variety showed 29·9 per cent. of sugar, which, when referred to the fresh fruit, is still over 1 per cent. less than that of the white Adriatic, or as 19·2 to 20·45 per cent. Dorée Narbus and Constantine, with respectively 27·4 and 24·04 per cent. sugar in their juice, show, on account of their dry flesh, much less sugar in whole fruit than either of the Adriatics. Another Smyrna variety showed the lowest sugar percentage, amounting to but eight parts in the hundred of whole fruit, about 4·5 per cent. less than the California Black, which gave 12·4 per cent.

The acidity of fresh figs seems to be very much lower than that found in any other fruits.

In regard to the nutritive value of figs as an article of food, it may be stated that the fig rates first in flesh-forming materials among Californian fruits; apricots and plums second; prunes and oranges third.

(The writer has recent evidence of the great value of fresh figs as an article of human food in a case of extreme prostration.)

The following table shows the mineral constituents of the fig fruit, and the consequent requirements of the tree upon the available mineral resources of the soil:

Percentage Ash-Constituents of the Fig.	White Adriatic.	Smyrna.
	Per cent.	Per cent.
Potash	60·13	48·60
Soda	1·17	2·20
Lime	9·12	....
Magnesia	5·32	....
Iron oxide	0·84	..
Manganese oxide	0·19	....
Phosphoric acid	11·07	11 20
Sulphuric acid	4·75	....
Silica	4·85	....
Chlorine	2·56	....

As to nitrogen, the investigation showed that among Californian fruits the fig, on the whole, extracts decidedly the largest amount of this element from the soil, and, therefore, it is but a truism to assert that the growing plant must have within its reach a sufficiency of nitrogen to maintain health, vigor, and productiveness.

With the exception of the grape, the analysis shows that the fig draws rather more heavily upon the mineral ingredients of the soil, that will need to be replaced by careful manuring, than do any of the Californian fruits yet examined.

In the ashes of the fig, as in the prune, apricot, orange, and lemon, the constituent potash is found to be the leading element, amounting to about three-fifths of the whole ash.

The fig, like the lemon, appears to range a little below the other fruits in its requirement of phosphoric acid, for we find the composition of the fruit ash to stand in the following order in their phosphoric acid percentages, namely: prunes, 14·1; apricots, 13·1; oranges, 12·4; lemons and figs, 11·1.

To sum up, it may be stated that the fig requires a soil very rich in food material. It is also advantageous for the vitality and fruit-bearing capacity of the fig tree to have even the lower layers of the soil abundantly supplied with soluble nutrients, so that the roots penetrating into the subsoil can be well nourished and made to develop vigorously.—*J. J. Willis, Harpenden, in the Gardeners' Chronicle.*

TYPES OF FLORAL STRUCTURE.

By the Rev. ALEX. S. WILSON, M.A., B.Sc.

A FLOWER commonly consists of organs of four different kinds, arranged in concentric circles or whorls. The order in which these organs occur is always the same relatively to the center of the flower. The carpels forming the gynœcium are most central; next come the stamens composing the andrœcium; outside of these is the corolla, made up of petals, invested externally by the sepals, which collectively constitute the calyx. There is no apparent reason why the carpels and stamens should not occasionally change places, and an explanation of this invariable order is still a *desideratum.*

A second very obvious character of flowers, which admits of better explanation, is the prevalence of certain numbers among the members composing the different whorls. There is a constant recurrence of the same number of parts in the different whorls of the same flower and in corresponding whorls of different flowers. The number five is exceedingly common. Thus in the violet, with its five sepals, five petals and five stamens, we have an example of a pentamerous flower. Three is another favorite number, and of this ternary symmetry the iris, with its three sepals, three petals, three stamens and three carpels is a good instance.

By founding his classification of plants so largely upon the number of the floral organs, Linnæus gave prominence to this numerical character, and, highly artificial though it be, the Linnæan system has the merit of recognizing the fundamental importance of this feature as an index of natural affinity.

When we study phyllotaxis, or the modes in which leaves are arranged on stems and branches, the reason for the prevalence of certain numbers in flowers becomes apparent. Leaves on a plant's stem are not arranged at random, but according to a definite law. A very frequent arrangement is the alternate, where they are separated by equal spaces or internodes, and so placed that a line drawn through the bases of successive leaves describes an ascending spiral. This line, winding round the stem, is known as the *generating spiral;* the fraction of the stem's circumference which it traverses in passing from one leaf to the next is the *angular divergence*, and the *leaf cycle* is the portion of the generating spiral included between one leaf and the next above it in the same vertical line. Angular divergence is expressed by such fractions as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, etc., where the denominator indicates the number of leaves encountered, and the numerator the number of revolutions round the stem made by the generating spiral in completing the cycle—that is, in passing from one leaf to the next above it in the same perpendicular line.

Frequently, though not always, the angular divergence is the same for the stem and branches of the same plant; it is generally constant for the same species, and may even be characteristic of genera and natural orders. A common case is where the leaves are separated from each other by one-third of the circumference of the stem; the angular divergence in this case is $\frac{1}{3}$, and the cycle includes three leaves. A still more frequent arrangement gives an angular divergence of $\frac{2}{5}$ with five leaves and two turns of the generating spiral to the cycle. Many plants, again, produce their leaves in pairs, one on each side of the stem; since the vertical planes of the successive pairs commonly cut each other at right angles, this arrangement, well exemplified in the mint and other Labiatæ, is described as opposite and decussate. Three, four or more leaves springing from the same node constitute a whorl or verticil; such a verticillate arrangement is seen in the leaves of the wood-ruff and other Rubiaceæ. The whorling of leaves may be regarded as resulting from the suppression of internodes at regular intervals. A shoot having three leaves placed according to the $\frac{1}{3}$ arrangement would, if we suppose its internodes to remain undeveloped, give rise to a whorl of three leaves; similarly a shoot, with an angular divergence of $\frac{2}{5}$, would furnish whorls composed of five leaves, if its internodes were suppressed. Hence it is held that each flower whorl represents a compressed leaf cycle, the number of its constituent parts depending on the leaf arrangement to which it corresponds. The frequency of the numbers 3 and 5 among the organs of the flower becomes intelligible in view of the prevalence among foliage leaves of the $\frac{1}{3}$ and $\frac{2}{5}$ arrangements.

Between phyllotaