.

"Reconstruction of the Antillean Continent." Ib. Vol. VI. (1894). pp. 103-140.

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† "On the Geological and Physical Development of Antigua." Quar. Jour. Geol. Soc., Lond. Vol. LVII. (1891). pp. 490-505.

"On the Geological and Physical Development of Guadeloupe." Ib., pp. 506-519.

"On the Geological and Physical Development of Anguilla, St. Martin, St. Bartholomew and Sombrero." Ib., pp. 520-533.

"On the Geological and Physical Development of the St. Christopher Chain and Saba Banks." Ib., pp. 534-544.

"On the Geological and Physical Development of Dominica, with Notes on Martinique, St. Lucia, St. Vincent and the Grenadines." In preparation.

"On the Geological and Physical Development of Barbados, with Notes on Trinidad." In preparation.

A few words may be said as to the means of reaching the different islands. From New York the ships of the Quebec Steamship Company leave on irregular dates, but averaging three or four sailings a month, sometimes first touching at St. Croix, next at St. Christopher (universally called St. Kitts) and then sail onward to the south. On other voyages the ship calls first at St. Martin, and then proceeds as before. Again St. Kitts may be the first stop. While most of the larger of the more southern islands are visited on each trip, this is by no means so certain as on the north bound voyages. After touching at St. Lucia, or St. Vincent, the steamers proceed to Barbados and often to Demerara, and some of the tourist steamers in winter, to Trinidad. Another line sails for Grenada and Trinidad direct. The Pickford and Black Line, from Halifax, sails regularly every four weeks for Bermuda, St. Kitts, and on to Trinidad. Local steamers of the Royal Mail Line sail regularly once a fortnight between the larger islands. There are other occasional steamers by which passage between the islands can be made. But to the smaller islands, one must depend upon small schooners or sloops of perhaps only ten tons capacity, which may usually be found sailing weekly from the larger islands, for carrying the mail, etc. Thus there is a weekly sloop from St. Kitts to St. Martin, Anguilla and Sombrero; from St. Martin to Guadeloupe; from St. Croix to St. Thomas and the Virgin Islands, etc. To and from Barbados and Martinique there are fortnightly steamers to England and France, and other steamers to the South American ports and Colon, as also to Jamaica. The Quebec Line and the Pickford and Black steamers sailing among the islands usually travel at night, so that the tourist can go ashore for the day and get a glimpse of these most beautiful tropical lands. The coasting voyages of the Royal Mail Line give no opportunities for seeing the islands, as they make brief calls, day or night, and then proceed onward.

SOMBRERO.

Sombrero is a lonely sentinel away out in the Atlantic, at the northern end of the Windward Chain, being situated forty miles beyond Anguilla. It is less than a mile long, with a breadth of a quarter its length. Its flat top is pitted by former workings for phosphate of lime. It is about thirty feet above the sea, with vertical walls, so that landing at the foot of a ladder is difficult. It is composed of a coral-bearing soft white limestone, found to be of early Pleistocene age. Pockets on the surface have been converted into phosphate of lime by birds, which, during some portion of the Pleistocene period, made it their home. There is not a tree on the island. The great lighthouse of this region is here, and six men are in attendance upon it. It is a dependency of St. Kitts, a sloop from which visits the island weekly (see map, Plate A, appended).

THE ST. MARTIN ARCHIPELAGO.

St. Martin, St. Bartholomew and Anguilla rise out of the same banks which are submerged from 100 to 200 feet. The whole forms a physical unit, being an isolated remnant of the dissected and submerged Antillean plateau. The margins of the plateau are further indented by deep valleys, heading in amphitheatres, as shown west of Anguilla and St. Martin, and south of St. Bartholomew, where the incisions on the two sides of the drowned tableland have united into a channel across it. These features are shown on the map (Plate A, appended). This mass rises prominently above the broad channel, 2,500 feet in depth, separating it from the Saba banks, but from its eastern side the descent to the Atlantic abyss is not known to be interrupted by other features.

St. Martin (see map, Plate A, appended) is mostly composed of mountain ridges (the highest point of 1,360 feet may be seen in figure 1, Plate I.) and valleys which broaden out rapidly, from the *cul de sac* of each, and terminate in bays, in front of which there are often beaches, such as that shown in the illustration, where the Dutch town of Philipsburg is built. These valleys are formed by the rapid erosion of high lands due to the tropical storms, one of which I witnessed, when eight inches of water fell in three hours. Such rainfalls in the dry season are due to the mountains, even low ones, condensing the moisture out of northeastern trade winds, while neighbouring flat islands, like Anguilla, have a great scarcity of rain. On the western side of St. Martin, Simpson's Inlet is a beautiful bay or lagoon, enclosed by ridges connected by sand beaches. Only an inconsiderable portion of St. Martin could be considered a coastal plain.

The mountains are composed of the old West Indian igneous foundation, probably, in part, older than the Tertiary era, though perhaps, in part, belonging to the earlier Eocene days. There are also volcanic tuffs, and a formation of grey limestone which is composed of calcareous layers intercalated with tufaceous beds, but the calcareous strata are more or less silicified into chert. Such are well seen along the shore, as at Pelican Point, illustrated in figure 2, Plate I., where also boulders three or four feet in length, more or less rounded by the waves, may be seen. The silicified formation contains manganese which has been economically worked, and also iron ore. Similar igneo-calcareous formations have been found in St. Bartholomew to belong to the Eocene period, from the fossils which Cleve* obtained in the calcareous layers. Remnants of the white limestone, or the Antigua formation, (of the Oligocene period) occur about Simpson's bay, and in the French portion of the island.

Tintamarre, an off-lying island, rising to a height of ninety feet above the sea, is a remnant of the former coastal plain of St. Martin. It is composed of two calcareous formations, both of white limestone, but the strata of the lower are more or less upturned, and contain Oligocene fossils; the upper, substantially horizontal, contains an old Pleistocene fauna.

Anguilla (see map, Plate A, appended) is a low-lying island, separated by a strait of four miles in width from St. Martin, of which it was a former coastal plain. Its highest point, near the northern cliffs which are being encroached upon by the sea, rise to only 213 feet in height. At points the old igneous foundation may be seen near waterlevel, beneath the white limestones. The disturbed lower beds contain an Oligocene fauna, and the upper horizontal beds hold Pleistocene fossils. It is often difficult to distinguish these formations apart, although separated by such a long geological gap. This island is also interesting from the occurrence of Pleistocene bones discovered by Mr. Wager Ray, and found by Prof. Ed. Cope to be those of *Amblyrhiza*,—rodents, as large as a Virginia deer, whose ancestors had migrated from South America in the Pleistocene period, when there was a continuous land connection with that continent.

Gravel formations have been found in these islands belonging to later days of the Pleistocene period. Coral reefs are now flourishing, especially off the coast of Anguilla, but they are not raised above the sea level.

The roads of the flat island of Anguilla are well made, as also those of St. Martin, which, however, have to pass over several high hills. St. Martin is politically divided between Holland and France. St. Bartholomew is French. Both French colonies are dependencies of Guadeloupe, and both are free ports. Anguilla is an English dependency of

*"On the Geology of the Northeastern West India Islands," by P. T. Cleve. Trans. Roy. Swedish Acad. Sc., IX., No. 12, p. 26.

St. Kitts. From St. Kitts there is a weekly schooner to St. Martin, Anguilla and Sombrero, from St. Martin a fortnightly schooner to St. Bartholomew and Guadeloupe; from St. Martin to Saba and Curaçao sails a monthly schooner. At St. Martin the Quebec Steamship Line calls about once a month on the outward passage from New York.

Anguilla has practically no exports and is a very poor island, the negroes living on "ground" provisions (tubers), some fruits, etc. St. Martin formerly produced sugar, but this industry has almost disappeared. Some cattle are raised for export, but the salt production is now the principal source of wealth. The few thousand people of these islands are almost entirely black or coloured, with only a few whites, mostly the descendants of the planters of slave days. But many of the old families have disappeared. English is the language spoken in the Dutch portion of St. Martin, but it is also generally understood on the French side of the island and in St. Bartholomew, whose inhabitants are largely of French origin. Before leaving this subject, I wish to express my very high appreciation of the Honorable Diedric C. Van Romondt, K.N.O., and formerly Governor, and his family, and to thank them for the princely hospitality shown to Mrs. Spencer and myself, such as characterized the palmy days of the West Indies. His charming suburban home is in the beautiful valley of Cul de Sac, opposite the highest point of the island, both of which may be seen in figure 1, Plate I.

THE ST. KITTS CHAIN, MONTSERRAT AND THE SABA BANKS.

Here we find three elevated remnants of the dissected Antillean plateau rising up as tablelands to 3,000 feet or more above the floor of the drowned valleys. But the channels separating them have a depth of 15 to 100 feet below the surface of the sea. On the St. Kitts remnant, St. Eustacia, St. Kitts itself and Nevis rise as the mountainous back-bone of the region, with the Saba banks, as a slightly submerged coastal plain, to the south. (See map, Plate A, appended). Montserrat is a repetition of the central mass. Saba is simply an extinct volcanic cone, rising precipitously from the floor of the sunken Antillean ridge, but at the foot of a submarine tableland now forming the Saba banks. Its height above the sea is 2,830 feet, with the water 2,250 feet or more in depth. On the floor of an extinct crater, at the height of several hundred feet, is perched the town of Bottom. It is a small Dutch settlement where the inhabitants are engaged in boat building, or as mariners.

Saba banks have an area of 800 or 900 square miles, rising to within 100 or 150 feet of the surface of the sea. This is a fine example of a submarine tableland not surmounted by any mountains. Its surface has been levelled over by coral growths and sands derived from them. It is the only conspicuous remnant of the coastal plains on the Caribbean side of the mountainous back-bone of the Antillean ridge until the Grenadines are reached. (See map, Plate A, appended).

Saba and Statia (the colloquial name of St. Eustatius), are both within sight of St. Martin, and can occasionally be reached by sloop from St. Martin and St. Kitts.

Statia, St. Kitts and Nevis are all situated on a narrow submerged ridge. The north-western end of Statia and the south-eastern end of St. Kitts are the remains of the old dissected and degraded mountains composed of the ancient trappean foundation of all the Antillean islands of the Windward chain, but the remaining portions of these two islands and Nevis are surmounted by volcanic ridges, belonging to geological days more recent than the early Pleistocene epoch, with the volcanic activity continuing down so recently that some of the craters are still preserved, such as that of Mount Misery (4,314 feet above the sea), with one side removed to a depth of 600 feet. It is about a quarter of a mile in diameter, with a lake partly filling the depression (according to my friend, Dr. Christian Branch, who then resided in the island). Statia has also a perfectly preserved crater, called the "Quill," rising to a height of 1,950 feet. (See view, figure 1, Plate II.). From the central ridges, the surface slopes in the form of a *glacis*, which is deeply dissected by valleys, as shown in figure 2, Plate II. At only one point on the north-eastern side of the island did I see any lava, and that belonged to a Pleistocene eruption, but Dr. Branch informed me that some black rock had been reported from near the summit of Mount Misery. The soil is made up of volcanic ashes of great fertility, which is constantly creeping down the slopes. At Basse Terre, St. Kitts, in 1880, a cloud burst upon Monkey hill, back of the town. (See figure 3, Plate II.). Over thirty inches of rain fell within three hours. The floods from such storms carry ruin before them. Great, deep valleys are rapidly excavated out of the loose, volcanic soil, while the material removed from them settles upon the more level land, in this case filling the streets and gardens with mud to several feet in depth. On the sloping ground every structure is washed away by the sheets of water, and people overtaken by them are whirled into the sea. Sometimes where the bodies are caught by an obstruction, this impediment to the current causes a deposition of mud, so that they may be quickly buried on the plains before reaching the sea. A similar flood, though not so severe, yet drowning many people, occurred in Montserrat during my stay on a neighbouring island. These floods give some idea of the very rapid changes in the physical features of this tropical region. But in addition the Atlantic ocean is encroaching upon the eastern sides of all the islands, owing to the waves being thus driven by the north-eastern trade winds. Accordingly, almost all the ports are upon the leeward sides of the islands. In St. Kitts, there are wild monkeys, but they belong to an African species, and it is not known who imported them.

Nevis is a nearly circular island radiating from a volcanic dome which rises to an altitude of 3,596 feet. It is nearly always wrapped in a cloud, like the summit of Mount Misery in St. Kitts. Its sloping surfaces are similar to those of St. Kitts, of which it is now a political dependency, though formerly the more important. In the seventeenth century there were several thousand white settlers who were forced to leave owing to the concentration of the lands into the hands of a few owners. Now the whites are few and poor. Here was born Alexander Hamilton, one of the fathers of the American republic. So also the wife of Lord Nelson, who, at his marriage here, was attended by Prince William (afterwards King William IV.), as best man. The island is separated from St. Kitts by a strait only a few miles wide, and very shallow.

The old eruptive foundation of these islands belonged to the very beginning of the Tertiary era, or to a little earlier geological time. During the Miocene, and until about the close of the Pliocene period, this region was a land surface, and no formations were accumulated beneath the sea. But in the Pleistocene period a most interesting phenomenon occurred. A volcanic upheaval raised Brimstone hill on the flanks of St. Kitts to a height of about 700 feet, without having produced a crater. (See view, figure 1, Plate IV.). In the outburst, the floor of the sea was thrust up so that a limestone veneer, about thirty feet thick, covers the sides of the hill, which is about half a mile in diameter, to a height of 400 feet, on which a strong fort was formerly raised. The formation thus lifted up contains fossils which show that it was formed at the close of the Pliocene or beginning of the Pleistocene period. The same phenomenon was repeated twelve miles away in Statia (see figure 1, Plate II.), but there the limestone mantle occurs to a height of over 900 feet, and on the summit a well preserved crater was formed.

Montserrat (see map, Plate B, appended), shows the old igneous foundation, small remnants of the earlier Tertiary (Oligocene) limestone, and the surface accumulations from two volcanic cones of apparently the same age as those of the other inner islands of the Windward chain.

Most of the roads in these islands are well made. Very fine sugar estates cover the slopes of St. Kitts and Nevis, but the industry is paralyzed, and prevailing poverty has succeeded the luxuriant wealth of a generation or less ago. In Montserrat, great quantities of lime juice and citric acid are produced. The people are mostly negroes, with a considerable number of Portuguese, descendants of labourers imported some time ago into St. Kitts. The old English white families are disappearing from different causes, the final being the intermarriage of those in reduced circumstances with people of colour, that is to say, with those whose blood is very slightly coloured. These in their turn become commingled with others of darker shades, so that eventually you find descendants of the most distinguished white families appearing like full-blooded negroes, in spite of the very strong prejudice against the mixing of the races, which socially ostracises the slightest trace of African blood.

ANTIGUA AND BARBUDA.

These two islands (see map, Plate B, appended) form another distinct tableland, rising 2,000 feet or more above the floor of the submerged Antillean plateau (see map, Plate B, appended). The island of Antigua impressed itself upon me as a little continent, with all the features necessary to complete one, and indeed this impression is not far wrong, for here may be studied all the geological and physical history of the dismembered and drowned tableland between North and South America, except the phenomena of the later volcanic activity. It is the starting point of investigation. Moreover, it is a fertile island and suggests prosperity, until one looks beneath the surface and finds that the prices paid for the sugar now are no more than the smallest pittance required for sustaining slave labour. The south-west quarter of the island is mountainous, the highest peak rising to 1,330 feet. This district is broken up into narrow ridges, with the valleys rapidly increasing in size, so that their lower reaches are broad flats extending into the shallow bays, where corals grow in profusion. In these valleys are small rivers, but over most of the other sections of the island the drainage is underground without water courses. The central belt of the island is a low depression, out of which rise several hills. The north-eastern part is somewhat higher and undulating. The mountain district is characterized by the old Antillean igneous foundation dating back to the beginning of the Tertiary era, or in part a little older. Even the latest trace of volcanic activity does not appear to have been as late as the Miocene period. The central portion of the island is underlaid by tuffs derived from the older volcanic remains, but contain some beds of silicious limestone and others of fresh-wa er origin with silicified wood and land shells. It belongs to the Eocene formation. The north-eastern part of the island is composed of white limestone—the Antigua formation belonging to the Oligocene period. But over this is a mechanical limestone, composed of the broken *débris* of an older one, dating back to the close of the Pliocene or beginning of the Pleistocene epoch, and probably still another seri(, of late origin composed of the same material, but distinguished by unconformity and the containe(fossils. There is also a still newer formation of gravel belonging to a later Pleistocene epoch.

Barbuda is a flat limestone island, with lagoons on the west. The highest point rises to only 115 feet. It is the remains of the old Antillean coastal plain extending seaward from the mountains of Antigua.

The termination of the central plain in the harbour of St. John's is illustrated in figure 1, Plate III., where the cliffs of the eastern rolling country are shown in the distance. Figure 2, Plate III., shows a fragment of the dissected coastal plain at Hodges' hill, which appears in the background to the right.

The population and the present conditions of Antigua are similar to those of St. Kitts. The roads are nearly always excellent. Being generally low, the island is rather dry and is not subject to the same rain-fall as the more mountainous islands. Dr. Christian Branch could find no remains indicating the permanent occupation of Antigua by the Caribs, who were numerous in all the other islands, and he attributes the fact to the scarcity of water at certain seasons of the year.

THE GUADELOUPE ARCHIPELAGO.

This is another remnant of the dissected Antillean plateau, of which the lower lands are now submerged. The summit of the ridge connecting it with Antigua is covered by about 2,000 feet of sea, but both sides of it are indented by deep embayments (see map, Plate B, appended). The tableland has been deeply dissected, so that being now sunken there are deep channels between the islands. The archipelago is underlaid by the old igneous foundation common to the Windward group, but on Guadeloupe proper this is surmounted by tuffs and by volcanic accumulations, which have been ejected during the time extending from the close of the Pliocene period to the present. There are several cones, the highest of which is 4,863 feet. Several eruptions have been recorded in the eighteenth and nineteenth centuries. Grande Terre is a rolling coastal plain, separated from the main island by a narrow strait, called Salt River. Its general characteristics are those of the limestone section of Antigua, being underlaid by white calcareous marl of the Antigua formation, with the remains of a mantle of mechanical limestone above, and also another calcareous formation belonging to the beginning of the Pleistocene epoch, while on the mainland, as at Petit Bourg, there is a mid-Pleistocene deposit of sand and gravel. Marie Galante and Petite Terre are also limestone islands like Grande Terre, forming part of the old coastal plains in front of the mountain section. The Saintes are remnants of the old igneous basement. Remains of a small elephant which emigrated from South America in the Pleistocene period have been found in Guadeloupe.

The roads in this French island are good. A coasting steamer sails round the island and to the dependencies. The main industry is sugar, which is principally raised on Grande Terre. Fine coffee is also cultivated, as well as some cocoa and vanilla. The people are mostly coloured, with a larger white population than in the English islands, but the coloured population is more unsatisfactory from our point of view, and dislikes the intrusion of foreigners. And in their policy they have done much to impair the prosperity of the island. In disembarking or embarking at Basse Terre, the capital, one is liable not merely to the imposition of the boatmen, but one's life may be imperilled by them, practically, without redress. So also one may be insulted, or even assaulted, as was the case of even an American Consul. The successful revolution in Haiti has left here a bad effect which has not disappeared. But from the white people with whom I came in contact I received only the greatest courtesy.

DOMINICA.

Here is a repetition of the mountainous part of Guadeloupe, from which it is separated by a depression about 2,000 feet below sea-level (see map, Plate B, appended). It (see map, Plate C, appended) has no coastal plains like Antigua and Guadeloupe, unless we so regard the banks, some twenty miles to the south-eastward, as the remnant of the

Antillean tableland, now dissected and submerged. Again one finds the old igneous basement, over the denuded surface of which are several igneo-sedimentary deposits (of the older Tertiary era) surmounted by the newer volcanic formations, which culminate in cones, one of which is 4,747 feet above the sea. The earliest eruptions occurred about the commencement of the Pleistocene period, and the last in 1880. After the renewal of volcanic activity, there was an early Pleistocene deposit of coral rock, preceded and succeeded by gravel accumulations; all except the last of these formations have been mostly removed by denudation so that only fragments are now to be found, on the small remnants of the coastal slopes, the best example being the Grand Savanna, as shown in its relationship to the mountains in figure 2, Plate IV. Some little flat land is found in the rapidly widened valleys, such as that at the mouth of the Layou river (figure 3, Plate IV.). Fragments of terraces in their natural condition are few, but one may be seen at Roseau, on which the church is built, (illustrated in figure 1, Plate V.). Back of the town is an erosion plain (Morne Bruce), at 400 feet above the sea, which was once a coastal feature. The corresponding terrace, on the other side of the valley, shown in figure 2 (which is almost a continuation of figure 1, and might be joined at letters A B), may be seen sloping outward, owing to the local elevation of the volcanic centres, and not to the regional rising of the land.

Dominica is the most beautiful of the islands. Portions of it have never been cultivated, and in some of the valleys one may see a tropical vegetation, among which are tree ferns of great size and loveliness. The situation of the town of Roseau, the capital, at the mouth of the Roseau valley, and in front of the terrace of Morne Bruce with the sloping terraces on the other side of the valley, which is headed in a high mountain (not seen in Figures 1 and 2 owing to cloud at the time of photographing them), is unsurpassed in its graceful beauty, in spite of the dilapidated appearance of the town. The valley itself becomes enlarged, after passing above its mouth, which is, in fact, a cañon or gorge cut by the river since the recent elevation of the land. It is shown in figure 3, Plate V., the view being taken from the summit of Morne Bruce.

On account of the floods of the swollen mountain streams, the coastwise roads are badly cut up, and because of the almost impossible undertaking of maintaining bridges, one is compelled to travel on horseback, except for a few miles near Roseau. There are a few degenerated descendants of the freedom-loving Caribs, who were so ruthlessly destroyed alike by the Spanish, French and English during the early bloody history of the West Indian region. As if by an irony of fate, the islands have ceased to be of commercial value to the conquerors, and their descendants have mostly disappeared, or sometimes have become lost in the admixture with the negroes, whom they imported to supplant the natives on their own soil. The negroes here are mostly from French settlements, and speak a jargon, almost unintelligible to the English or French visitor. Hardly any industries flourish. A little sugar is still cultivated, cocoa and limes are grown quite extensively. Mr. Frampton has started the cultivation of the kola bean.

MARTINIQUE, ST. LUCIA, ST. VINCENT AND THE GRENADINES.

These islands (see maps, Plates C and D, appended) form a continuation of the mountain chain of Guadeloupe and Dominica and are composed of the same old igneous foundation and overlying tuffs, and later gravel deposits, and probably of some remnants of the old Pleistocene limestone (as in Guadeloupe and Dominica), though I did not see them. The older basement is more exposed than in the more northern islands, and the old traps are decayed to considerable depths. In fact, as we go farther south, the physical features assume more mature forms. Thus Martinique is deeply indented by the Bay of Fort Royal, and the hills to the south of it are erosion features. But the northern part of the island is surmounted by the more recent volcanic ridges and cones, the highest of which rises to a height of 4,438 feet. Martinique is more or less flanked with sloping surfaces (due in part to the sloping beds of tuffs underlying them) as in St. Kitts (illustrated in figure 1, Plate VI.). Remains of base level erosion benches may be seen as in figure 2, near St. Pierre.

Martinique is the most important of the French islands, but, unfortunately, it is so often placed in quarantine, on account of yellow fever, from which the other islands are generally free, that one is uncertain of being able to visit it, for if even a single case of fever breaks out, the traveller cannot leave, except by going on a French steamer bound for France, or by chartering a sloop and lying at sea for sixteen days, an experience which, for even a few days, one does not desire to have repeated. On this account, although lying in front of the island we did not land. This was the home of Josephine Beauharnais, afterward the wife of Napoleon I.

St. Lucia (see map, Plate C, appended) is surmounted by a cone rising to 4,000 feet. The igneous rocks, belonging to the ancient basement of the island, are deeply eroded and also decayed. Here is the best harbour among the islands, generally the only anchorage being in the open roads. We also find here the only pier in the Windward Islands, at which the ocean steamers can land, and this was built on account of the great coaling station. There is also a fine botanical garden at Port Castries, the capital. The slopes of the southern side of the island are largely cultivated for sugar cane. As elsewhere, the coloured population greatly predominates. The *fer de lance*, one of the most poisonous of the snake family, is as common as in Martinique. On the south-western coast, the Pitons rise on one side out of the sea (to 2,619 feet) as shown in figure 3, Plate VI. They are remains of a crater, partly blown away, partly carried off by the waves, and denuded by torrential rains. Travellers frequently mention them.

St. Vincent (see map, Plate C, appended) repeats the features of St. Lucia. The highest cone in the Soufrière mountains rises to an altitude of 4,048 feet. Just south of it, the large crater is occupied by a lake at an altitude of 1,930 feet, but the rim of the crater is from 3,000 to 3,600 feet above the sea. The volcanic eruption of 1812 sent the ashes to Barbados, more than a hundred miles away, where the dust obscured the sun for three days. Some of the valleys have a mature form, as that of the very beautiful Buccament, illustrated in Plate VII. This, however, was desolated by a hurricane about four years ago. The valley crosses the island to the sea, so that a little submergence would separate the hills, to the right in the picture, from the main portion by a strait. This feature is constantly appearing among the Windward Islands. There was a very fine and far-famed botanical garden before the hurricane, which carried every tree-top away, blew every insect off the land and covered the island with showers of fine earth.

The Grenadines (see map, Plate D, appended), represent the most complete subaërial dissection of the ancient volcanic foundation, so that a large number of islets and rock rise above the extensive banks which have a length of over a hundred miles, and are submerged 100 or 150 feet. But Grenada, as large as St. Vincent is surmounted by the later volcanic ridges with the highest point attaining an altitude of 2,749 feet. Grenada is the most celebrated of the islands for tropical fruits of fine varieties. The Trinidad steamers from New York stop here, but not the Windward Island lines, except the regular fortnightly Royal Mail steamer.

TRINIDAD.

This is not an Antillean island, (see map. Plate D, appended), but a part of South America, being situated on the continental shelf, and separated from the mainland by only a shallow strait.

Along the northern coast there is a range of mountains containing crystalline schists, and rising to points 3,000 feet above the sea. Isolated ridges occur in other parts of the island, in some cases having a height of 1,000 feet. Elsewhere the island is generally low, with occasional extensive swamps. Apart from the northern mountains, the sandy, shaly, and calcareous strata are of a much more clastic nature than the formations of the Windward Islands, for these materials have been supplied by the South American rivers, such as the Oronoco;—but they belong to the same geological periods as those of the Antillean chain. There are no volcanic accumulations as in the other islands. During the long Miocene-Pliocene period, land surfaces prevailed and gave rise to most of the present topographic features. These, however, were thinly covered by subsequently deposited mantles, so that the general changes of level of land and sea, the connection with North America, and the drowning of the region again, are phenomena common to the history of the other islands. Among the strata certainly no more recent than the Eocene period, are radiolarian and foraminiferal organisms that were accumulated at abysmal depths of the ocean, of perhaps two miles or more. These are of importance in showing that where there had been shallow seas, or even land, the region had sunken to the great depth mentioned, and been raised again, so that other shallow water formations could cover them and constitute the foundation of the modern land features.

Trinidad is a beautiful island of large size, but its fertile plains are only partly cultivated, as much of the island is still covered by primeval forest. The roads of the cultivated districts are excellent. Sugar cane is the principal product. Pitch Lake is most valuable, and is far famed. It lies on a flat plain a mile from the sea and 110 feet above it, and has an area of about a hundred acres. No high land occurs within sight of it. It is immediately surrounded by a small open wood. It is a dreary spot. The pitch rises and overflows a loose sandstone, which is covered by a red earthy loam. The surface of the pitch is hardened, and only plastic near the centre, so that it can almost everywhere be walked upon. But through the fissures of the crust are numerous springs of water and sulphuretted hydrogen, sending an offensive odor through the whole district.

Situated near one of the mouths of the Oronoco, Port of Spain is a city of commercial importance, and having been almost destroyed by conflagrations, it has been rebuilt with a modern appearance. Near it is located the largest and most celebrated botanical garden in the West Indies, except that of Jamaica.

In Trinidad there is a larger percentage of whites than in the other islands described, but they embrace several nationalities. Besides the negro labourers, there are many Hindoos imported to the sugar estates. Being on the edge of the belt of Trade Winds, with the intervening mountains, the island seems much warmer than Barbados, which is separated by less than two degrees of latitude. Trinidad has direct steamship communications with New York, but not by way of the Windward Islands. The Halifax steamers touch it once every four weeks. The Royal Mail line gives a fortnightly connection with Barbados. Occasional vessels of various lines also stop here, by which one is able to reach the Venezuelan ports, the Isthmus of Panama, and Jamaica.

BARBADOS.

This outlying island (see map, Plate E, appended) is situated somewhat more than a hundred miles east of the main Antillean Chain, but on the same submarine plateau (see maps, Plates D and E). The surface of Barbados rises in terrace steps, or slopes, to an altitude of 1,104 feet. Except in, and adjacent to the Scotland valley, on the northeastern side of the island, the surface rocks are composed of a white limestone, or a coral formation. But in the valley referred to, and adjacent to the coast, there are beds of sand, accumulated when this region was connected with the continent, and received the sands carried down the rivers—perhaps the ancient Oronoco. This deposit cannot be newer than the early Eocene days, and I am inclined to regard it as belonging to the Cretaceous period. Upon its surface is a marly deposit containing foraminifera and radiolaria, like similar accumulations in Trinidad. These were formed in oceanic abysses at a depth of two miles or more, in a geological epoch that may be referred to the Eocene period. The region, after having sunken to such a great depth, rose so that upon the oceanic beds we find a shallow-water formation of white limestones, as in Antigua and the other islands mentioned before, belonging to the Oligocene series. During the long

Miocene-Pliocene period the land underwent changes of level, at times very high, so that the broad valleys between the island and the main group were being modified into rolling features by atmospheric agents, acting for a very long time. About the close of the Pliocene period, the region was depressed, so that only a very small islet remained away out in the Atlantic. Then followed the great elevation of the region, when all the islands and the continent were united. This was succeeded by another subsidence, so that the terraces round Barbados were cut out of the new coral reefs, as the land was again rising. Since their elevation the streams and rains have begun to excavate small cañons into the margins of the terrace steps. The occurrences of these terraces and little valleys give diversity to the surface features, for there are no mountains here. (See figure 1, Plate VIII.). The sea is encroaching upon the east coast, as in all the other islands, on account of which all the ports are on their western or leeward side. An illustration of the encroachment is shown in figure 2, Plate VIII., where the raised coral reef is breaking away and great blocks are lying along the coast.

The fertile sugar estates have been occupied by numerous owners, which has given rise to social conditions somewhat different from that found in the other islands. Within twenty years after the arrival of the first planters (1625), the population rose to 50,000, including many cavaliers, Irish labourers, and Indians stolen from other islands. The population now numbers 200,000, of whom one-fourth are whites. As the area is only 166 square miles, it is the most densely settled country in the world, so much so that the labourers on the estates get only three days' work a week, and another set work the remaining time—and that at twenty cents a day. More than half of the coloured infants die within a year, but even this does not keep down the increase. These conditions intensify misery caused by the ruined sugar trade. The people live on "ground" provisions (sweet potatoes, at fifteen cents a bushel, when bought; yams, a large tuber); bread-fruit, used green in place of potatoes; sugar cane and some fruits. They also get a small quantity of fish at times, of which the flying fish is most delicious.

In the church of the parish of St. John is the tomb of Theodore Paleologos, the last representative of the Christian Emperors of the Eastern empire, he having died here an exile in the seventeenth century.

GENERAL CHANGES OF LEVEL OF LAND AND SEA.

The primary object of my three visits to the West Indies and to the Central American region, and another to be begun in a few days, has been to carry on my investigations of the great changes of level which have occurred in late geological times, for there one finds the most complete evidence at present obtainable. In visiting the Windward Islands, I wished to extend the observations made elsewhere bearing upon the time of the great earth movements, and in doing so I had to investigate the geological formations, the results of which have been published in papers mentioned in the foot-note. Besides the geographical descriptions, with some geological results given here, I have included the charts of the region from which much more information can be gathered.* On these I have also drawn certain lines of soundings to bring out the drowned valley-like features.

While a somewhat less elevation of the region would connect the more northern of the Windward Islands, as we have seen, a rise of 3,600 feet would unite Dominica and Martinique (by way of the banks shown on map, Plate C), with an embayment between them reaching to a depth of 6,600 feet, miles within the line connecting the two islands. An elevation of 3,300 feet would bring the ridge between Martinique and St. Lucia to the surface, with another deep indentation to the west, a tributary of which heads in an amphitheatre, incising the island mass north-west of St. Lucia to a depth of 6,624 feet, within the line where the shelf is sunken only 600 feet. Between St. Lucia and St. Vincent, the connecting ridge is mostly within 1,200 feet of the surface, except for about five miles where the channel across the col reaches to a depth of about 3,000 feet below sea level. From this point the drowned valley rapidly deepens to nearly 6,600 feet within the line of the islands. The deepest part of the drowned valley crossing the ridge between St. Vincent and the Grenadines is only a mile wide and does not exceed a submergence of 1,300 feet. The Grenadine banks, really a submarine tableland, are covered by 100 or 150 feet of water, and the western slopes show the indentations, amphitheatres or cirques reaching to the same great depth, and still further away the soundings suggest that the submerged Antillean plateau in part rises more than 9,000 feet without quite reaching the surface of the sea. The cirques or amphitheatre-valleys on the eastern sides of the islands have not been so fully shown as on

* The charts are a reduction of Chart 40, U. S. Hydrographic Office. The various larger charts of the different islands should be consulted.

the western, on account of the eastern slopes being the more precipitous, and the soundings fewer in number. Between the Grenadine and Trinidad banks (see Plate D), the connecting plains may not be submerged to more than 750 feet, except in a narrow channel. The various forms of the valley-like indentations of the border of the great submarine Antillean plateau are similar to those upon the slopes descending from the high tablelands of Mexico and Central America, which have been fashioned by the rains and streams, and accordingly their occurrence is interpreted as evidence that the former altitude of the now sunken plateau was as great as the present submergence of the valleys now drowned. This conclusion is only to be modified, in referring to the islands, or their districts, which have been the scene of Pleistocene or more recent volcanic activity, for here we find local elevation due to plutonic forces which have not affected the great earth movements of the region. Among the Windward Islands the evidence of the full height at which the land stood has not been determined, as among the Bahamas and on the south-eastern margin of the North American continent, where we have found that it exceeded 12,000 feet. At the time of the great elevation of the Antillean plateau, the region west of the Caribbean sea—Central America—was low.

The valleys are the result of two periods of erosion,—namely that of the Miocene-Pliocene, with the production of broad rounded forms, and that of the early Pleistocene days when the elevation reached the maximum height and all the islands were united so as to connect South and North America. This last epoch was of the shorter duration with the deepening of the old valleys, the formation of cañons, and the excavation of cirques or amphitheatres, at the heads of the narrow valleys, as they were dissecting the tablelands.

In the remains of elephants, and the large rodents of Guadeloupe and Anguilla, we have confirmatory evidence of the great elevation during the early Pleistocene epoch, for these mammals migrated from the continent about that time. But all the Pleistocene animals have disappeared from this region, and the modern species have not found their way to these islands, for since the very general subsidence which exterminated the former species, there has been no connection between the islands and the continent.

Beyond the proper limits of this study, between St. Croix and St. Thomas, of the Virgin Island banks, there is a remarkable basin attaining a depth of 15,000 feet (see map, Plate F), unlike any other feature in this region. But the col at the head of the valley connecting it with the channel leading to the Atlantic basin is submerged only 6,402 feet, or about the same depth as the cirque of St. Lucia, or the indentations within the lines of the Windward Islands, and consequently this St. Croix indentation can be brought within the same investigations of changes of level as the Antillean Chain. By the rise of the land to this amount the migration of South American mammals could have even reached the North American continent. Such was the explanation of the occurrence of the numerous South American types of bears found at Port Kennedy, near Philadelphia, upon the remains of which Professor E. D. Cope was at work when overtaken by his untimely death, for these types had no geographical distribution that would suggest a connection with South America by way of Mexico and Central America.

In conclusion, I must thank the many kind friends, whom we made in all the islands, for their lavish hospitality, so that our scientific trip was converted into a social holiday and a pleasant memory never to be forgotten.

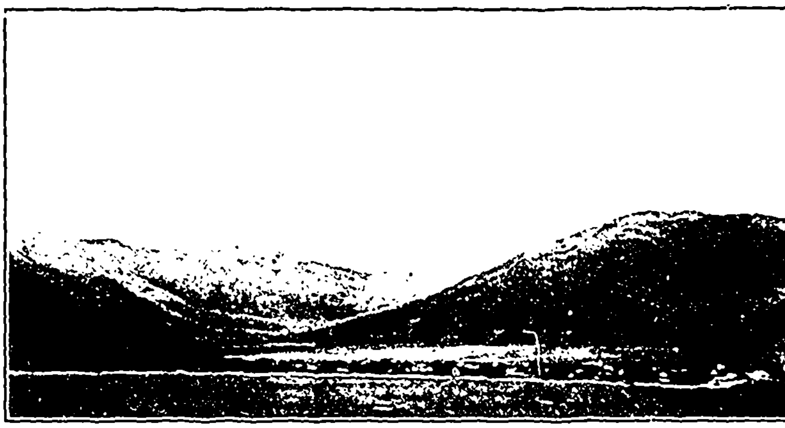


FIGURE 1.—View of the Valley of Cul de Sac. Beach on which is built the town of Philipsburg, with salt pond in rear, Island of St. Martin.

FIGURE 2.—Pelican Point, St. Martin, with sea rolled boulders, some four feet long.

FIGURE 1.–The "Quill" of Statia, from Brimstone Hill, St. Kitts.

FIGURE 2.–*Glacis* of volcanic ashes, dissected by rains, St. Kitts.

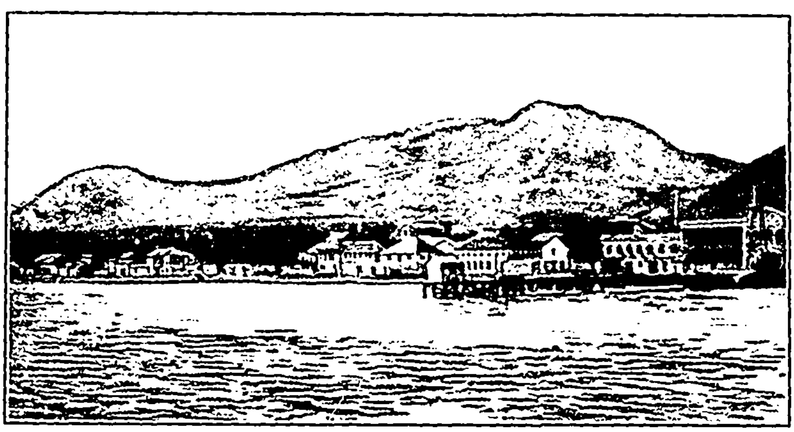


FIGURE 3.–Monkey Hill, and town of Basseterre, St. Kitts.

FIGURE 1.—Harbour and City of St. John's, Antigua.

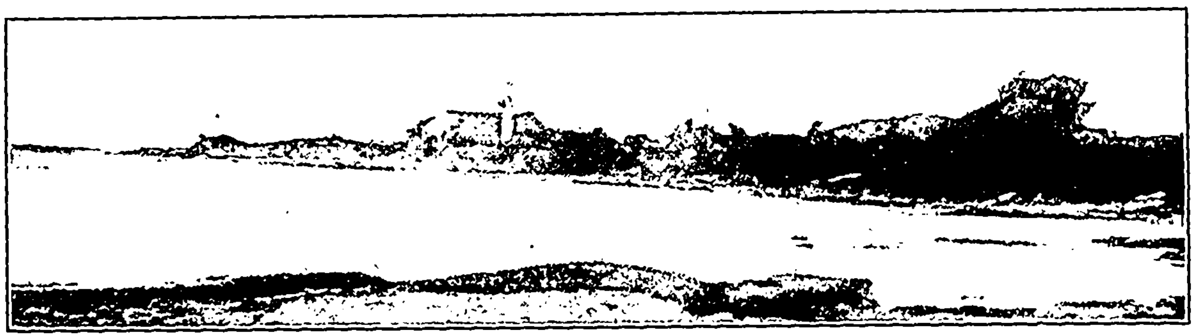


FIGURE 2.—Coast of Antigua, near Hodge's Hill (on the right).

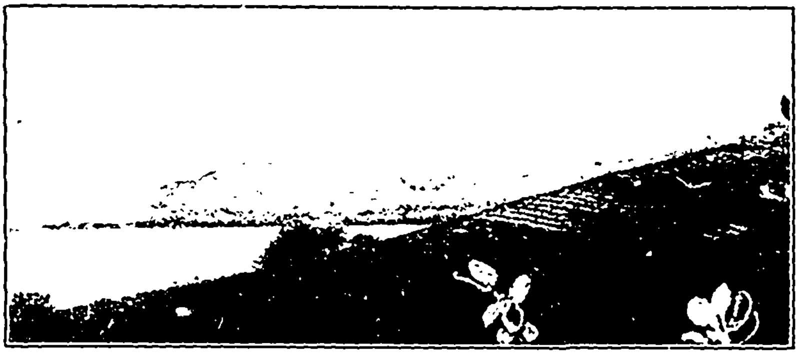


FIGURE 1.—Brimstone Hill, 700 feet high, on the flanks of the volcanic ridge, St. Kitts.

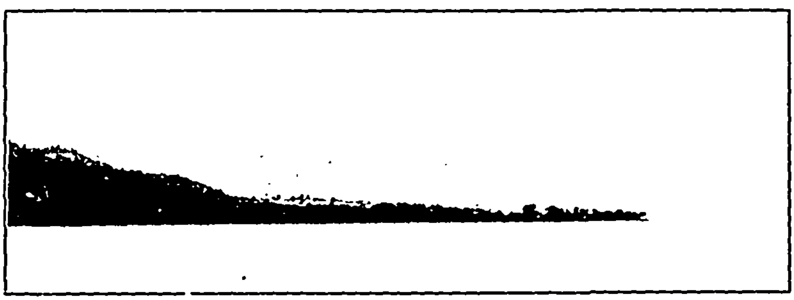


FIGURE 2.—Grand Savanna and Mountains, Dominica.

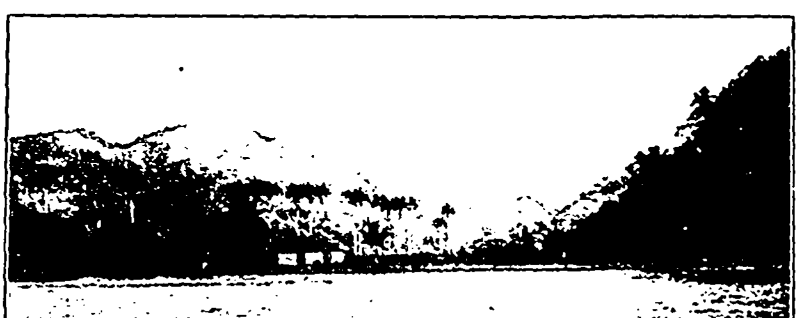


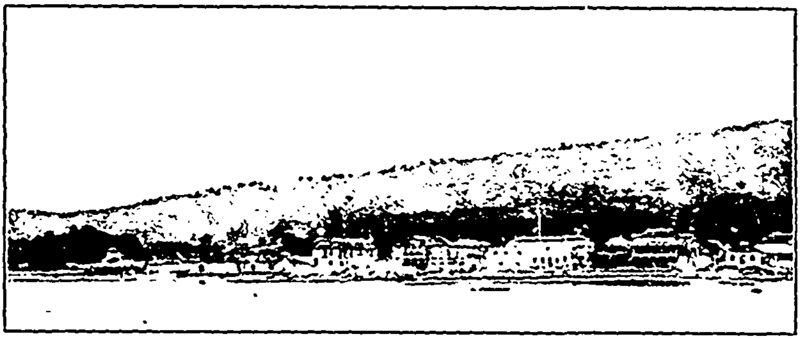
FIGURE 3.—Layou Valley, Dominica.

A

B

FIGURE 1.—Roseau Town and Valley, Dominica. Morne Bruce in foreground (400 feet high).

A



B

FIGURE 2.—Nearly joins Fig. 1 at A B. Sloping terraces back of Town.

FIGURE 3.—Roseau Valley, from Morne Bruce.

FIGURE 1.—View of the north-western side of Martinique.

FIGURE 2.—View near St. Pierre, Martinique.

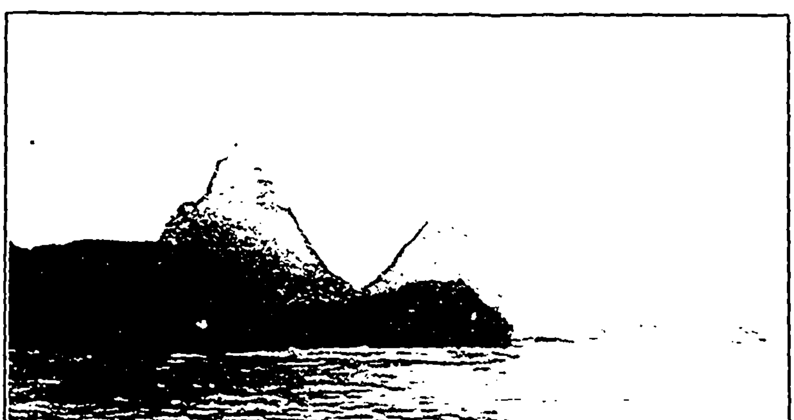


FIGURE 3.—The Pitons, St. Lucia.

PLATE VII.

Buccament Valley, St. Vincent.

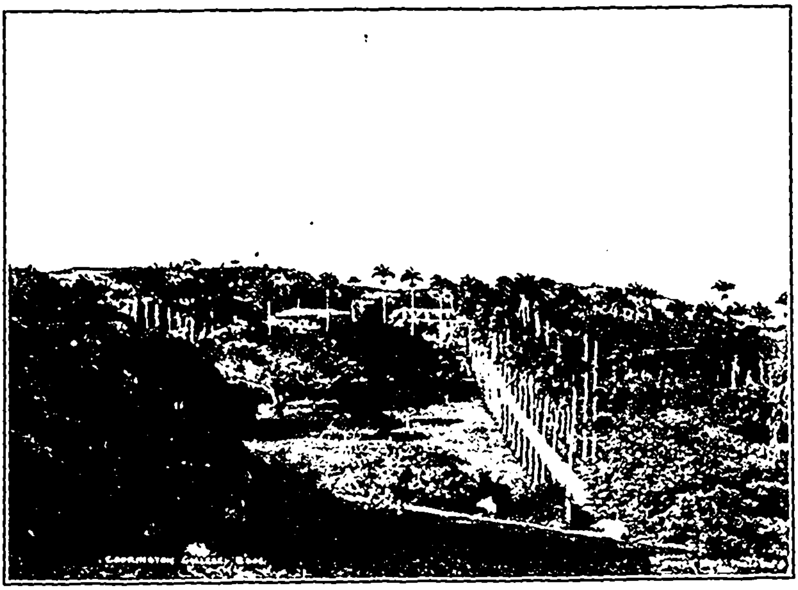
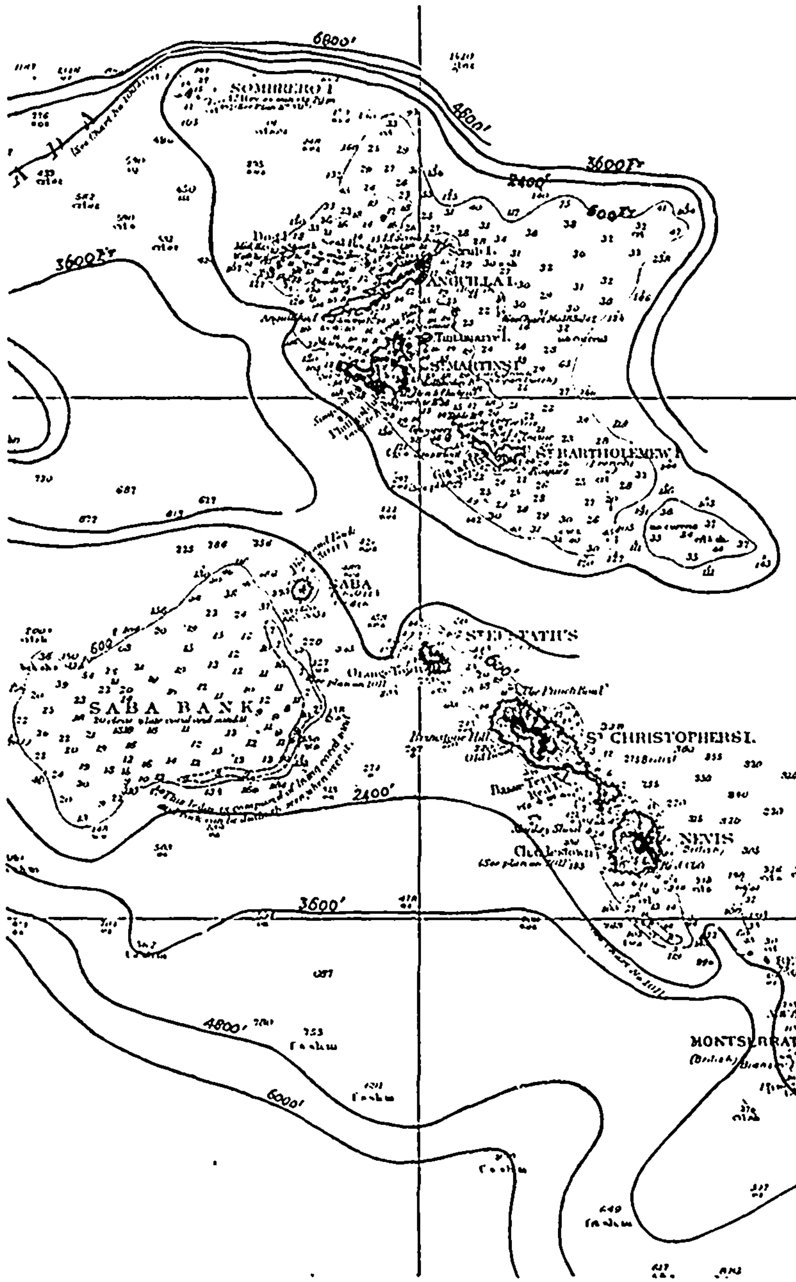


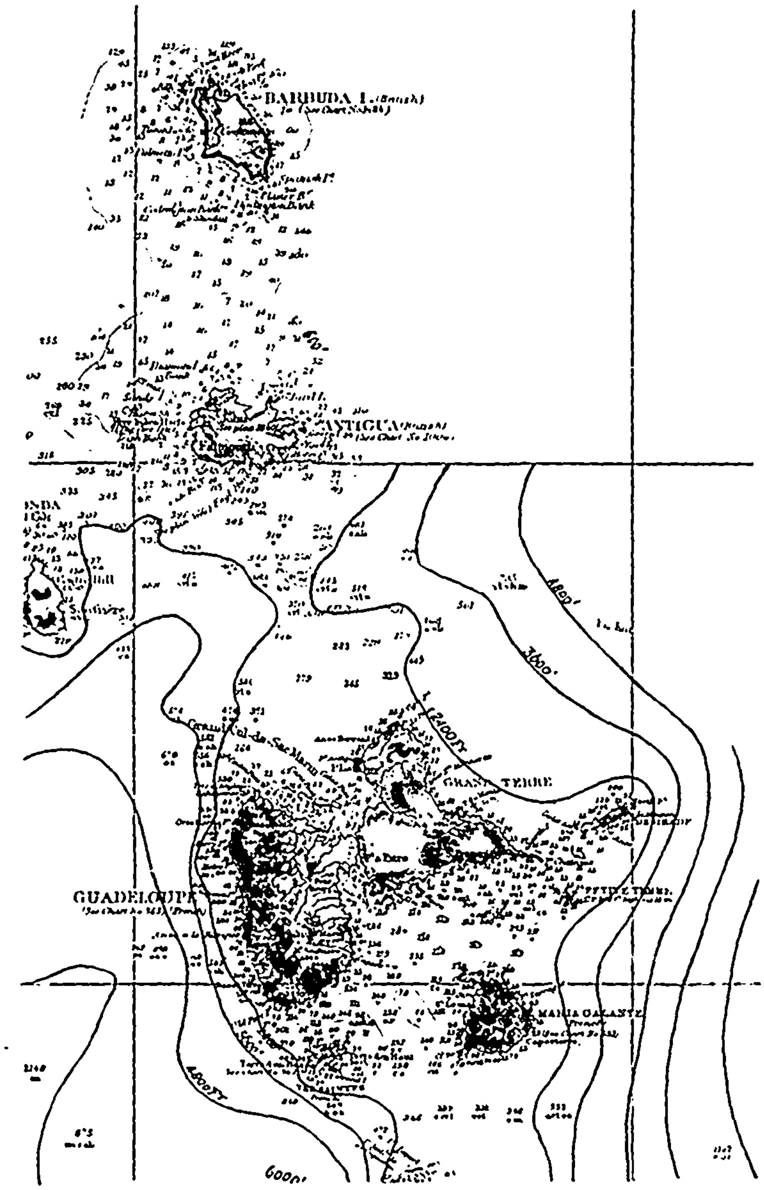
FIGURE 1.—View about Codrington College, Barbados.

FIGURE 2.—East Coast of Barbados, showing Terrace at 150 feet altitude, and fallen masses of coral rock.

PLATE A.

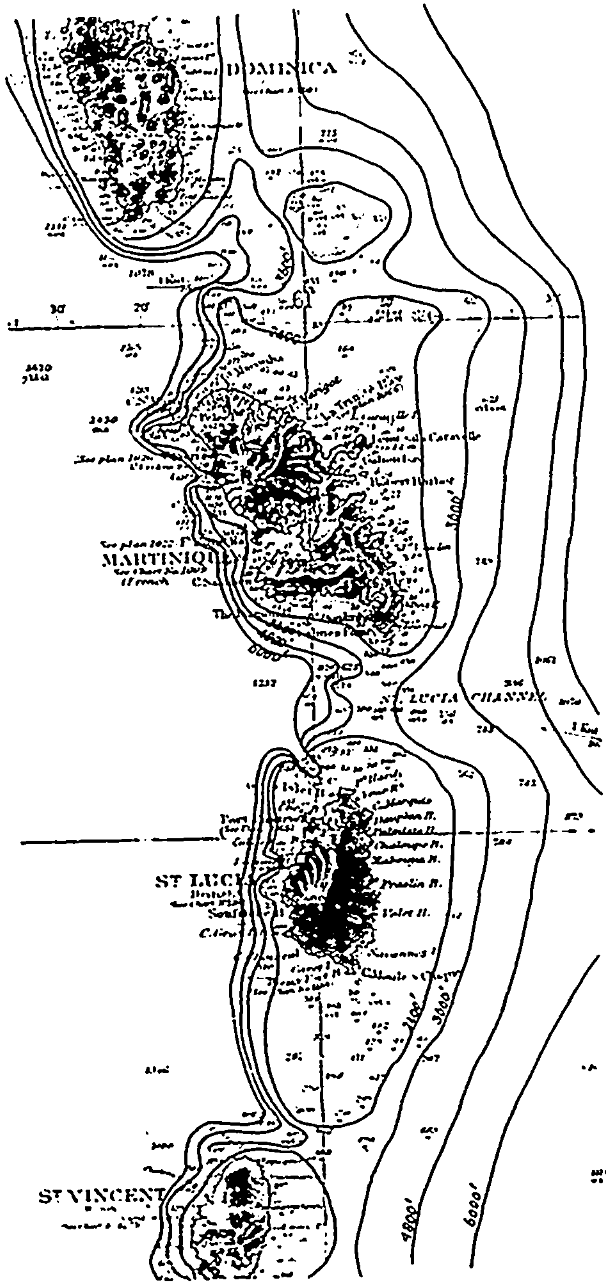


SCALE—24.5 English miles to one inch; heavy contours in feet; ordinary soundings in fathoms of six feet. All the maps (F, A, B, C, D, E) can be joined into one.

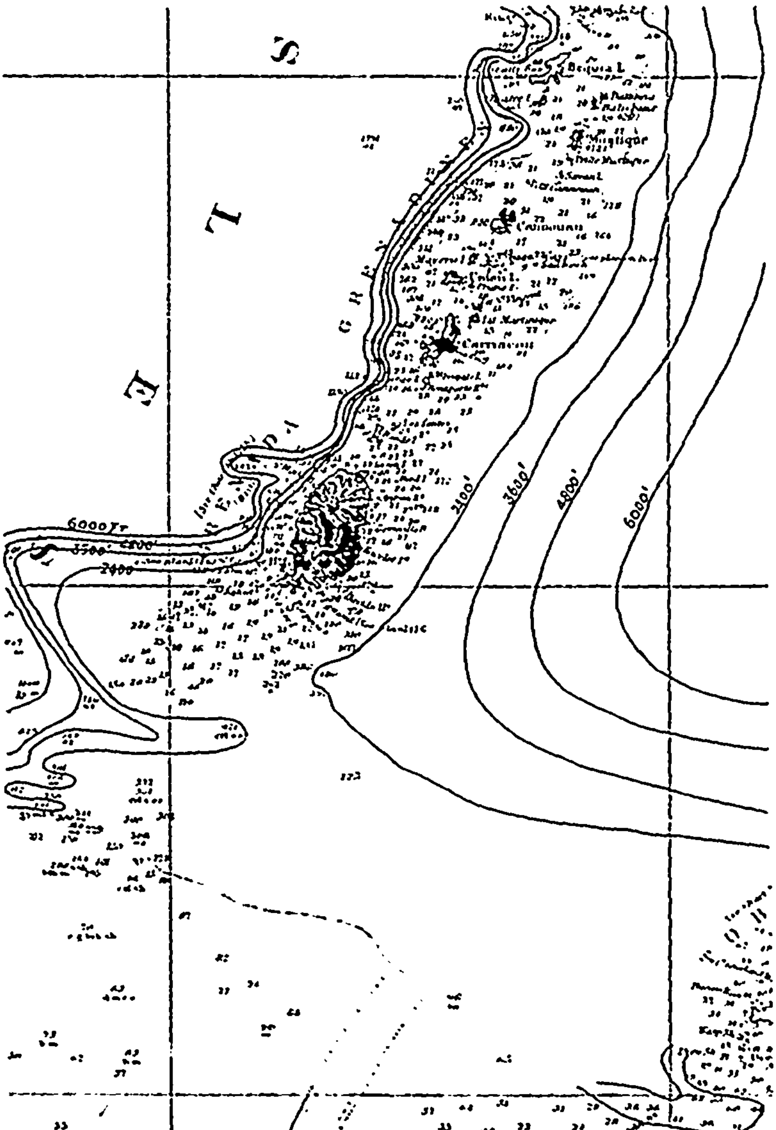


SCALE—24.5 English miles to one inch; heavy contours in feet; ordinary soundings in fathoms of six feet. All the maps (F, A, B, C, D, E) can be joined into one.

Plate C.

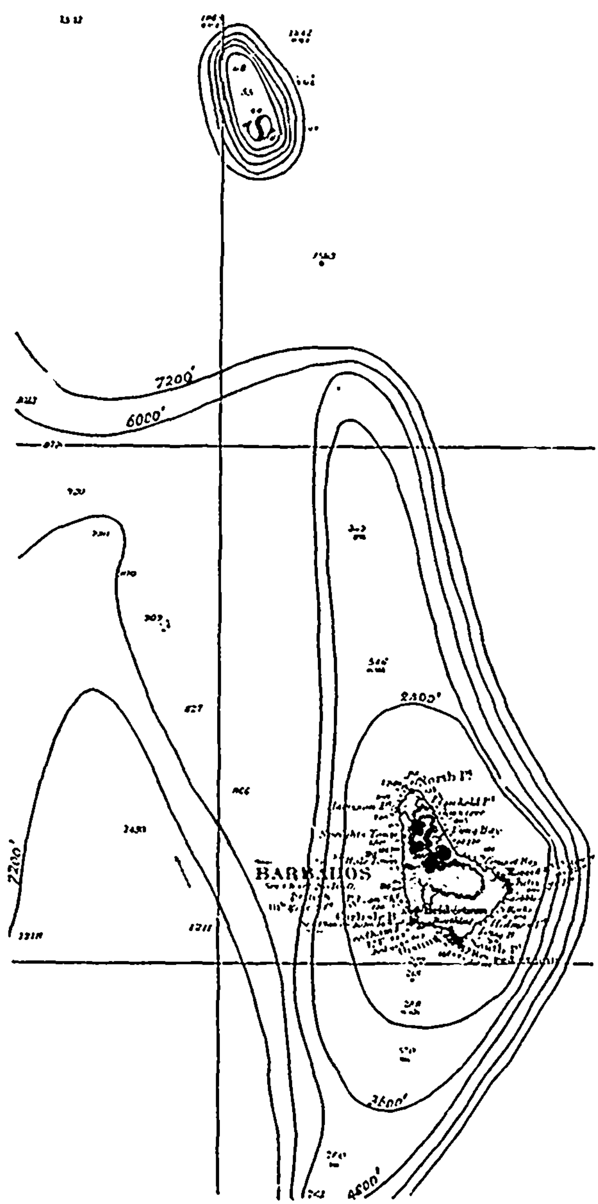


Scale --24.5 English miles to one inch; heavy contours in feet; ordinary soundings in fathoms of six feet. All the maps (F, A, B, C, D, E) can be joined into one.

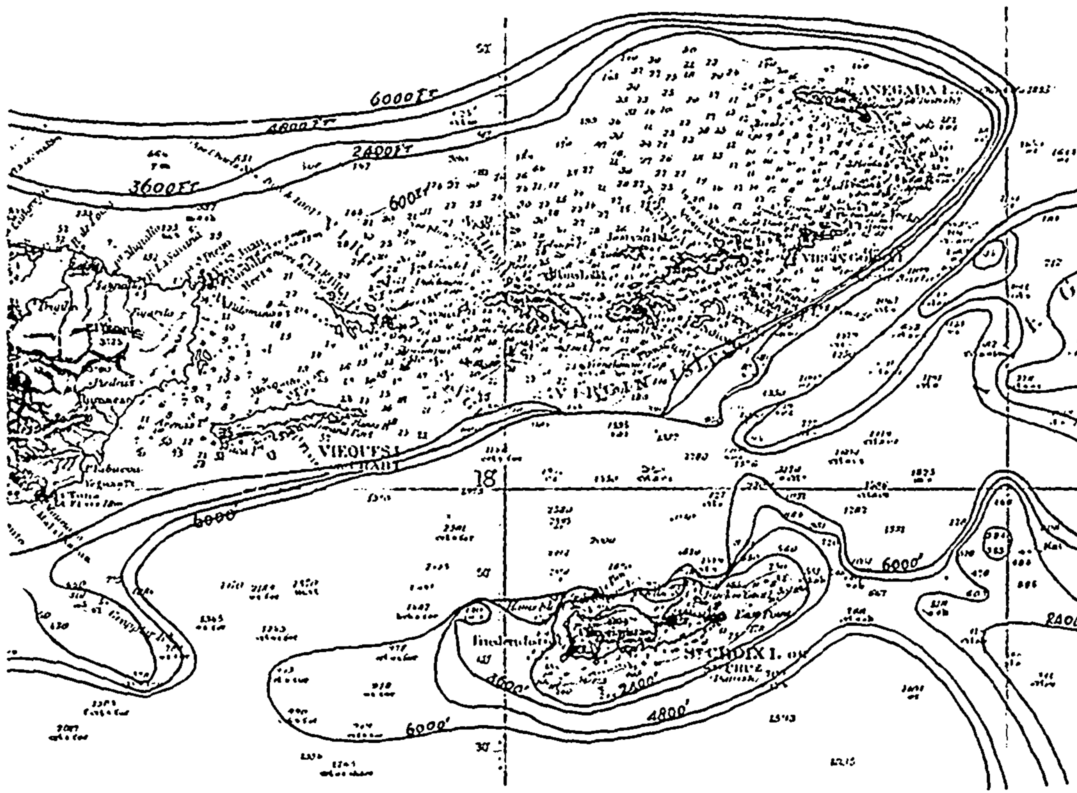


SCALE—24.5 English miles to one inch; heavy contours in feet; ordinary soundings in fathoms of six feet. All the maps (F, A, B, C, D, E) can be joined into one.

PLATE E.



SCALE—24.5 English miles to one inch; heavy contours in feet; ordinary soundings in fathoms of six feet. All the maps (F, A, B, C, D, E) can be joined into one.



SCALE—24.5 English miles to one inch; heavy contours in feet; ordinary soundings in fathoms of six feet. All the maps (F, A, B, C, D, E) can be joined into one.

PHOTOGRAPHY IN NATURAL COLOURS.

BY J. S. PLASKETT, B.A.

(Read 15th March, 1902.)

THE subject to be discussed in this paper has, ever since the discovery of photography some sixty years ago, excited the keenest interest and attention, not only among photographers and scientists, but among the lay public as well. From time to time, results have been obtained which have led many people to believe that the problem was approaching a solution. Again and again glowing reports have been published stating that the long-looked-for process had at last been discovered. But in nearly every case it has proved that the colours obtained were either unlike, or, if like, were not dependent upon the colours of the light waves which produced them; and it is very doubtful whether any real progress towards realizing a practical solution of the problem of obtaining a direct photograph in colours has been made.

The nearest approach to such a solution is reached by the Lippmann process, in which the colours are produced by the interference of light, this interference giving rise, in the taking process, to what are known as standing waves in the photographic film. These standing waves cause a peculiar, laminated structure in the deposit of silver on the plate, the position of the laminae corresponding to the lengths of the waves, and hence to the colours, that give rise to them. The explanation of the colours seen, when such a plate is viewed by reflected light, is quite similar to that accounting for the colours of thin films such as soap bubbles. The theory is not, however, perfectly complete and satisfactory as the cause of certain abnormalities in the process is not evident. The true colours can only be seen when the heliochrome is viewed by reflected light at normal incidence, and are hence not very easy to observe. Probably the most satisfactory way of viewing it is to strongly illuminate the surface and, by means of a lens, form an image of this surface upon a screen. The technical difficulties of the process are very great, so great, indeed, that, during the ten years it has been discovered, only comparatively few good examples of interference heliochromy, as it is termed, have been produced.

Even this process does not give us a direct photograph in colours, taken in an ordinary camera, like an ordinary monotone such as the world is looking for, and still less does the three-colour process, which is an indirect and composite method, fulfil such an ideal. It is, however, the only really practical method at present available, and is the one I shall attempt to describe in this paper. It was, in its inception, based on the Young-Helmholtz or three-colour theory of vision, and, although the principles of the three-colour process are independent of any visual theory, yet a short statement of the essential points of this theory may be of service in simplifying the succeeding explanations.

The facts of colour vision are accounted for in the Young-Helmholtz theory by assuming that there are three fundamental colour sensations, a red, a green, and a blue-violet; and that all colours, except deep spectrum red and the extreme violet, according to Abney's latest researches, are compound sensations, produced by the excitation simultaneously of two, or sometimes even of the three colour sensations. Although this theory has been very generally discredited by physiologists and psychologists, it still possesses many strong advocates on the physical side, and will always retain considerable interest on account of the historical associations connected with it. It has the merit of giving a simple and direct explanation of the main facts of colour vision, while those not explainable on this hypothesis meet with little better fate at the hands of the other theories advanced.

Maxwell supported this theory and, by means of a modified form of spectroscope which he called a colour box, made measurements to determine the ranges of these colour sensations. These measurements placed in the form of curves, can be projected upon the screen (Fig. 1). They are of great interest to all students of the three-colour process, not only for their historical value, but principally by reason of the fact

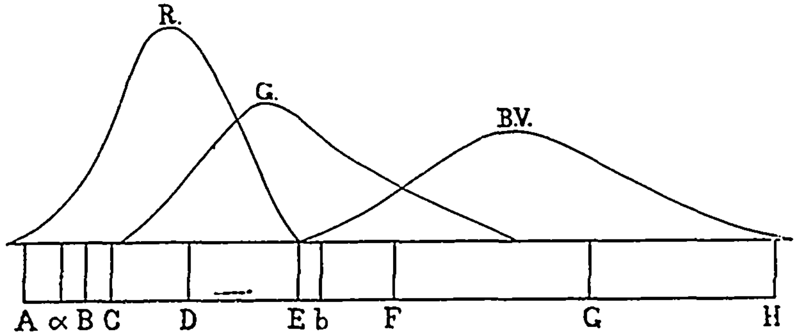
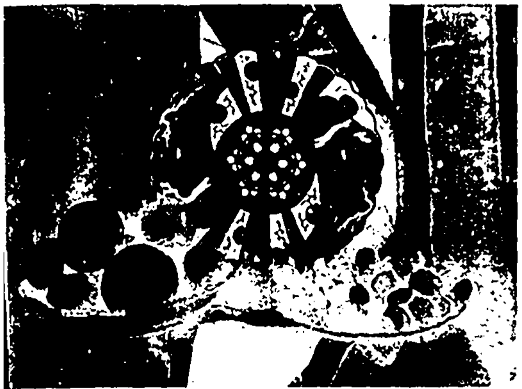
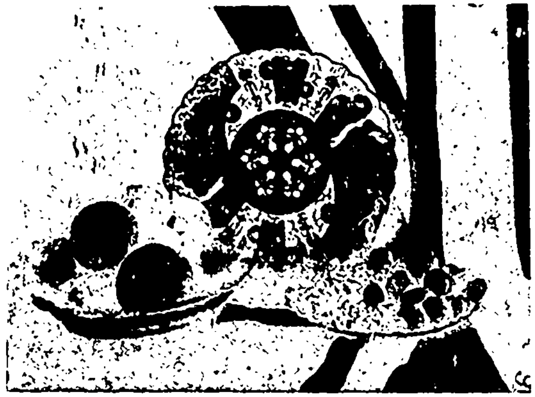


FIG. 1.—Maxwell's Colour-Sensation or Colour-Mixture Curves.

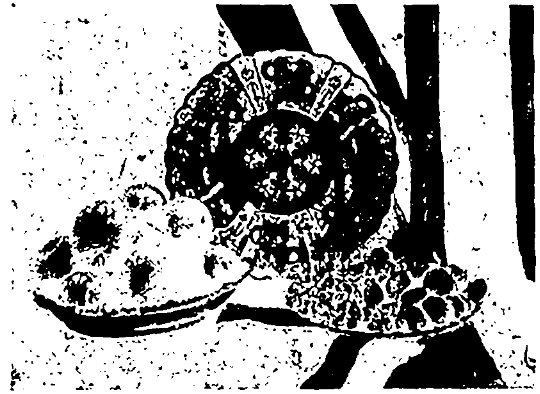
PLATE.



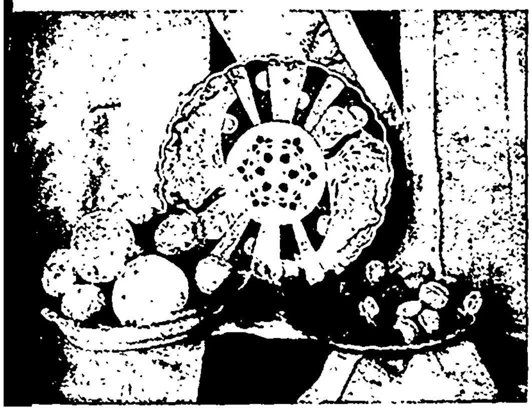
Negative taken through Red Filter.



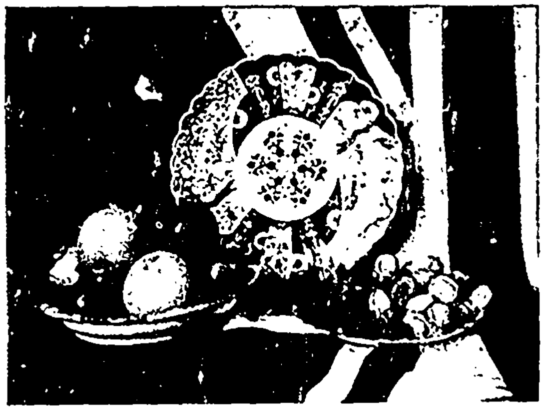
Negative taken through Green Filter.



Negative taken through Blue-Violet Filter.

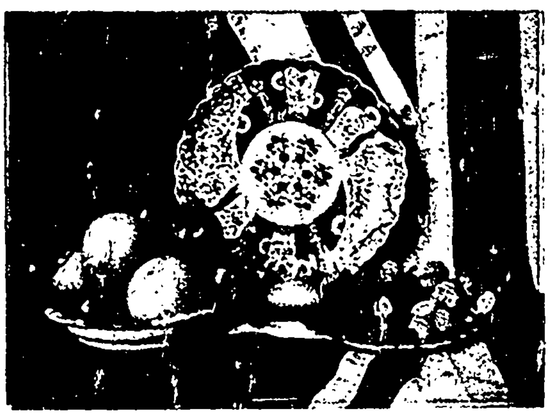


Positive from above Negative.
Blue-Green Complementary to Red.



Positive from above Negative.
Magenta-Pink Complementary to Green.

Positive from above Negative.
Yellow Complementary to Blue-Violet.



The Three Positives Superposed.

that they were and are used by Ives as the basis of his method of obtaining photographs in colour. These curves indicate graphically what Maxwell believed to be the amount of action produced on each of the colour sensations by any particular part of the spectrum. It has long been known, however, that, although these curves give a fair approximation, they do not exactly represent the ranges of the sensations and they are now superseded by the new measurements of Sir Wm. Abney, probably the most widely known authority on colour photometry and on photography. He spent some nine months in 1898-99, in redetermining the colour-sensation curves on the Young theory, and his paper treating on the subject was published in the Transactions of the Royal Society for 1899. A diagram of these new values can next be shown (Fig. 2) illustrating the difference between the two sets of curves. It will be noticed that, although the general

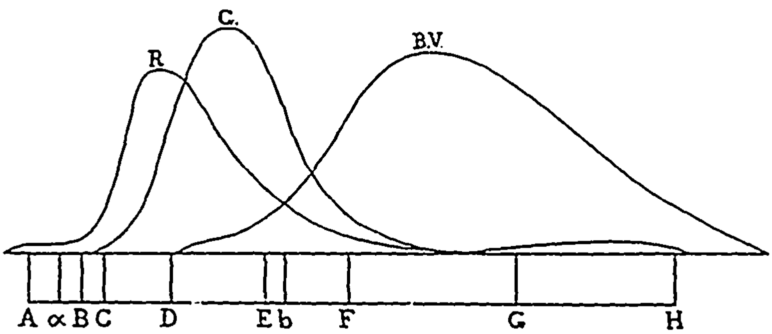


FIG. 2.—Abney's Colour-Sensation Curves.

forms are similar, Abney's sensation curves include each a longer range of the spectrum than Maxwell's but are not so long as those of Helmholtz where each sensation embraces the whole spectrum. But Abney's values, determined by the aid of more modern methods, and in the light of recent researches must be regarded as giving the closest approximation to the truth. From the method of their determination, and as will be seen later, Maxwell's curves could more appropriately be called colour-mixture than colour-sensation curves, and are very essential in both the theory and the practice of the three-colour process.

The three-colour process of photography is based on the experimental fact, which is probably most readily explained by the Young theory, that all spectrum colours, and hence all the colours of nature, can be imitated, to a very close degree of approximation, by mixing in varying proportions colours taken from three narrow sections of the spectrum. These sections or colours coincide very approximately with the dominant hues of the sensation curves; that is they are a particular red, green, and blue-violet. Abney has chosen as the most suitable position for these primary, fundamental, or reproduction colours about $\lambda 6700$ in the red, $\lambda 5120$ in the green, and $\lambda 4600$ in the blue; these particular wave lengths, which are in ten millionths of a millimetre, coincide very approximately with the wave lengths due to the red and blue lithium and the green magnesium lines and are hence easily located in the spectrum.

Before discussing and illustrating the mixing of spectrum colours, it will be advisable to clearly distinguish between two methods of colour mixture commonly employed which will be frequently referred to in this treatment of the subject. These are positive and negative mixture, or mixture by addition and mixture by subtraction. The former is effected by adding coloured light to coloured light, and the latter by adding absorption to absorption; while the resultant colours produced in the two cases are, in general, essentially different. Perhaps the commonest fallacy on the subject of colour mixture is the prevailing belief that the mixture of yellow and blue gives green, but it can easily be shown that the mixture of yellow and blue lights can not by any possibility give green. If a piece of yellow glass be placed in one lantern, forming a yellow patch upon the screen, and a piece of blue glass in another lantern, forming a blue patch, the overlapping of these patches and the consequent mixture of the coloured lights, as is at once seen, [*shown*] gives us white light, which, although it may be yellowish or bluish in hue, is without any approach to a greenish tinge; by no variation in the intensities of these colours, provided the hues remain yellow and blue, can green light result. If, however, one lantern be stopped and the yellow glass placed in front of the blue glass, a green patch at once appears on the screen, [*shown*] showing that the colour produced by superposing the absorptions, as is always done in the mixture of paints or pigments, is essentially different to that resulting from the mixture of coloured lights. To prevent confusion, it is very necessary that this distinction be carefully borne in mind in the subsequent treatment; and it will at once be evident that positive mixture is the only kind that can be employed in mixing spectrum colours.

The mixing of the three primary spectrum colours is effected by a modification of Abney's well known colour patch apparatus. This consists, first of all, in a means of forming a pure spectrum, and, secondly, of an arrangement for combining any of the spectrum colours, in any desired proportions, to form a patch upon the screen, visible to the entire audience. The light from the crater of the electric arc is converged, by the condensers of the lantern, upon the slit at one end of a collimating tube which contains at the other end a lens whose principal focus coincides with the slit. The beam of light from the lantern hence emerges from the collimating tube parallel, and will form a distinct image of the slit at the principal focus of any lens inserted in its path. The interposition, between this and the collimating lens, of direct vision prisms, constructed to give dispersion without deviation, breaks up the single uncoloured image of the slit into a number of overlapping coloured images forming a pure spectrum [*shown*] in the plane containing the principal focus of tha lens. If a large condensing lens be placed beyond this plane, its function will be to collect all these coloured images, and form an image of the last surface of the prisms. This image is, however, too small to be visible at any distance, and an enlarged image of this image may, by means of another large lens, be formed upon a screen beyond, and of such a size as to be plainly visible to all. By causing this image to fall upon a small square of white card on a black velvet background, the effect of coloured edges can be eliminated; and the colourless nature of the image formed in this case is evidence that the union or recomposition of all the spectum colours gives white light [*shown*]. If a card containing a narrow slit be moved along in the plane of the spectrum, the patch on the screen will assume each spectrum colour in turn, isolated, of course, from its fellows and hence uninfluenced by contrast. The substitution for this single slit of a brass frame containing three slits, whose relative positions and apertures can be varied at will, and which was specially constructed for this experiment, enables us to determine the resultant colour produced by the mixture of any two or three spectrum colours, in any desired proportions. If the positions of these slits be made to coincide with the primary colours, as determined by Abney, which can easily be done by burning lithium and magnesium salts in the arc, thus "scaling" the spectrum, the resultant colours produced by the mixture of these primary colours can be at once determined.

The union of the three primaries, red, green, and blue-violet, in certain definite proportions, easily determined by trial, and measured by the relative apertures of the slits, produces an uncoloured patch on the screen [*shown*]; and this white light, although not optically equivalent, being produced by the mixture of three narrow isolated bands instead of the whole range of the spectrum, can not be distinguished from ordinary white light. Nor can colours, produced by the mixture of these spectrum primaries, he distinguished visually from spectrum or natural colours. By closing the green and blue-violet slits, the red of the spectrum, through the third slit, colours the patch red; the gradual opening of the aperture in the green produces, by the mixture of red and green, orange-red, orange, and yellow; the green aperture remaining open and the red being closed gradually, gives yellow-green and green. The same procedure followed with the green and blue-violet slits produces blue-green, blue, and blue-violet; and with the blue-violet and red slits forms violet, purple, and red, the whole range of spectrum colours including also the purples. *(Matching of colours shown).* Any colour in nature may be matched in like manner, the tints being produced by first matching the hue, and then opening all the slits sufficiently to add the required amount of white; the shades being produced by making the slits narrow enough to sufficiently diminish the luminosity.

The correct proportions of the primary colours necessary to reproduce the colours of the spectrum are indicated graphically by Maxwell's sensation or, more properly, colour-mixture curves (Fig. 1). These curves, determined by the aid of his colour box, a modified form of spectroscope, and in principle similar to the experiment just described and shown, do not so nearly represent the stimulation of the fundamental nerve sensations or processes of the eye to produce any colour sensation, as the amount of the primary colours required to match the same colour. Although the positions of Maxwell's primaries are not quite correctly chosen, the amount of error introduced in his colour-mixture curves is practically negligible; and hence the amount or intensities of the primaries necessary to reproduce any spectrum colour are immediately given by measuring the lengths of the corresponding ordinates to the curves. The relative intensities of the primaries necessary to produce any colour whatever can be determined by matching the colour by the three slits, and then measuring their relative widths; unit width being determined by the relative apertures required to give white light.

The possibility of matching any colour by the mixture of the three primary or reproduction colours forms the basis of the three-colour process of photography. If, by any photographic process, three coloured images of any coloured object can be obtained, one red, one green, and one blue-violet; and if each image contains in its various parts, the correct proportions of its own colour required to match the colours of the object, then the optical superposition or mixture of these images should give us a correct representation of the colours of the object. The red, green, and blue-violet images of some fruit against a red background can be shown side by side upon the screen by means of three lanterns. On bringing these images to one position or superposing them on the screen [*shown*], their mixture produces, as is seen, a very good reproduction of the original colours.

The method of obtaining these coloured images, as will be at once observed, is to back with coloured glass photographs on glass or transparencies in black and white, exactly similar to ordinary lantern slides. Consider the red image only for simplicity. A transparency of the object must be obtained in which the relative transparency of the various parts corresponds exactly to the amount of the primary red required (in union of course with the green and blue-violet), to match the colours of the object. Working backwards from the transparencies, the negatives from which they are made must have the relative opacities of their parts corresponding exactly with the amounts or intensities of the reproduction colours required to match the colours of the object. Negatives fulfilling these conditions will be correct, not only for the method of positive superposition already referred to and shown, but for every method of synthesis.

The colour-mixture curves of Maxwell (Fig. 1), indicate graphically the amounts of red, green, and blue-violet light required to match the

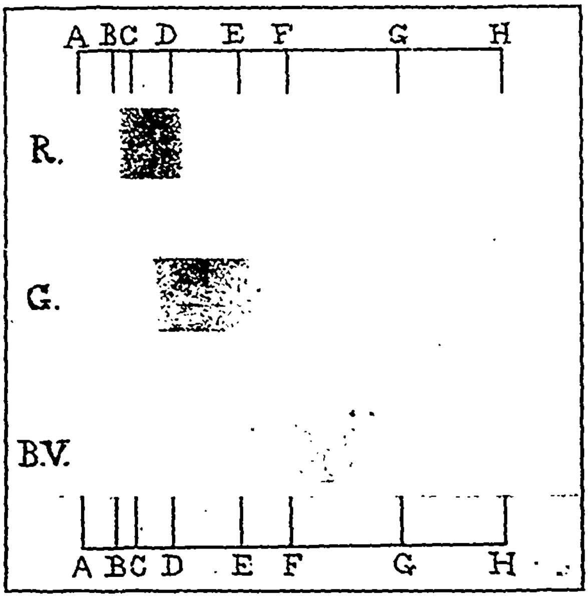


FIG. 3.—Colour-Record Negatives of the Spectrum.

colour of any part of the spectrum, and, from what has just been said, can therefore act as standards indicating the correct opacity patches on a set of negatives of the spectrum. The projection, upon the screen, of three negatives of the spectrum on one plate (Fig. 3) shows the approximate agreement of the deposits with the curves; while a transparency from these negatives shows the agreement between their relative transparencies and the curves.

The method of obtaining such negatives is that of selective absorption. The effect of interposing red, green, and blue glasses or stained films in a beam of white light is to absorb, roughly speaking, all but the red, green, and blue light, respectively; this can be easily shown by interposing them in the beam producing the spectrum [*shown*]. If

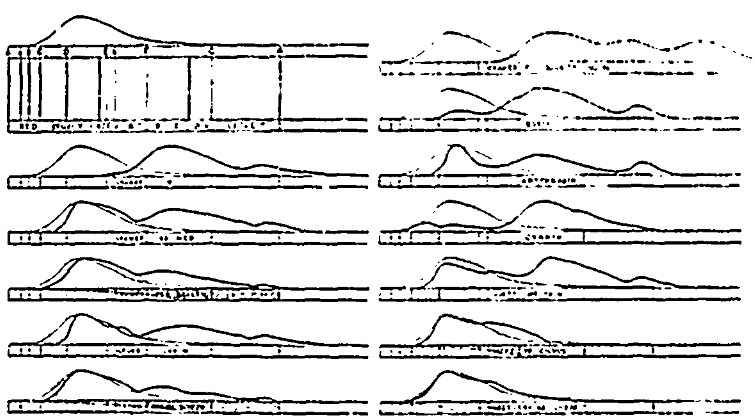


FIG. 4.—Action of the Spectrum on Photographic Plates.

they be placed in the path of the light entering the camera, near the lens say, they will perform the same office of picking out or selecting, hence the name, the red, green, and blue parts of the object, and allowing only these parts to be registered on the respective plates. This seems simple enough, but in practice the question of colour screens or filters, as they are termed, is much complicated by the fact that no photographic plate yet produced represents the spectrum in degrees of monotone corresponding to the visual intensity. It will probably be remembered, by those who heard the paper presented by the writer to the Institute last year on "Colour Values in Monochrome," that, only after tedious experimenting, could orthochromatic plates be made to render the spectrum approximately correctly. The curves representing the action of the spectrum on such plates are shown in Fig. 4, by the irregular curves in each part of the diagram, the regular curves indicating the luminosity or visual intensity. It is the compensation of these irregularities by the filters that renders their adjustments so difficult.

The spectrum method of adjusting filters, which are almost universally composed of stained films or liquid solutions, consists in so altering their absorptions that the opacity patches produced on negatives of the spectrum obtained through them agree with the colour-mixture curves (Fig. 1). Photometric measurements of the densities of the negatives are required, and the tedious nature of this process renders it impracticable for commercial use. It would I am satisfied give results unexcelled by any other means, and this statement I hope to prove at some future date by constructing a set of filters by such a method.

The ideal method has, so far, only been considered; the use of pure red, green, and blue-violet spectrum light for the primary or reproduction colours, and the theoretical colour curves, based on measurements made with such light. In practice, however, such conditions can not prevail; the nearest approach to the pure colours obtainable by selective absorption must necessarily be used for the reproduction colours, and the colour curves must be changed slightly to compensate for the errors thus introduced. The stained films that were used for backing the transparencies already shown are examples of such monochromatic colours. Their analysis in the spectrum shows that all but a fairly narrow band of the spectrum is absorbed [*shown*], but they do not approach the purity of colour obtained by the three slits. These reproduction colours, which must, first of all, fulfil the same condition as the three spectrum primaries that, when mixed positively, white light shall be produced, can be used in the same way as the three pure colours to match any colour. This is effected by backing with these colours three circular openings one in each of the three lanterns and causing the three coloured patches thereby produced to overlap on the screen [*shown*]. The intensity of the colours can be diminished, not, as in the spectrum experiment, by narrowing the aperture but by interposing patches of developed grey of different densities. By suitably varying the intensities of these reproduction colours, in a similar degree to the spectrum primaries, the whole range of spectral and extra-spectral colours can be produced [*shown*] exactly as in the former experiment.

The use of these reproductions, instead of the pure colours naturally leads to the use of an artificial instead of a pure spectrum as a test object in the adjustment of filters. A number of small squares of coloured glass, representing the principal colours of the spectrum as red, yellow, green, blue, violet, and also including purple and white, are mounted on another piece of glass forming the artificial spectrum. The amount of the reproduction colours necessary to match each of these glasses in luminosity and hue is accurately measured, giving the analogue of Maxwell's colour-mixture curves. The photometric measurement of the densities of the resulting negatives is avoided by reducing the luminosities of these glasses sufficiently, by means of rotating sectors or patches of developed grey, to render the quantity of red light. say, coming through each glass equal. A negative of such an apparatus, taken through a correctly adjusted red filter or screen, should give a series of patches of equal density; and, since the equality of the densities of adjacent patches can be accurately estimated by the eye, no photometric measurements are necessary, and the adjustment of filters is much facilitated. A similar apparatus is, of course, required for the green, and for the blue-violet filters.

This device, due to Sir Wm. Abney, is usually called an Abney sensitometer, and is of very great service in three-colour work; a simpler form of the same instrument is also very largely employed in the adjustment of compensating filters for orthochromatic plates. The set of filters employed in making the examples of three-colour work to be presently shown were adjusted by an Abney sensitometer, and were supplied by Mr. Sanger Shepherd, of London, who was awarded the medal of the Royal Photographic Society in 1899 for his three-colour filters. They were adjusted for use with the Cadett Spectrum plate, and will evidently, when the varying colour sensitiveness of different plates is remembered, only give correct results with this plate. The Cadett Spectrum and the Lumière Panchromatic are the most suitable plates for three-colour work. There are other panchromatic plates manufactured, but these have hardly, as yet, entered into serious competition with the above named brands. The Cadett plate is not so sensitive to red as the Lumière and requires a longer exposure through the red filter, but has the decided advantage of giving a much longer scale of correct gradation, and, in subjects with much contrast, will be more likely to produce correct results. It is possible to use a different brand of plates with each filter, but not advisable where good work is desired as it will be found almost impossible, on account of the different qualities of the plates, to secure a harmonious set of negatives. In three-colour photo-mechanical process work, this last procedure is frequently followed but the negatives and positives require and receive considerable retouching and etching.

On comparing the absorptions of these taking screens with those of the reproduction glasses [*shown*], it is at once seen that the former pass much broader bands of the spectrum than the latter. This distinction is very important, and was first pointed out by Mr. F. E. Ives, of Philadelphia, perhaps the most familiar name in the literature of the three-colour process. It is mainly owing to his genius and perseverance that photography in colours occupies the position it does to-day. The necessity for this distinction can perhaps be most clearly seen in attempting to make a colour photograph of the spectrum. If the reproduction glasses are used as taking filters, the evident result will be three narrow isolated bands of colour instead of the continuous spectrum; while if the taking screens are used as reproduction glasses, unnecessary impurity and degradation of colour will result from the mixture of colours, other than the primaries, in the taking filters.

The negatives obtained through these filters will not be alike, but in some cases the differences are not marked. This, of course, is due to the fact that the colours in nature are, in general, of a very complex character, and pass, when analysed by the spectroscope, nearly all the spectrum colours; hence all three negatives will frequently be influenced by the same colour though not of course to the same degree. The projection of three such negatives side by side upon the screen [*shown*] will illustrate, more fully than can be described, the various points of difference between them [Plate]. The differences are most marked in negatives of the spectrum and least marked in outdoor subjects where the colours are, as a rule, very impure or mixed in character. The purer the colours the more the filters differentiate them into their three classes, and the greater the differences in the negatives. The negatives may be called colour-record negatives, and are quite similar in appearance to ordinary negatives [Plate], possessing no colour whatever in themselves. The slight variations in the densities of the corresponding parts are the means employed, in the various methods of synthesis, of obtaining the positives in colours; the same negatives being suitable for every kind of synthesis.

The two principal methods of obtaining colour positives from the colour-record negatives are by positive synthesis and by negative synthesis. Positive synthesis includes triple projection and the Kromskop, and is the method followed by Mr. Ives. Triple photographic prints on paper, the three-colour photo-mechanical process, and triple superposed transparencies all come under the heading of negative synthesis. The latter subdivision embraces most of the work done by the writer which has, so far as he knows, not before been undertaken in Canada. Positive synthesis depends on positive colour mixture or the superposition of coloured lights, while negative synthesis depends on negative colour mixture, the addition of absorptions, or the superposition of coloured dyes or pigments.

In positive synthesis, a transparency in black and white, an ordinary lantern slide in fact, is made from each of the three negatives; and each transparency is illuminated by its own reproduction colour. That is to say the transparency from the negative taken through the red filter is illuminated with pure red light, that from the green filter with pure green light, and that from the blue-violet filter with pure blue-violet light; this is effected, practically, by backing each transparency with its corresponding reproduction glass. Since the relative transparency or redness of the red positive is proportional to the amount of the primary red, of the green positive to the amount of the primary green and of the blue-violet positive to the amount of the primary blue-violet required, when united, to match the colours of the object, evidently any method

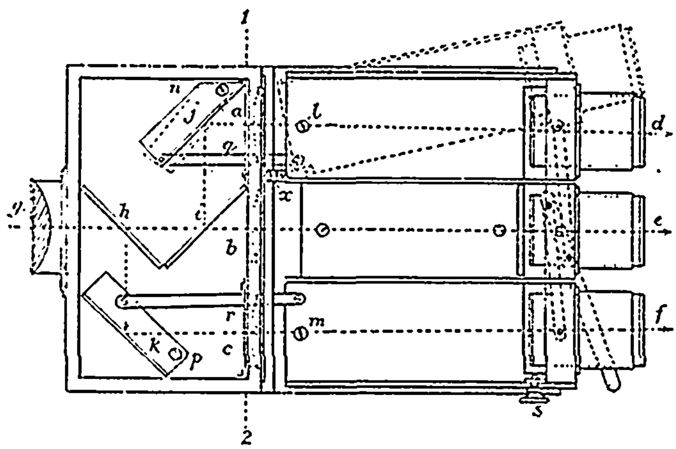


FIG. 5.—Ives' Lantern Kromskop.

of seeing these three images at one time and in one position on the retina should reproduce the colours of the object. One method of effecting this is by triple projection in which the three images are superposed and registered on the screen. The three lantern slides from the three negatives are placed one in each lantern and backed with their suitable reproduction glasses, thus giving the required red, green and blue-violet images on the screen. Each of these images, it may be mentioned in passing, according to the Young-Helmholtz theory, stimulates its respective process to the same degree as the original object. Again, the superposition of the green and blue-violet images, on the same theory, would, to the red colour-blind person appear similar to the original object, the superposition of the red and blue-violet would appear natural to the green colour-blind, and of the red and green to the violet colour-blind.

The superposition and registration of the three images [*shown*], give us as you will agree, a very good reproduction of the original colours. It may be as well to point out, however, that it is a mere optical illusion, for the colours though visually similar are not optically the same. In the one case we have, collectively at any rate, the whole range of the spectrum and in the other only three narrow bands in the red, green, and blue. The principal drawbacks to this method of synthesis are the necessity of using three lanterns and the difficulty of registration. These can be partially overcome by means of Ives' lantern Kromskop a diagram of which may be shown (Fig. 5). A beam of light from the source, preferably the electric arc, is rendered parallel by the condenser *g*, and divided into three approximately equal portions by the unsilvered reflectors *h* and *i* and the silvered mirrors *j* and *k*; these three beams then pass through the reproduction filters *a*, *b*, *c*, and the three transparencies and are focussed and registered upon the screen by the objectives *d*, *e*, *f*, which are adjustable for this purpose. The three transparencies are made on a single oblong plate from negatives on a single plate, these negatives being taken in a special camera which insures the same relative position of the three images in every case. Registration for one slide then will be registration for all and this difficulty is lessened. Only a comparatively small picture can be successfully shown, however, owing to the loss of light in the colour screens, a diameter of three or four feet being the limit for a brilliant image.

Instead of superposition on the screen the three images may be united by superposition on the retina. This can be effected by another device of Ives, called the Kromskop or photo-chromoscope, a diagram of which is given in Fig. 6. It depends upon the principle of transparent or partially transparent reflectors. In Ives' instrument A. B. C. are the positions of the three transparencies from the red record negative at A, from the blue-violet record negative at B, and from the green record negative at C. At A is the red reproduction screen and at B is a violet screen; D is a transparent mirror of blue-green glass and E a transparent mirror of yellow-green glass. The red image from A falls upon the mirror at D and is reflected to the eye, any entering the mirror being absorbed since its colour, blue-green, is complementary to red. The violet image at B is reflected from the yellow-green mirror at E and transmitted through D, becoming blue-violet and thus reaches the eye. The transparency at C, being transmitted through yellow-green and blue-green, reaches the eye as green. The red, green, and blue-violet images are superposed on the retina, reproducing, in a very faithful manner, the original colours.

The writer was unable to obtain either a lantern attachment or a Kromskop. The difficulty was overcome in the former case, as has just been seen, by the use of three ordinary lanterns; in the latter case by constructing a modification of Ives' Kromskop. This differed in principle by the substitution, for the coloured glass reflectors, which could not be obtained, of transparent mirrors silvered on the front surface. If unsilvered or uncoloured glass were used the reflected images would be doubled and registration could not be obtained.

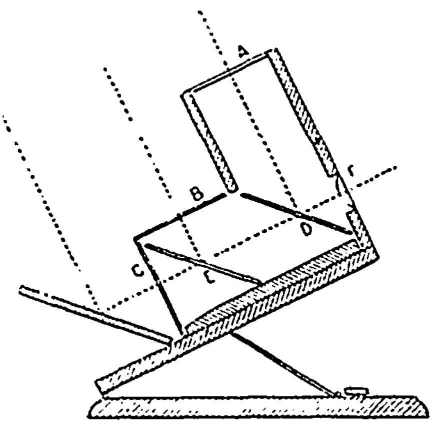


FIG. 6.—Diagram of the Kromskop.

Considerable difficulty was experienced in getting a satisfactory film of silver upon the thin plate glass used. It must be remembered that the construction of a mirror, silvered on the front surface, even when the coating is opaque, is by no means an easy matter: moreover that the mirrors for the Kromskop require a transparent and uniform coating of silver on the front surface, which must be of such density as to transmit a definite proportion of the incident light, the quantity transmitted being determined by the condition that the field of the instrument remains uncoloured. Evidently the silvering process was not a simple matter, and several trials were necessary. Success was, however, finally obtained and the instrument constructed gives excellent results.

The great objection to these methods of positive synthesis lies in the fact that the colours can only be seen by means of special apparatus, and although effects are produced by the Stereo-Kromskop, embracing both the natural colours and stereoscopic relief, which can not be excelled by any other method, yet some process of producing slides to be projected by an ordinary lantern or viewed like an ordinary transparency, would be decidedly more useful.

Such slides and transparencies are examples of the second method of producing coloured positives, *i.e.* by negative synthesis. They depend upon the superposition of coloured transparencies or pigments, and the basis of the method is essentially different. It is, in fact, exactly complementary to the former method, in which the effects were produced by adding coloured light to coloured light, hence the name, positive. This latter method depends upon the addition of absorption to absorption, or the addition of colours (by negative mixture remember) which are obtained by subtracting the positive colours from white light, and is called negative by reason of the subtractive nature of the superposed absorptions.

From the three negatives, transparencies are made as in positive synthesis, but, instead of being in black and white, they are in colours complementary to the reproduction colours. That is, from the red-record negative, a transparency is made in minus red or blue-green, from the green in magenta-pink, and from the blue-violet in yellow. The colour and appearance of these three transparencies are represented approximately, although not exactly, by the three coloured positives shown in the Plate. The superposition and registration of the three transparencies produces a slide similar in external appearance to an ordinary lantern slide but exhibiting the colours of the object.

Let us examine into the reason fo. the complementary nature of the printing and reproduction colours; that they are very nearly complementary is at once evident by the spectroscopic test [*shown*]. Consider the transparencies, by the two methods, from the negative taken through the red filter. In positive synthesis its lights are coloured red, or red is transmitted, while its shadows are dark or red is absorbed. In neg.tive synthesis its lights are white or red is transmitted and its shadows blue-green, complementary to red, and hence red is absorbed. Thus red is transmitted by the lights and absorbed by the shadows in the two cases; and the same thing will be true for the green and blue-violet records, so that the superposition by the two methods should give identical results.

A simple concrete example may perhaps help to render this somewhat difficult point more clear. Consider the effect of photographing a pure green patch on a white ground. The grounds in the three negatives will be opaque; the patch in the red and blue-violet record negatives transparent, and in the green record negative opaque. The corresponding transparencies will have transparency of the grounds from all three, transparency of the patch from the green and opacity of the patch from the red and blue-violet record negatives. In positive synthesis the ground will be composed of red, green, and blue light superposed, giving white; while the patch will be green since the opacity of the other two prevents red or blue-violet from reaching the retina or screen. In negative synthesis, in the superposed transparencies, the three grounds will be colourless giving white, while the patch will be coloured blue-green in the transparency from the red, and yellow in the transparency from the blue-violet record negative, there being no colour from the green record negative. The superposition, by negative colour mixture, of blue-green and yellow gives pure green. The results are identical, visually, although they may be and, in fact, are essentially different spectroscopically.

An illustration of the three prints, in the complementary colours, and of the finished picture resulting from their superposition is found in the Plate. The method of formation of any colour in the picture by the negative mixture of varying quantities of the three printing colours will illustrate, better than any description, the reason for using complementary colours in the printing or staining of the components. The principal steps in making a transparency or print by the three-colour process are illustrated in this Plate. The three negatives, without colour of course, taken through the red, green, and blue-violet filters illustrate the essential differences in densities due to different colours, and indicate the general character of colour record negatives. The separate prints are quite similar to ordinary prints from the above negatives, but are in colours complementary to the reproduction colours. The superposition of these three, or the printing of one over the other, produces the finished picture. In the Plate the printing was effected by three process blocks made from the three negatives, but it could be accomplished photographically by using carbon tissues of the required colour, and transferring them to a common support in accurate register. Such a process would be exceedingly tedious and somewhat uncertain, and an easier method is offered in three-colour transparencies or lantern slides. Here three separate coloured films are made and superposed giving, when bound together, the finished slide. The examples of colour prints made by the writer are by this latter method of superposing three transparencies, and can be projected upon the screen. In the majority of cases, as will be seen later, the colours are fairly true to nature, and, where such is not the case, the reason is generally obvious. It must be remembered, however, in criticising three-colour work that the slightest change in conditions during one stage of the process may be the cause of considerable change in the colours produced. Hence absolute accuracy should not be expected, but a range of colours agreeing very well, in general, with the originals can be, with care, always obtained.

The three methods of negative synthesis, above referred to, follow exactly the same principle. In the three-colour transparencies, part of the transmitted white light is absorbed by the colours giving the resultant effect. In three-colour prints on paper, whether photographic or photo-mechanical, the white paper reflects all the colours, part of them being absorbed by the dyes or inks in the same manner as in the transparencies; hence similar results should be obtained by the three methods.

As a matter of fact, however, leaving three-colour photographs out of the question, as being not yet in a practical stage, the range and gradation of colours obtained in three-colour transparencies is superior to that usually reached by the three-colour photo-mechanical process. The causes of this inferiority of the latter process are not far to seek. In the first place, printing inks fulfilling the theoretical conditions of absorption, transparency, and permanency required for this purpose have not yet been produced; and certain shades of green and brown cannot be obtained by these already in use. Fugitive inks, more nearly complying with the two first conditions, can be obtained giving better colour renderings, but the employment of these for most purposes is undesirable. In the second place, the difficulty, I think, lies in the process worker trusting too entirely to empirical methods, and not attempting to place his work on a true scientific basis, without which complete success can not be hoped for. It is unfortunately true that some sort of coloured effect can be obtained with incorrect screens and printing colours, but delicate and accurate colouring is impossible without the use of scientifically adjusted filters and colours.

Before concluding, a short description of some of the principal technical details of the process may prove of interest and possibly even of some service to those undertaking this fascinating branch of photography.

The first step in the process of making a three-colour transparency is to obtain the correct ratios of exposure through the three filters. Remembering that in the synthesis equal quantities of the reproduction or printing colours gave white or grey, it is evident that objects free from colour must be represented by equal density in the three negatives. The ratios of the exposures made, in a steady light, on such a test object as a piece of crumpled white blotting paper, must be so adjusted that the density of the resulting negatives, after development for the same time in one tray, will be equal. Each batch of emulsion requires a test of this nature as the relative colour sensitiveness of different batches varies slightly; for example, in one emulsion the ratios of exposure were found to be red, 60; green, 8; blue, 1; and in another red, 30; green, 6; blue, 1.

The exposure through the red filter is about five hundred times the normal exposure without a filter, so that, using ordinary apparatus, and allowing for the changing of plate holders, filters, etc., a set of three exposures, under the best possible conditions, of a well lighted outdoor subject will require at least a minute; while for indoor exposures ten minutes and upwards, depending upon the light, will be required. Any movement of camera or object, any error or omission in the sequence of operations, about fifteen in number, or any change in the quality of the light, unless correctly allowed for, renders all three negatives useless. The use of a special camera, in which all three exposures are made simultaneously, considerably reduces the time of exposure, and, by lessening the number of operations, diminishes the liability to error: but such a camera is expensive to purchase and troublesome to keep in order.

It is advisable before development to mark or letter a corner of the film on each plate, as it will be frequently found difficult to distinguish the negatives from one another. The plates are developed together in one tray in a metol developer, without bromide; with any other developer, especially hydroquinone, the images will not appear equally, and a different range of gradations will be obtained giving faulty results. Short development producing soft delicate negatives is required; over development bleaches out the light tints of colour. Under exposure causes excessive colour contrasts, while over exposure weakens the contrasts. The negatives are fixed and washed in the same manner as ordinary negatives, and after drying are ready for making the transparencies.

For positive synthesis, whether for triple projection or the kromskop.

three ordinary lantern slides are required. These must also be soft, delicate, of a neutral tint, and of the same density.

The three-colour transparencies, by negative synthesis, are composed of three coloured positives, one on glass and two on celluloid. From the negative taken through the red filter an ordinary lantern slide in black and white is made, and the black silver image is changed to a blue-green or minus red colour by an iron process. The positives from the green and blue-violet record negatives are made, by a modification of the carbon process, on transparent celluloid coated with a soluble emulsion of silver bromide in gelatine. These films, which are quite similar to the regular Kodak film, are sensitised by soaking for three minutes in a solution of bichromate of potash; and when dry are exposed under the negatives to daylight, the celluloid side being next to the negatives. The image, being partially visible, forms a guide to the length of exposure required, which averages about five minutes in diffused light. The parts of the bichromated gelatine unexposed to the light dissolve in warm water, and, when the silver bromide is also dissolved out in a solution of hyposulphite of soda, there is left an image in colourless gelatine in relief.

The colour is given to these images by soaking in baths of aniline dyes; the print from the green-record negative in minus green or magenta-pink, and from the blue-violet-record negative in minus blue or yellow [Plate]. The gelatine being in relief, varying depths of colour in the images are obtained, reproducing all the gradations. Perhaps the most tedious part of the process is to obtain the correct depth of colour in the prints. This can be tested by observing the roughly superposed prints. A general blue, pink, or yellow tinge throughout the picture shows that the corresponding prints are too deeply stained. The colour given to black or grey objects also forms a delicate test; rusty brown blacks indicate that the pink print is too strong, greenish blacks too weak; violet blacks indicate that the yellow print is too weak. Prints too strong are quickly reduced by soaking in water, while if too weak are strengthened, to a certain limit, by a longer immersion in the dye bath. This, of course, does not apply to the blue-green image which when once made cannot be changed in intensity, and, if not suitable, the only remedy is to make another.

When the colours are correctly adjusted, the prints must be mounted in register. The registration is not difficult if the prints are all of the same size, and, when effected, a cover glass may be put on and the slide bound in the ordinary way. The numerous internal reflections diminish the brilliancy of the image, and it is preferable to seal the components in optical contact with Canada balsam. Although this is a disagreeable and troublesome process, one is amply repaid by the superior brilliance of the slides. These may be viewed in the hand or projected by an ordinary lantern similarly to the regular slides and require no special care in their handling.

The natural colour slides made by the writer, some twenty in number, embrace reproductions of the spectrum, colour charts, and coloured pictures; flowers, and fruit; views around the University and some other subjects. These, which can now be exhibited, illustrate fairly well the capabilities of the process [*Slides shown*]. Many instances, in which a slide in the natural colours, if obtainable, would prove of very great value, will at once suggest themselves and the process has now reached the stage where any such slides can be made; and the further simplification of the details ought to render such slides a regular commercial product.

The three-colour process is an indirect, and, to a certain extent, cumbersome method, and not at all what is usually looked for in colour photography. The ideal process would be such that a photograph in colours could be produced similarly to, and with little more trouble than a photograph in monochrome. This problem, however, seems no nearer a practical solution than it has for the last twenty or even fifty years, and there is no process at present in sight which holds out any hope of realizing such an ideal. But, in consideration of what has already been accomplished in science and the arts, he would be foolish who would venture to put a limit to man's achievements in this or any other branch of science.

JOSEPH BRANT IN THE AMERICAN REVOLUTION.

BY LIEUT.-COL. E. CRUIKSHANK.

SECOND PAPER.

(Read 26th April, 1902).

THERE can be no more convincing proof of the extreme importance that was attached to the subjugation of the Indians than the fact that Washington was willing to detach an entire division of his best troops upon this service for the greater part of a year and weaken his own army so much in consequence that he was obliged to remain almost wholly on the defensive during their absence. Preparations for this expedition began in the winter of 1778-9. As early as February 11th, 1779, Washington had instructed Major-General Philip Schuyler to collect intelligence for that purpose.

"It will be necessary immediately to employ proper persons unacquainted with each other's business to mix with the hostile Indians that the most unequivocal information may be gained of their strength, their intentions, and what ideas they may have acquired of our design. We should also learn what support or assistance they expect in case our intention should be known to them or, what precautions they are taking to oppose our operations.

"The Indians in friendship with us may be sent on this purpose. The half-tories also, if they can be engaged and will leave pledges as a security for their fidelity, might prove very useful instruments. Similar investigations should be carried into Canada and the garrison at Niagara.

"I shall likewise depend on your having the routes to the object of the expedition critically explored both by Indians and others so that a complete knowledge of distances, natural difficulties, and the face and nature of the country may be obtained."

On March 3rd, 1779, letters were addressed to President Reed, of Pennsylvania, and Governor Clinton, of New York, informing them of the proposed invasion of the Indian country and requiring the assistance of a body of militia from each State, suggesting at the same time that as great a proportion as possible of the troops to be furnished by them should be composed of persons who had been driven from the frontier by the Indians.

"This class of people," Washington observed, "besides the advantages of a knowledge of the country and the particular motives with which they are animated, will be most likely to furnish the troops best calculated for the service. They should be a corps of active rangers who are at the same time expert marksmen and accustomed to the irregular kind of wood-fighting practised by the Indians."

A few days later the command was offered to Major-General Gates who possessed the highest reputation of any officer in the Continental army in consequence of his success at Saratoga.

"The objects of the expedition," he was informed, "will be effectually to chastise and intimidate the hostile Indians, to countenance and encourage the friendly ones, and to relieve our frontiers from the depredations to which they would otherwise be exposed. To effect these purposes it is proposed to carry the war into the heart of the country of the Six Nations, to cut off their settlements, destroy their next year's crops, and do them any other mischief which time and circumstances will permit."

The force it was intended to place at his disposal was stated at 4,000 Continental troops, rank and file actually fit for service, and as numerous a force of militia as might be deemed necessary.

But Gates absolutely declined to undertake the service on the plea that he no longer possessed the "requisite youth and strength" for such an enterprise, and the choice of Congress then fell upon Major-General Sullivan, an officer of considerable military experience and ability.

Rumours were then spread abroad designedly of an intended expedition against Quebec by way of Coos, N.H., to prevent the British garrisons in Canada from affording any support to the Indians with regular troops.

On March 25th, Washington definitely stated the proposed plan of operations in a letter to General Schuyler.

"The route by the Susquehanna appears to be more direct, more easy and expeditious, and more secure. There is very practicable navigation for boats of eight or ten tons all the way from Sunbury to Tioga, about 140 miles, and for small boats as far as Shemung about eighteen miles beyond Tioga. The distance from Shemung to the heart of the Seneca settlements is not above 60 or 70 miles through an open and travelled country very susceptible of the passing of a body of troops with artillery and stores."

After announcing his intention of dividing the invading force into three columns to move simultaneously up the Mohawk, Susquehanna, and Allegany rivers, he added:—

"These different attacks will terrify and distract the Indians, and, I hope, facilitate our project. It is also to be hoped in their confusion they may neglect in some places to remove the old men, women, and children and that these may fall into our hands. If they attempt to defend their country, we may obtain some decisive advantage, if not, we must content ourselves with distressing them as much as possible and destroying this year's crop."

The Congress of the State of New York promptly furnished a thousand militiamen under General James Clinton, a brother to the Governor, who was instructed to assemble this force at Canajoharie on the Mohawk river by May 12th. The first blow was directed against the Onondaga village, the most accessible settlement of the hostile Indians. On April 20th, Clinton advanced swiftly from Fort Schuyler with about 500 soldiers and surprised the village in the absence of most of the men, captured thirty-four women and children and burnt every building there.

The preparations for the main expedition under Sullivan's command went on without interruption. Hundreds of boats built for the purpose were incessantly employed for several months in transporting supplies to Wyoming, which was selected as the base of operations.

"The expedition you are to command" Washington wrote to Sullivan on May 31st, "is to be directed against the hostile tribes of the Six Nations, their associates and adherents. The immediate objects are the total destruction and devastation of their settlements, and the capture of as many prisoners of every age and sex as possible. It will be essential to ruin their crops now in the ground and prevent their planting more. . . . .

. . . .

. . . . Parties should be detached to lay waste all the settlements around with instructions to do it in the most effective manner that the country may not be merely *overrun*, but destroyed.

"After you have very thoroughly completed the destruction of their settlements, if the Indians should show a disposition for peace, I would have you encourage it on condition that they will give you some decisive evidence of their sincerity by delivering up some of the principal instigators of their past hostility. Butler, Brant, the most mischievous of the Tories that have joined them or any others that may be in their power that we are interested to get in ours. They may possibly be engaged by address, secrecy, and stratagem to surprise the garrison of Niagara and the shipping on the lakes and put them in our possession."

The inroads by Brant upon the Minnesink and by Macdonnell on the west branch of the Susquehanna were mainly designed to divert Sullivan from prosecuting his invasion of the country of the Senecas, but he resolutely refused to detach any portion of his force for the defence of the frontiers. Finally when all his preparations were complete he advanced on August 11th, to Tioga Point at the confluence of the Tioga with the Susquehanna where he formed a fortified depot for his supplies. About the same time Brant with his party returning from his attack on Minnesink rejoined Colonel Butler at a place called Chuckmet, or New Town, fourteen miles from Sullivan's encampment, where he was endeavouring to assemble the Indians for the defence of the Seneca towns. A letter written by Brant about this time to Colonel Daniel Claus has been preserved.

SHIMONG, August 19th, 1779.

"I am deeply afflicted; John Tayojaronsere, my trusty chief, is dead. He died eight days after he was wounded. Five met the same fate. I am very much troubled by the event as he was of so much assistance to me. I destroyed Onawatoge a few days after. We were carrying off two prisoners. We were overtaken and I was wounded in the foot with *buckshot but it is of small consequence. I am almost well.*

"We are in daily expectation of a battle which we think will be a severe one. We expect to number about 700 to-day. We do not quite know the number of the Bostonians already stationed about eight miles from here. We think there are 2,000 besides those at Otsego, represented to consist of two regiments. This is why there will be a battle either to-morrow or the day after. Then we shall begin to know what shall become of the people of the Long House. Our minds have not changed. We are determined to fight the Bostonians. Of course their intention is to exterminate the People of the Long House. The Seven

Nations will continue to kill and devastate the whole length of the river we formerly resided on.

"I greet your wife. I hope she is still well and that you yourself may also be well."

On the same day that this letter was written Sullivan was joined by Clinton's brigade which floated down the Tioga on the crest of an artificial freshet they had created by damming that river near its source, and increased his force to above 5,000 effective men. The Indians became panic-stricken at the appearance of such an overwhelming army which was attended by a multitude of packhorse drivers and boatmen, and the majority seemed to think only of placing their families and moveable property in a place of safety. Butler bitterly complained that he was unable to assemble more than 300 warriors to resist the enemy's advance when their chiefs had promised to join him with at least a thousand. He had brought with him from Niagara to their support about three hundred of his corps of rangers and fourteen volunteers from the detachment of the 8th or King's Regiment then stationed at that post. With this comparatively small force be kept up a show of confidence and assured the faltering chiefs that he hoped to repel the invaders with the rangers, assisted only by their brethren led by Brant even if they declined to come to his assistance.

On August 27th, he advanced a few miles nearer the enemy's camp and occupied a position selected by the Delawares as the place where they should await an attack. It was a ridge extending from the river to the foot of the mountain and covered in front by a large creek, but was much too extensive to be held by so small a force. The defence of the right flank in the low ground next the river was entrusted to Captain John Macdonnell with sixty rangers assisted by Brant with thirty volunteers from the loyalists and Indians.

Two days later Sullivan advanced and after cannonading their position for several hours turned their left flank when the Indians in that part of the field made such a precipitate retreat that the rangers and Brant's volunteers were nearly surrounded before they became aware of this movement and forced to disperse to effect their escape which they succeeded in doing with slight loss.

The Indians were so thoroughly dispirited by this affair, which was called by the Americans the battle of Newtown, although they had lost only five men killed and nine wounded, that they could not be induced to make another stand even by the influence and example of Brant and the Seneca chief Sangerachta, who are described by Butler as having behaved on all occasions with great courage and determination.

The victorious army destroyed forty Indian villages with their adjacent orchards and cornfields but did not succeed in taking more than a dozen prisoners, and failed to lay waste a considerable part of the fertile valley of the Genesee, whither the Indians retreated. Brant continued during these operations to watch their movements with great vigilance but his sole success was the destruction of an isolated party of thirty men under a Lieut. Boyd.

On September 8th, Butler reported that the enemy had taken possession of Canadasaga, the principal Seneca village the day before. "Joseph Brant who stayed to reconnoitre says that to all appearances they cannot be less than 3,000."

Two days later he stated that Sangerachta had gone with Brant to meet the chiefs at Genesee. "There is a very good understanding between them and they concur with each other on every occasion."

"Shortly after Lieut.-Colonel Mason Bolton, the commandant at Niagara, reported that the Indians are extremely dissatisfied that troops have not been sent to Oswego or this [post] notwithstanding all the efforts of Major Butler, Sangerachta and Joseph Brant to keep them in line."

In his next letter (September 17th) Bolton remarked that "Joseph Brant who upon all occasions deserves everything that I can say in his favour, has just arrived. Sangerachta has behaved extremely well. He has great weight with the Six Nations. Joseph some time ago was not on the best terms with him. They had their quarrels like other great men."

Early in October Brant again returned to Niagara from the Seneca country and reported that the invaders had retired to Wyoming. By this time, Sir John Johnson had arrived there with a reinforcement of four hundred troops from Montreal, and after a consultation with Colonel Bolton sailed for Oswego with the intention of attempting a raid upon the Mohawk valley. Bolton stated that "Joseph with a number of the Six Nations went by land to the Three Rivers, the place of rendezvous, determined, I believe, to cut off the Oneida village and attempt something more if opportunity offers, but as the season is so far advanced I think it scarcely possible."

His forecast proved correct. Foul weather set in and continued until the expedition was abandoned and Brant returned to Niagara on November 15th.

Snow fell that winter to an extraordinary depth and many Indian women and children perished miserably from cold and famine mainly in consequence of the devastation of their settlements. The animosity of the Indians against their enemies was thus greatly intensified.

Guy Johnson arrived at Fort Niagara late in the autumn and superseded Butler in control of the Indian Department. About the middle of February Brant was despatched to the frontier with Captain Hendrick Nelles, Lieut. Joseph Clement, twelve white volunteers, and 220 Indians. This was much the largest force he had yet commanded and he began operations by forming a close blockade of Fort Schuyler, by which the garrison was reduced to great distress. There is no record of his movements for several months, but the following manif sto has been preserved which is dated at the Delaware on April 10, 1780.

"That your Bostonians (*alias* Americans) may be certified of my conduct towards all those whom I have captured in these parts know that I have taken off with me but a small number. Many have I released. Neither were the weak and helpless subjected to death, for it is a shame to destroy those who are defenceless. This has been uniformly my conduct during the war. These being my sentiments you have exceedingly angered me by threatening or distressing those who may be considered as prisoners. Ye are (or once were) brave men. I shall certainly destroy without distinction does the like conduct take place in future."

At the end of April Brant was still out, but had sent in Lieut. Clement for supplies, and he does not seem to have returned to Niagara until the end of June when he reported that the Oneidas were prepared to abandon the rebels on the first favourable opportunity.

Early in July he marched out again "with a strong party of warriors" with the intention of raiding the few remaining settlements in the Mohawk valley. On August 8th Bolton reported his first success.

"Joseph has paid a visit to the Oneida village which with the fort he set on fire. One hundred of them are now on their way to this post and the rest thought it proper to retire to Fort Stanwix which obliged him and his party of 370 men to march with all expedition possible towards the Mohawk river as there was no doubt but that an express would be sent off to alarm the inhabitants."

Three days later Guy Johnson furnished additional details.

"Captain Brant has already effected a very good piece of service and is advancing against the rebel frontiers. On his march from hence he came upon the only remaining Indian village, sixteen miles from Fort Stanwix. He found the village abandoned but met some Indians who told him they had returned through fear of parties of strange Indians with many other particulars in which it appeared they had deceived him for they soon deserted and gave notice to the garrison of Fort Stanwix. Captain Brant then burnt the rebel fort at the village with other buildings and marched to the Indians below Fort Stanwix where he met the Oneidas in camp and called upon them to follow the example of the rest of their people and return to the British Government. About 100 replied that it was their desire and they are now partly come into this place. The small remainder ran towards Fort Stanwix which they reached except two who were shot. He then drew towards the fort where he proposes to remain a few days to deceive the rebels and then proceed against the frontiers. The fort burnt by that party was a great inconvenience to us, and its destruction with the return of the Indians to their true alliance will distress the rebels and lay that route open to our parties.

"Lieut. Clement has just arrived express from Captain Brant. He has destroyed and taken so many cattle with what may be expected from his having subdivided his party who are gone against other places, must be severely felt by the rebels along that country. This occurred about the 2nd inst.

"Lieut. Clement reports that Captain Brant has burnt and destroyed the Oneida village of Conowaroharie with the rebel fort and village, and retired somewhat to deceive the enemy. They proceeded to the Mohawk river with about 300 Indians and arrived at the settlement called the Kley's Barrack about 10 o'clock a.m., on August 2nd, which having reconnoitred, he and the chief warriors thought proper to detach David Karacanty with the greater part of the Indians to make a detour and suddenly attack Fort Plank, while Joseph and the remainder should come on directly and prevent any scattering parties from taking shelter in the fort. In this they were disappointed by the too great eagerness of the Indians to take prisoners, who scattered and alarmed the settlement, by which a considerable number of men got into the fort which made an attack inexpedient, as it was well fortified and had two pieces of cannon mounted. Disappointed in this they advanced to the upper part of the settlement where the rebels had a fort at the house of Hendrick Waldrod which they abandoned. This they immediately burned, and scattering, the Indians destroyed houses till they came to Elias Map's where they had another picketted fort which they likewise burned. The extent of the settlement destroyed was on the Mohawk river in length above two miles and above five in breadth, and containing above 100 houses, two mills, a church and two forts. They took and killed about 300 black cattle and 200 horses besides hogs, poultry, etc., and destroyed a considerable quantity of grain of different kinds. The number of rebels killed and prisoners amounts to about 45. Captain Brant released a number of women and children and having effected this he retired to Butler's Mills about three days since. With the greater part of the Indians he intends to pay the rebels another visit before their return, for which purpose they have divided into seven parties."

These detachments marched by separate routes against Schoharie, Cherry Valley, and the German Flats, where they took many prisoners, destroyed buildings, and created intense alarm.

By one of these parties Brant transmitted a threatening message to a militia officer at Schoharie which has been preserved in the Clinton Papers.

"I understand my friends Hendrick Nuff and Cook are taken prisoners near at Esopus. I would be glad if you will be so kind as to let those people know that took them not to use my friends too hard, for if they will use them hard and hurt them I will certainly pay for it, for we have several rebels in our hands [which] makes [me] mention this for it would be disagreeable for me to hurt my prisoners. Therefore I hope they will not force me."

Early in September General Haldimand determined to despatch two strong expeditions against the frontier of New York, which were designed to advance simultaneously, one from Crown Point towards Albany, the other from Oswego upon the Mohawk valley. The objects of these movements, he stated, were "to divide the strength that may be brought against Sir H. Clinton, to favour any operations his present situation may enable him to carry out as well as to destroy the enemy's supplies from the late plentiful harvest and to give His Majesty's loyal subjects an opportunity of retiring to this Province."

Lieut.-Colonel Butler, with 200 rangers and 220 regular troops from the garrison of Niagara, was directed to join Sir John Johnson at Oswego and act under his orders. His instructions forbade him to take "a single man who is not a good marcher and capable of bearing fatigue. I hope Joseph is returned," the Governor added, "as I would by all means have him employed on this service."

Contrary winds prevented Butler from arriving at Oswego until October 1st, and by that time the garrisons on the Mohawk were warned by their Indian spies that he had sailed from Niagara on an expedition of some kind. It was not until daybreak on the 17th that the weary column, commanded by Sir John Johnson, passed the fort at the head of Schoharie, having made a long detour through the wilderness for the purpose of attacking the enemy in an entirely unexpected quarter, and swept along the west bank of that stream down to the Mohawk, burning every building and stack of grain as they went along. Sir John then "detached Captain Thompson of the rangers and Captain Brant with about 150 rangers and Indians to destroy the settlement at Fort Hunter on the east side of Schoharie Creek, which they effected without opposition, the inhabitants having fled into the fort." Advancing swiftly up the Mohawk the invaders laid waste the country on both sides until midnight, when utterly exhausted they halted at the narrow pass called "the Nose" to snatch a few hours' sleep. Before daybreak they were again on the march and soon encountered Colonel Brown with 360 men from Stone Arabia who attempted to check their further progress. While the detachments of the 8th and 34th Regiments advanced directly upon the front of the enemy's position, Brant with a party of Indians made a circuit through the woods to turn their right flank, and Captain John Macdonnell led a body of rangers in the opposite direction to turn their left. The position was carried with trifling loss to the assailants, while Colonel Brown was killed and about a hundred of his men killed or taken. Johnson reported that "Captain Macdonnell and Captain Brant exerted themselves on this occasion in a manner that did them honour and contributed greatly to our success. Captain Brant received a flesh wound in the sole of his foot near his former wound."

Before night they were forced to fight a sharp rear-guard action with a pursuing force of more than a thousand men under General Van Rensselaer. They turned upon their assailants, drove them from their position and crossed the river unmolested. During their raid they had destroyed thirteen gristmills, many sawmills, a thousand houses and about the same number of barns, containing, it was estimated, 600,000 bushels of grain. The severity of the blow from a military point of view was freely acknowledged by their enemies.

James Madison wrote from Philadelphia on November 14th. 1780:—

"The inroads of the enemy on the frontiers of New York have been most fatal to us in this respect. They have almost totally ruined that fine wheat country which was able, and from the energy of the government was likely, to supply magazines of flour both to the main army and the northwestern posts. The settlement of Schoharie which alone was able to furnish, according to a letter from General Washington, 80,000 bushels of grain for public use has been totally laid in ashes."

Brant returned to Niagara where he remained about two months to recover from the effects of his wound, but on the first day of February he again marched for the Mohawk river at the head of 185 Onondagas and Oneidas, accompanied by thirty rangers under the command of Lieut. John Bradt, a nephew of Colonel Butler, and Volunteer Hare. He was instructed to blockade Fort Stanwix and observe the motions of the enemy generally. The perils and hardships of such an expedition had been vastly increased by the destruction of the Indian villages and the devastation of the border settlements, as Colonel Johnson pointed out.

"This post (Niagara) is unluckily at a great distance from the rebels settlements, which not only occasions delay, but causes each party to carry three weeks or a month's provisions as (since the loss of the Indian towns,) none can be had by the way. The Mohawk river has ceased to be an object as being almost totally ruined."

They arrived one day too late to intercept a convoy of provisions, but cut off a party of soldiers sent out from the fort to cut wood of whom was one killed and sixteen captured. After lurking in the vicinity for several weeks, they returned to Niagara on March 17th.

By this time reports had been received from Detroit that parties of frontiersmen from Pennsylvania and Virginia had been directed to assemble at various stations on the Ohio river, under the command of Colonel George Rogers Clark, with the avowed intention of invading the territory of the Western Indians and possibly attacking that post. Colonel Guy Johnson accordingly determined to despatch Brant with an escort of seventeen young Seneca warriors to deliver "a speech and belt [of wampum] to the Indians there and also to the Shawanese villages, to encourage them to act with vigour and to watch the enemy's motions, with the promise of such aid as time and circumstances will permit from hence."

For some time Brant had received pay as commanding officer of a corps known as "Captain Brant's Volunteers," composed partly of white men and partly of Indians, but soon found that this station impaired his influence among his own people.

Brigadier General Watson Powell, who succeeded Colonel Bolton in command at Fort Niagara, wrote to General Haldimand on May 15th, 1781 :—

"I do not think Captain Brant is quite pleased with his situation, as he told me the day before he went off that he wished to give up his company. I believe he would be happier and have more influence with the Indians which he in some measure forfeits by their knowing that he receives pay."

He added that Brant was very anxious to go to Oswego, where a British post had lately been established and make it his base of operations as soon as he returned.

Brant and his party sailed for Detroit in one of the armed vessels on Lake Erie about the middle of April, and on the 26th of that month Major De Peyster, attended by the officers of the garrison, held a council with a number of the chiefs and warriors of the Hurons, Ottawas, Pottawatonies, and Miamis at which they declared their firm determination to support the Shawanese who were believed to be the first object of the enemy's attack.

Brant's speech at this council is thus reported:—

"The-ya-en-dinega (*alias*) Capt. Brandt addressed himself to the several Indian nations and said :—

"I am pleased to find that you are ready to assist your brethren the Shawanese. You see me here. I am sent upon business of importance to your several nations. I shall follow you and your father to the camp that is to be formed at Sandusky at which place I shall deliver to you the speeches of the Six Nations in presence of the Ohio Confederacy who will be there. I hope when you are acquainted with the contents of my embassy, it may furnish means to unite you more strongly in the cause we are mutually engaged, and continue our friendly intercourse as the meeting will be general." (Haldimand Papers, B 123, p. 27).

Scarcely had the council dissolved when a messenger arrived from Sandusky with the alarming report that a strong body of the enemy, under Colonel Brodhead, had surprised and destroyed the Delaware village of Cooshocking and had then divided into two parties which were supposed to be advancing upon Sandusky by different routes. Brant immediately marched with his small party to the assistance of the Hurons at that place and was soon followed by Captain Andrew Thompson with a company of Butler's Rangers.

Shortly after Brant's arrival at Upper Sandusky he addressed the following letter to Captain Matthew Elliot and Isidore Chene, the Huron interpreter, who had remained at the village near the mouth of the river known as Lower Sandusky.

"UPPER SANDUSKY, *May 19th, 1781.*

SIR,—This is to acquaint you that we received an account last night from Moravian Town that there is two thousand rebels coming to this place in four parties, each of them five hundred. They intended to meet together about two days' journey from this place. Two of the Moravian Indians brought this news. If this is true they can't be now far off from this place. But I think you had better remain still where you are till you hear from us again, because the news is not certain yet until our spies return. Sir, I will be very glad if you can send me five gallons of rum by the bearer, I mean if you can do it conveniently, also, I wish you to spare me eight pieces of pork. George Girty and an Indian just arrived from the Shawanese towns brought a string of wampum message from those different nations, that they would be glad if they could get some of the ammunition as soon as possible, which Major De Peyster promised them, and also would be happy if the Major would send some of his men to assist them, because they are now sure the enemy will soon get into this country. They think if he does not send men immediately it will be too late as it happened last summer. They have sent four different parties for spies but [they] are not yet returned. They are doing according to the Major's desire. This is the purport of their message. I leave it to yourselves whether you will let Major De Peyster know this news or not. Do what you think is best. It would not be amiss if you could get a few horses and send some of the ammunition to this place.

I wish you to do all you can to encourage the Indians that came from Detroit who are not yet tired of staying there for it won't be long before we shall meet the enemy. No more at present.

I remain your

Sincere friend and humble servant,

JOS. BRANT.

(Haldimand Papers, B 101, p. 73).

Brant appears to have remained at Sandusky for several weeks until it was definitely known that a considerable body of the enemy was descending the Ohio in boats with the design, it was supposed, of attacking the Shawanese villages near Chillicothe and thence advancing upon Detroit. Captain Thompson with his company of rangers and Brant and McKee at the head of a body of Mingos and Hurons hastened to the assistance of the Shawanese. From Chillicothe Brant and George Girty went forward with a small party to the confluence of the Big Miami and the Ohio, to watch the movements of the enemy.

Their initial success was reported by Brant in a letter to McKee dated "about ten mile below the mouth of the Big Miami river, August 21st, 1781."

"Three nights ago we layed at the mouth of the Miamies river. We heard a number of boats pass but we could not tell how many for it was dark. When they go past the mouth [they] fired cannon. We was going to attack them but we could not. We suppose [them] to be Clark's army. I [have] been at the Bone Lick yesterday to see whether he was there, but I could see no sign of it.

"This morning we saw a boat coming down the river and got ready ourselves and took the boat with seven men, one major amongst them, of militia, Cracrath, who was following Clark as he is gone down sure enough and has about three hundred and fifty men with him. They [are] deserting from him very fast. The prisoners do not know who far Clark is gone down the river. They suppose [him] to be at the Falls. Likewise the prisoners says there is one hundred and fifty men coming down the river with ten small boats, one large one and one still larger horse boat [with a] number of them in it, which is expected to be here next day after to-morrow the longest. They was at the Three Islands five days ago. We are about ninety strong at present with different tribes. These Indians and chiefs particular desires you and the Indians that is with you to come on as fast as possibly you can to join this party. Whilst the enemy are scattered we can easy manage them. And further desires [an] express should be sent to different Indian villages, for every man of them should come immediately to this place for there is no signs. any other party can go against the Indians except Clark as the prisoners say there is no other can be sent. No more at present, please to excuse my writing, I wrote in a hurry.

"Please let all the Indians know if they don't come to assist us we [are] determined to attack the enemy as well as we can." (Haldimand Papers, B. 182, p. 424.)

The detachment that they then lay in wait for consisted of one hundred of the "best men of Westmoreland County" in Pennsylvania, including a small company of rangers, under the command of Colonel Archibald Lochry, the lieutenant or commandant of the militia of that county. On August 24th, Lochry's flotilla arrived in the vicinity of the spot where Brant's party lay in ambush and observing an inviting natural meadow on the Indiana shore he ordered his men to land there for the purpose of cooking provisions and cutting grass for their horses. While thus employed they were surprised and driven to their boats but their escape was prevented by a party of Indians in canoes. The entire corps was cut off. Lochry and six other officers and thirty privates were killed, and twelve officers and fifty-two men were made prisoners including Craycraft's party.

A few days later Brant was joined by Thompson and McKee with all the men they could assemble at the Shawanese villages, and the united force proceeded down the Ohio in the hope of overtaking Colonel Clark. They had advanced within thirty miles of Louisville where it was reported that he was awaiting Lochry's arrival, with the intention of attacking him in his camp when they found that so many of their Indian followers had deserted and returned to their homes, that they were obliged to abandon this design and resolved to attack some of the smaller forts in Kentucky instead. On arriving at the main road leading from Louisville to the upper forts, a party of Miami Indians who formed their advance guard surprised and captured a convoy of wagons escorted by a party of horsemen, several of whom were killed. An ambush was formed near the scene of this attack and next day they entrapped a strong party of Kentucky militia led by Colonel Floyd, the lieutenant of the county. Floyd and forty of his men were killed and a number taken prisoners with the loss of only four Indians.

During this expedition Brant accidentally wounded himself in the leg with his own sword and was consequently obliged to remain for the winter at Detroit where he was joined by his wife who came from Niagara to nurse him.

Late in April, 1782, he arrived at Fort Erie in the first vessel from Detroit, accompanied by the small band of Seneca warriors who had followed him during his western campaign. Soon after his return to Fort Niagara he consented to go to Oswego although he stated that he would have preferred to join the Shawanese again with whom he thought his services would have been more effective, and on June 24th he embarked in one of the armed vessels on Lake Ontario for that post with about 200 warriors.

At this time his relations with the officers of the Indian Department do not seem to have been very satisfactory, as General Watson Powell wrote a few days after his departure :—

"I am sorry to say there have been frequent complaints since I came here that Captain Brant was a great expense to the Government and more difficult to please than any of the chiefs, and more particularly since his return from Detroit."

After Brant's arrival at Oswego there was practically a cessation of hostilities all along the New York frontier and the garrison of that place undertook no offensive operations. In September, 1782, he accompanied Sir John Johnson and Colonel Hope in a tour of inspection by way of the Ottawa and French rivers to Mackinac and Detroit. From the latter post he went with Captain Potts of the 8th Regiment to the mouth of the Miami river on Lake Erie to select a site for a new military post and proceeded to Sandusky to meet Captain McKee on his return from another raid into Kentucky which had culminated in the battle of the Blue Licks.

After his return to Niagara his dissatisfaction seems to have greatly increased as he wrote to Sir John Johnson in the following terms on Christmas Day, 1782 :—

"I have been very uneasy since we had the news of the Shawanese' misfortunes who fell into the hands of the white savages, the Virginians, and did alarm the Five Nations greatly and made them to hold councils about the matter and make speeches to the General but badly translated into English. We, the Indians, wish to have the blow returned on the enemy as soon as possible, but I am afraid it will again be a trifling affair when our speech gets below, which is too often the case, which will be a very vexatious affair, because we think the rebels will ruin us at last if we go on as we do, one year after another, doing nothing only destroying the government goods and they crying out all the while for the great expenses, so we are, as it were, between two hells. I am sure you will assist all you can to let us have an expedition early in the spring, let it be a great or small one. Let us not hang our heads between our knees and be looking there. I beg of you, don't tell us to go hunt deer and find yourselves shoes because we shall soon forget the war for we are gone too far that way already against the rebels to be doing other things. I have changed my mind since my arrival here.

You know I was very sparing of the Indian officers to be struck off. I am writing now to be; so if you do leave few, a little department, you will save so much money. Government may be able again to give the warriors proper clothing as they formerly had. You never saw such confusion in the department, nothing equal to at present.

"My complaint in the ear is still bad but I hope I shall be able to get out this winter to the Mohawk river. I will try to be at Oswego in thirty days' time or little more. I am as much forward to go to war as I ever did but I am not so well contented as I used to be formerly, because the warriors are in want. They are treated worse instead of better. I shall tell you the particulars if you should want to know why I write you so."

Some months later Colonel Allan Maclean, of the Royal Highland Emigrants, who had succeeded General Powell in the command of Fort Niagara, observed that "Captain Joseph Brant, though a brave fellow who has been a faithful, active subject to the King, has been the most troublesome because he is better instructed and more intelligent than any other Indian."

The dissatisfaction of the Indians had by that time greatly increased upon learning the proposed terms of peace by which they considered that their interests were sacrificed.

The war was at an end. Brant's reputation as a successful partisan stood high both among friends and enemies. None of the leaders of the Indians had been so actively and continuously engaged, and none had been so uniformly distinguished by courage and ability.

THE BEGINNING OF MUNICIPAL GOVERNMENT IN ONTARIO.

BY PROF. ADAM SHORTT, QUEEN'S UNIVERSITY.

(Read 12th April, 1902.)

AFTER the conquest of Canada, very satisfactory progress was being made towards the converting of the country into an English colony, by methods very similar to those which had worked so successfully in the colony of New York, originally a Dutch settlement. But, unfortunately for this promising development of a united Canada, difficulties arose between the mother country and the older colonies. The nature of the rights claimed by the colonists, proved to the majority of the ruling party in Britain that full British rights and liberties, even as they were in those days, were quite inconsistent with the retention of the colonies in that condition of submissive dependence, which was called for by the colonial system of the time. The object of this system was to foster the colonies, not with a view to their own good, but with a view to the good of the mother country. Nevertheless, it was honestly believed by many of its advocates, that, in serving the purposes of the mother country, the colonies would share in her prosperity and greatness, and obtain all the benefits that were possible to people who had abandoned the political, social, and other privileges of the home land for the greater material gain, but necessarily inferior life of the colonies.

As the difficulties with the colonies increased, the conviction grew that the colonists had been permitted to usurp many liberties, which were quite inconsistent with their dependent position. It was freely admitted by many that France and Spain, not England, had dealt wisely with their colonies in keeping them in due subjection.

Possessed of such convictions, and with a view to employing the joint French-Canadian and Indian forces as a rod of correction to bring the arrogant colonists to a due sense of their inferior status in the empire, every one of the numerous measures, then either in operation or preparation, for the Anglicizing of Canada was abandoned. All the ordinances passed after the Conquest were repealed by the Quebec Act, which re-established in its purity the French-Canadian civil laws and institutions. Only the English criminal law was retained, since it would afford, it was thought, a better hold upon the people, it being much more severe than the French criminal law.[1]

This reactionary attitude on the part of the British Government, which was responsible for the loss of the American colonies, requires special attention in connection with the subject before us, since it serves to account for the peculiar attitude of the colonial governors towards the self-governing aspirations of the loyalists and others who afterwards settled in the western districts.

The more intelligent loyalists and early settlers, while refusing, from circumstances or conviction, to break with the Home Government, were not by any means prepared to endorse its views with reference to the entire subordination of the colonies to the wishes of the mother country. No sooner, therefore, were the loyalists settled in the newer districts of Canada, than the Government began to be bombarded with their claims for British rights and British institutions.[2]

Haldimand, Dorchester and Simcoe, the governors who first had to deal with them, all complain of the independent spirit which they manifested. While it cannot be denied that the governors had much cause for resentment at the turbulent arrogance of many of the loyalist troops and some of their officers, when disbanded, yet they showed no little suspicion as to the real loyalty of the best of them.[3] Both Haldimand and Dorchester strongly favoured the retention of the whole colony, including the loyalist settlements, under the French-Canadian laws and institutions established by the Quebec Act. They professed to fear another revolution as the natural and inevitable consequence of granting them British freedom; and in this they were probably not far astray, assuming that their views of what a colony should be were correct. Dorchester's experience, however, at length compelled the reluctant admission that, owing to the temper of the people, together with the example before them of the late colonies now enjoying their British institutions in independence, it would be impossible to retain the loyalists and others under the French-Canadian system.[4]

1 See the correspondence of Governors Carleton and Cramahe with the Home Government. Canadian Archives, Vols. Q. 5 to Q. 11. Also the Debates on the Quebec Act, from the notes of Sir Henry Cavendish, London, 1839.

2 Numerous references to this subject are scattered throughout the state papers of the period. See more particularly, Canadian Archives, Vols. Q. 24, 25, 27.

3 Among many official papers in the Canadian Archives bearing on this subject, see the collections of despatches relating to the settling of the loyalists, in the Haldimand papers, Vols. B. 63 and 64.

4 See various despatches in Canadian Archives, as in Vols. Q. 39 and 42.

He took part, therefore, in framing, or at least revising the Constitutional Act of 1791, which made possible the adoption of English laws and institutions in Upper Canada. But when we come to look into that act, we observe that the greater part of it is taken up with provisions for establishing an hereditary political aristocracy and an episcopal state church.

It was a firm conviction with the high Tory party of the time, that had the colonies been supplied with an hereditary landed aristocracy and a well-endowed state church, there never would have been any revolution in them.[1] Hence, great care was taken by the authors of the Constitutional Act, to make very special provision for these two bulwarks of monarchical rule.

Having thus briefly outlined the situation to be occupied by the early settlers of Western Canada, we are in a better position to understand the peculiar circumstances attending the attempts to introduce local or municipal government in Upper Canada.

It was at once natural and inevitable that those loyalists who had really exercised full citizenship in the colonies, should seek to reproduce here the various customs and institutions economic, religious, social and political, to which they had been accustomed in the colonies before the Revolution. While, therefore, the Government might look askance upon these institutions as the real cause of the Revolution, the loyalists, nevertheless, cherished them as the very essence of the British system as they had known it. To these things they had remained loyal, for these they had fought and suffered. We can imagine their feelings, therefore, on being told that all these laws and institutions were illegal, that to be good British subjects they must give up all that they had hitherto valued as the very essence of the British system, and adopt a French-Canadian system, which they had hitherto regarded as of all things the most alien. To accept the laws and institutions of a conqueror might indeed be hard, but must be expected as the natural sequel of conquest. But how little to be expected that those who had followed the British flag should lose more completely the essentials of British freedom than those who had remained in the revolted colonies? The supposition could hardly be taken seriously, it was too bad to be true.

Being for some time engaged in procuring the merest necessaries of life, and laying foundations for future property, interpretations of the

1 See, among other literature of the period, Knox's Extra Official State Papers, Vol. II., pp. 21, 30, 33, etc.

civil law, and the services of a local administration were not much in request, and their want was not felt. Criminal law was more in demand for the punishment of breaches of the peace, and the criminal law was English. Only on one point did the first British-American settlers come into direct contact with French-Canadian institutions, and that was in the tenure of their lands. These were granted only on the French-Canadian feudal basis, with all the obligations and restrictions which that involved. This, therefore, was the burden of the first complaints which poured in upon the Government. A little later the settlers began to express a desire for those institutions of local government to which they had been accustomed, and which in some sections they were tentatively reproducing before there was any legal sanction for them.

What, then, was the nature of those municipal institutions which the people sought to introduce?

There were two quite distinct types of local government developed in the American colonies. Their differences chiefly depended upon the character and circumstances of the immigrants from Britain, who laid the colonial foundations.[1]

The New England colonists of different migrations were almost entirely drawn from the middle classes of the mother country, and especially from those districts in which the Puritanic spirit had been strongly developed. But Puritanism is simply a general expression for a type of mind characterized by independence of thought, and consequently of action, in the various departments of practical life, whether religious, social, economic or political. Where almost the whole of the social fabric was composed of such people, and especially in a new country, self-government in general, and local government in particular were inevitable.

The settlers of New England, being very largely of the same social class, and having few or no servants, maintained their individuality, and exercised with the freedom of a new country those local rights and privileges which they had introduced from England.

In the southern colonies, on the other hand, of which Virginia was the special type, the settlers were mainly of the middle and upper classes, with less of the Puritanic strain. Moreover, they soon obtained from Britain a large element of the lower class in the capacity of servants. These were much inferior to their masters in moral fibre,

1 For an excellent summary of the municipal institutions of the American Colonies, see "Town and County Government in the English Colonies of North America, by Edward Channing, Ph.D., Johns Hopkins University Studies in History and Political Science. Second Series, Vol. X., 1884.

intelligence, enterprise and strength of character generally. Later the planters obtained negroes as servants, and the whites, gradually emancipated from service, yet remained for the most part in a backward condition as a permanent lower social order. Under these circumstances the superior white minority asserted and secured the right to rule in local as well as central affairs.

The other colonies exhibited various modifications or combinations of these two types, according to their social structure, or their contact with New England or Virginia.

The majority of the loyalists and other settlers in Upper Canada came from New York colony, with smaller proportions from the adjoining colonies of Pennsylvania, New Jersey and New England. In these regions the New England type of local government prevailed.

The local unit of the New England system was the old English parish or town, with officers who were at once civil and ecclesiastical, and who combined in themselves legislative, executive and judicial functions.

The New England parish or town, in its town meeting, had power to legislate on all matters of purely local interest, affecting the everyday life and comfort of the people; and its legislation, expressed in by-laws, was executed by officers of its own. The town had certain duties with reference to the parish church, the relief of the poor, and the oversight of the public morals. These duties were performed by the wardens, usually termed church wardens, though they were really civil officers. The town clerk kept a record of the proceedings of the town meetings. The constables looked after the peace and protection of the town, and raised hue and cry in pursuit of offenders.

There were also overseers of the highways who attended to the maintenance of the roads and levied a labour tax for that purpose. Other officers were the assessor and collector of the taxes, fence viewers and pound keepers. There was also a body of select men, corresponding to our present town or township councillors, having a general oversight of town matters, with power to act in emergencies. All these officers were elected annually at the general town meeting.

The Court of Quarter Sessions, which was early established in the colonies, was mainly a court of justice in New England. Nevertheless, all regulations made by the select men of the town had to obtain the sanction of the Court of Quarter Sessions before being regarded as legal, The Quarter Sessions also had the duty of laying out all the highways in the county, though the several towns undertook their opening up and maintenance. From this body, too, licenses were to be obtained by the keepers of public houses. It also levied certain rates for the support of its own officers and functions, and apportioned these rates to the several townships. The executive officer of the Court, for the county, was the sheriff, who was appointed by the governor. For militia purposes the colony was divided into shires, for each of which a lieutenant was appointed, whose duty it was to call out the militia.

In Virginia the shire, or county, was the central unit of local government, presided over by a lieutenant, corresponding to the Lord Lieutenant of an English county, and appointed by the governor-in-council. There was also a sheriff, with sergeants and bailiffs as required. Then there were the county courts, composed of justices of the peace, corresponding to the Courts of Quarter Sessions of New England, but with much more extensive municipal authority. They exercised most of the powers allotted in New England to the town meeting and the select men. Thus the county court, which met monthly, had power to erect and keep in repair the court house and jail, it had sole charge of the highways and bridges, and let contracts for their construction; it divided the county into walks or precincts, over which surveyors were appointed, corresponding to our pathmasters, who called upon the people for their quotas of labour. The court also appointed constables, and as in New England, licensed inn-keepers. The poor were looked after in Virginia by the Church, through its vestry and church wardens, the latter being two in number, appointed by the vestry from among themselves. In this connection it is interesting to note that New York and after it Upper Canada, combined both systems, the town meeting electing one church warden, and the parson appointing the other. Inasmuch as the justices of the peace were appointed by the governor-in-council, the local administration of Virginia was in no way dependent upon the will of the people in general, whereas, in New England, local government was very directly dependent upon the people. In Upper Canada, as we shall see, the people sought to obtain the New England system, while the governor and council endeavoured to fasten upon them the Virginia system.

Having thus briefly summed up the two typical forms of local government in the American colonies before the Revolution, we are in a position to understand whence came much of the peculiar combination which was afterwards found in Upper Canada.

In New York colony the population was made up of very heterogeneous elements, as regards nationality and creed, hence the ecclesiastical features of the New England system are wanting. On the other hand, the powers of the Court of Quarter Sessions were more extensive than in New England, though much less so than in Virginia. While, therefore, in most parts of New York the town meeting was a very important institution, yet it had a narrower field of operation, being encroached upon in this respect by the Court of Quarter Sessions. It is this modification of the New England system which we should naturally expect to find reproduced in Canada.

After the Quebec Act, which uprooted all previously planted British institutions, and the American invasion, which prevented the operation of almost any civil government, the governor and council once more set to work to build up a system of courts and local administration, in accordance with the re-established French-Canadian laws. Little progress, however, was made in the latter field before the arrival of the loyalists in 1785. Throughout the war, a steady stream of refugees sought the protection and aid of the British Government in Canada. The first regular body of loyalists, strictly so called, was brought in and settled under military leadership. Governor Haldimand had expected to superintend their settlement himself, but being engaged in other quarters, he assigned the task to Sir John Johnson in May, 1784. In a couple of private letters to Johnson, he stated that he intended to recommend him for the position of Lieutenant-Governor and Commander of the Western District, and Superintendent General of all the refugee loyalists to be settled there.[1] Though this plan was not realized, yet in July, 1784, Johnson was appointed to superintend the settling of the loyalists and Indians in the new district.

In order that the leaders might have adequate authority to deal with such legal matters as were connected with the settlement and the keeping of the peace, magistrates' commissions were given to Sir John Johnson, Maj. De Lancey, Maj. Holland, Maj. Ross, Maj. Jessup, and Mr. Collins, who were thus constituted the first justices of the peace for the new settlements.[2]

As already stated, these settlements were to be established under French-Canadian law, and the lands granted under the French feudal tenure. The dividing of the district into townships had nothing to do with legal administration or local government, but was entirely a matter of convenience in surveying the territory and recording the lots of land.

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1 Canadian Archives, B. 65, pp. 22 and 29.

2 Canadian Archives, B. 65, p. 28.

Express instructions were issued that the townships should not be named, but merely numbered ; they were not even to be referred to as townships, but as Royal Seigneuries.[1] Thus did the government seek in advance to head off the distrusted town meeting.

In dealing with the malcontents among the loyalists, Haldimand, writing on August 20th, 1784, recommends to Major Ross, then in command at Cataraqui, to employ the civil power as far as possible, and adds that he will send up commissions of the peace for Major Van Alstine and Captain Sherwood, which he believes, in addition to those already sent, will make a sufficient number.[2]

As yet these justices were merely peace officers, there were still no Courts of Quarter Sessions. In all matters not permitted to be disposed of in a summary manner by one or more magistrates, recourse must be had to the courts at Montreal. But in the following year, 1785, an ordinance was passed "for granting a limited civil power and jurisdiction to His Majesty's Justices of the Peace in the remote parts of this Province."[3]

Meanwhile, the magistrates and chief men of the settlements, headed by Sir John Johnson, began to send in those petitions already referred to, for relief from the French-Canadian system, and for more extended local administration. In their petition of April 11th, 1785, sent directly to the King in London, they submitted a plan for the government of the new settlements. In brief, it provides for the forming of the territory, from Point Beaudet westward, into a district distinct from the Province of Quebec. It was to be placed under the direction of a lieutenant-governor and council, subordinate, however, to the governor and council in Quebec. This district, having Cataraqui as its metropolis, was to be subdivided into smaller districts or counties, with courts of justice appropriate to each. The petition expatiates at length upon the advantages of such an arrangement, and upon the hardships of the present situation. Those who signed this petition, ten in number, were all officers who had served in the late revolutionary war.[4]

The following year, the magistrates at Cataraqui and at New Oswegatchie (Prescott), being requested to do so, sent their views as to the needs of the Western settlements. in a memorial addressed to Sir John Johnson, the superintendent of the district. In these memorials, in addition to the usual prayer for deliverance from the French-Canadian

1 Canadian Archives, B, 65, p. 31.

2 Canadian Archives, B. 64, p. 182.

3 Laws of Lower Canada, Vol. 1, p. 105.

4 Canadian Archives, Q. 24-1, pp. 76-84.

system, they show a growing anxiety with reference to local government, education and facilities for trade. In the Cataraqui memorial, after referring to the need for local courts of justice and increased powers for the magistrates, they continue, "The election, or appointment, of proper officers in the several townships, to see that the necessary roads be opened and kept in proper repair, we conceive would be of great utility, by facilitating the communication with all parts of the settlement. Humanity will not allow us to omit mentioning the necessity of appointing overseers of the poor, or the making of some kind of provision for persons of that description, who from age or accident may be rendered helpless. And we conceive, it would be proper that the persons appointed to this charge, as well as the road masters, should be directed to make regular reports of the state of their districts to the courts at their meetings, and be in all cases subject to their control."[1] Here, we observe that the magistrates, naturally favouring the conservation of their own power, lean to the side of the Virginia system, in which the Court of Quarter Sessions, and not the town meeting, should be the centre of local administration.

The New Oswegatchie memorial, though briefer, is to the same effect. It prays that the new settlements may be formed into separate counties or districts, from Point Beaudet upwards, each having its own courts, judges and civil officers.[2]

These memorials and many others affecting the whole judicial and local administration of the Province of Quebec, were referred to a committee of the Council, composed of one English and two French-Canadian members. Their report is very exhaustive and very interesting, but only certain portions of it bear directly on the question in hand. It brings out, however, the utter inadequacy of such local administration as existed under the French-Canadian system, for the regulation of the loyalist settlements, where the quasi-civil machinery of the French Canadian Church was entirely wanting. Mr. Finlay, the English member of the committee, strongly supported the claims of the loyalist settlements to be erected into separate districts, and recommended an ordinance to be passed authorizing this division. But the two French-Canadians on the committee strongly opposed any weakening of the French-Canadian system, and supported their views with most interesting and subtle argument based on legal, social, political and international grounds.[3]

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1 Canadian Archives, Q. 27-2, pp. 510-518.

2 Canadian Archives, Q. 27-2, pp. 519-520.

3 Canadian Archives, Q. 27-1, pp. 199-206.

However, the outcome of the matter was the ordinance of April, 1787, making further provision for the administration of the new settlements.[1] The most important section bearing on our present inquiry is the following, "Whereas, there are many thousands of loyalists and others settled in the upper countries above Montreal, and in the bays of Gaspe and Chaleurs below Quebec, whose ease and convenience may require that additional districts should be erected as soon as circumstances will permit, it is enacted and ordained by the authority aforesaid, that it may be lawful for the Governor or Commander-in-chief for the time being, with the advice and consent of the Council, to form by patent under the seal of the province, one or more new districts, as his discretion may direct, and to give commission to such officer or officers therein as may be necessary, or conducive to the ease and convenience of His Majesty's subjects residing in the remote parts of the province." In accordance with the authority granted in this ordinance Lord Dorchester issued a proclamation, dated July 24th, 1788, dividing the western settlements into four districts, named Lunenburg, Mecklenburg, Nassau and Hesse.[2] On the same day appointments were made to the following offices in each of the new districts: judges of the Court of Common Pleas, justices of the peace, sheriff, clerk of the Court of Common Pleas, and of the Sessions of the Peace, and coroners.[3]

Courts of Quarter Sessions were thus organized, and began their sittings the following year. The first court for the district of Mecklenburg was held at Kingston on April 14th, 1789,[4] and the first court for the district of Lunenburg was held at Osnabruck, on June 15th, in the same year.[5]

Except as regards the criminal law, the justices were still required to administer the French system in accordance with the Quebec Act. But as this immediately led to difficulties, the justices of the district of Mecklenburg submitted certain problems to the Government at Quebec. For instance, proclamations to be legal were required to be made at the church doors of the parish, and to be published in the *Quebec Gazette*. But in the whole of the western settlements there were only two church doors, and no one was known to take the *Quebec Gazette*. The justices, therefore, made a characteristic suggestion, namely, that as most of the settlers had to go to one or other of the two grist mills of the district, at

1 Laws of Lower Canada, Vol. I., p. 121.
2 Canadian Archives, Q. 37. p. 178.
3 Canadian Archives, Q. 39. pp. 134-139.
4 Early Records of Ontario, *Queen's Quarterly*, Vol. VII., p. 55.
5 Lunenburgh, or the Old Eastern District, by J. F. Pringle, Cornwall, 1890. p. 47.

Kingston and Napanee, the proclamation should be posted there, a suggestion which was accepted. Again, having no officers corresponding to the French notaries, mortgages and other documents requiring registration could not be registered. Further, under the French system the public highways were under the direction of the officers of the militia, subject to the supervision of the grand voyer. But this arrangement could not be carried out in the English districts. The granting of licenses to keep taverns was in the hands of the Secretary of the Province or his agent, and could be arranged only in Montreal. And finally it is prayed that if Government will not grant them any relief from the French system, then, inasmuch as they are entirely ignorant of the requirements of that system, the Government may send them full instructions as to the laws and how they are to be enforced.[1] But by this time a change in the constitution had been recognized as inevitable and was then being prepared, hence no action was taken on this memorial. In default of instructions the justices in civil matters simply followed the laws and customs which they had known, and decided cases on the good old English principle of equity and good conscience.

The duties of the Court of Quarter Sessions, as interpreted, were partly judicial, as in connection with the maintenance of the peace, partly legislative, as in prescribing what animals should not run at large, or what conditions should be observed by those who held tavern licenses, and partly administrative, as in appointing certain officials, and in laying out and superintending the highways.[2] We find, for instance, that before 1789 the magistrates had appointed church wardens for the township of Fredericksburg, and doubtless for several others, and that these church wardens were exercising their powers as if they were living in an English colony under English laws.[3]

It is noteworthy that most of the civil or municipal administration undertaken by the justices of the peace was based upon the old English law and custom as it was in the days of Queen Elizabeth and the Stuarts, and not as subsequently modified in Britain.[4]

The first loyalist settlers were chiefly military men, many of them not having been actual settlers in the colonies, and some of them being German auxiliaries. They came to Canada under command of their officers, who, as we have seen, were appointed the first magistrates of the districts. As might be expected, most of these settlers did not take

1 Canadian Archives, Q. 43, 1 and 2, pp. 404-415.

2 Early Records of Ontario. *Queen's Quarterly*, Vol. VII.

3 Early Records of Ontario. *Queen's Quarterly*, Vol. VII, p. 58.

4 Early Records of Ontario. *Queen's Quarterly*, Vol. VII., pp. 58, 245, 327.

a very strong interest in introducing and maintaining the self-governing institutions of the former colonies. Yet some of the first and nearly all of the later arrivals, being largely farmers and civilians, such as those settled in Fredericksburg, Adolphustown and the Prince Edward peninsula, at once attempted to reproduce in Canada their familiar institutions. Thus, while in the townships in the immediate neighbourhood of Kingston, there appears to have been little anxiety with reference to town meetings, yet in the townships named, town meetings were established before there was any legal warrant for them, as, for instance, the record of Adolphustown will show.[1]

But we must turn now to that change in the fortune of the western settlements which came with the passing of the Constitutional Act of 1791. By it the western districts were formed into an independent province, with a representative assembly and an opportunity to introduce English laws and institutions.

To preside over the formative period of this new Government, General John Graves Simcoe arrived in Upper Canada. Simcoe was a man whose life had been spent in the profession of arms. He was, from all accounts, a most efficient officer, saturated with the military spirit. A man of simple, straightforward ideas, devoted to military methods, when in authority he was accustomed to give his commands to go and come and find them obeyed without question. Almost incapable, by temper and experience, of recognizing any other form of administration, he sought to organize his Government as nearly as possible on a military basis. Self-government by the people at large he fervently and frankly abhorred. Aristocratic military and ecclesiastical rule he considered to be the only possible form of stable government for a decent and respectful people and a well-meaning ruler. As governor of Upper Canada he felt that the whole responsibility for the successful administration of the colony rested upon his shoulders. His sense of responsibility, however, was felt not towards the colonists, but towards the Home Government, hence his extreme unwillingness to share with the colonists the administration of the country which they occupied. Canada did not belong to the colonists, but to Great Britain; the governor was not appointed by the colonists, or in any way responsible to them. He was sent out to administer a British colony in the interests and for the glory of the country which sent him. True, those interests and that glory were to be expressed in a happy and prosperous condition of the colony, but the proper methods and means for accom-

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1 Early Municipal Records of the Midland District, in Appendix to the Report of the Ontario Bureau of Industries, 1897.

plishing that result were not matters upon which the colonists could be expected to have sound ideas, and a little experience of them proved to Simcoe's own satisfaction that his conviction was well grounded. Only men of military training were fit to be trusted to carry out with loyalty and discretion the commands of their superiors. Hence, while still in London,[1] Simcoe surrounded himself with a band of military men, chiefly fellow officers in the late American war, and took them with him as his Executive Council, and afterwards as the chief members of his Legislative Council. The minor officials he expected to select in the colony from among the officers already settled there. He had also arranged to have the Assembly composed of military men, trusting that the loyalists would, under his direction, aided by the influence of Sir John Johnson, select as their representatives the half-pay officers in the Province. Here, however, he came upon his first disappointment. Writing from Navy Hall to the Colonial Secretary, on November 4th, 1792,[2] he states that in his passage from Montreal to Kingston, while the first election was in progress, he discovered that the general spirit of the country was against the election of half-pay officers, but that, to use his own words, "the prejudice ran in favour of men of the lower order who keep but one table, that is, who dine in common with their own servants." Only by stopping over at Kingston, and specially exerting his personal influence, did he manage to bring in his attorney-general, Mr. White. If such was the attitude of men but lately disbanded from the ranks in which they had fought against the advocates of self-government, what might be expected from later arrivals who were merely loyalist in name? No wonder that Simcoe should gravely attempt to put into practice a scheme for maintaining a number of military companies scattered over the colony, into which he intended to recruit crude republicans from the neighbouring states, and there, on soldier's pay, by salutary drilling, useful manual labour, and friendly lectures on the evils of self-government, convert them into well affected British subjects, fit to be trusted with a bush farm in a back township.[3] No doubt the broth would have been well flavoured had he been able to catch his hare.

The settlers having preferred men of the lower order to Simcoe's half-pay officers, we are prepared to find some assertions of popular claims which did not meet with the approval of the governor. We come upon one such at the very threshold of the new legislation. The

1 His plans for the government of Upper Canada are detailed in his letters to Dundas, written in London. See, for instance, letters of June 2nd and August 12th, 1791, Canadian Archives, Q. 278, pp. 228-255, and 283-307.

2 Canadian Archives, Q. 279-1, p. 79.

3 Canadian Archives, Q. 278, p. 287.

first bill introduced into the Assembly of Upper Canada, in the first session of the first parliament, September 19th, 1792, was a bill, "to authorize town meetings for the purpose of appointing divers parish officers." But, afte. passing its second reading, it was ordered that the further consideration of the bill be postponed for three months. On the same day another bill was introduced to authorize "the justices of the peace to appoint annually divers public officers." This, again, was followed by a bill to authorize "the election of divers public officers." None of these, however, managed to get through the House.

In these proposals we observe the conflict of the two rival American systems typified by New England and Virginia, the one seeking to vest in the people the election of their local officers and the regulation of their local affairs, the other seeking to confine these rights to the justices of the peace in Quarter Sessions, who again derived their positions from the Governor-in-Council.

Simcoe, in his report on the session to the Home Government says that the lower House "seemed to have a stronger attachment to the elective principle in all town affairs than might be thought advisable."[2] The following session the bill with reference to town meeting was once more introduced and passed, but with such modifications as made it quite harmless as a measure of local self-government. Writing to Colonial Secretary Dundas, in September, 1793,[3] Simcoe says that he managed to put off the bill of last session on town meetings as something that should not be encouraged. But as regards the opposite measure proposed, he says that "to give the nomination altogether to the magistrates was found to be a distasteful measure." Many well affected settlers were convinced that fence viewers, pound keepers and other petty officers to regulate matters of local police would be more *willingly obeyed if elected by the householders, and especially that the* collector of the taxes should be a person chosen by themselves. "It was therefore thought advisable not to withhold such a gratification to which they had been accustomed, it being in itself not unreasonable, and *only to take place one day in the year.*" When we turn to this act[4] we find that it merely permits the ratepayers to elect certain executive town officers, whose duties were either prescribed by the act, or left to be regulated by the justices in Quarter Sessions. Beyond the permission to fix the height of fences, the town meeting had not legally any

1 See Journals and Proceedings of the House of Assembly of the Province of Upper Canada, 1792, Canadian Archives, Q. 270-1, pp. 87 *et seq.*

2 Canadian Archives, Q. 279-1, p. 83.

3 Canadian Archives, Q. 279-2, pp. 335 *et seq.*

4 33rd Geo III., cap. 2.

legislative function. The town officers were independent of each other, and responsible, not to those who elected them, but to the magistrates. By an act passed the following year[1] a slight additional legislative power was given to the town meetings, permitting them to fix the limits of times and seasons for certain animals running at large, but even this power was afterwards curtailed. This first act, therefore, while authorizing town meetings, effectively strangled all interest in them, except where, as in Adolphus and neighbouring townships, the limitations of the act were to a certain extent disregarded. For years to come the Court of Quarter Sessions remained the only living centre of municipal affairs.

Recognizing the democratic tendencies of the people, Simcoe reports to the home Government that, "in order to promote an aristocracy, most necessary in this country, I have appointed Lieutenants to the populous counties, which I mean to extend from time to time, and have given to them the recommendatory power for the militia and magistrates, as is usual in England."[2] He selected them as far as possible from the Legislative Council.

With the same object in view he proposed to erect the towns of Kingston and Niagara into cities, each with a corporation consisting of a mayor and six aldermen, to be justices of the peace, and a suitable number of common councillors. This was a standard arrangement in Britain, as it was afterwards in the first chartered cities in Upper Canada. But the members of Simcoe's corporations were advised "to be originally appointed by the Crown, and that the succession to vacant seats might be made in such manner as to render the election as little popular as possible, meaning such corporations to tend to the support of the aristocracy of the country."[3]

In 1795, the Duke of Portland, writing to Simcoe, discourages his projects for the incorporation of cities, and disapproves of his appointment of lieutenants of counties. He is afraid that the effect may be the very opposite of what Simcoe intended, that instead of strengthening the power of the central government, it may weaken it by scattering its functions, while it requires to be strong to check the influence of the popular assembly.[4]

What we find, then, as the result of the various influences brought together in Upper Canada is, that the Virginia type of local or municipal

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1 34th Geo. III., cap. 8.

2 Canadian Archives, Q. 279-1, p. 85.

3 Canadian Archives, Q. 287-1, p. 164.

4 Canadian Archives, Q. 281-2, pp. 328 *et seq.*

government, and not that of New England, was practically brought into operation in this province. This was mainly through the influence of Governor Simcoe, aided by the justices of the peace already in the field, who naturally wished to enlarge their powers. Hence the municipal administration of the country centered in the Courts of Quarter Sessions, whose members being appointed by the Governor-in-Council were responsible to the Executive alone.

The various acts passed for local administration simply enlarged the powers of those courts to deal with municipal matters. In course of time certain towns obtained special charters and with them a measure of local self-government varying in range from town to town. But it was only after the struggle for responsible government had resulted successfully, that representative municipal institutions, such as we now know them, were introduced and applied to the whole Province.

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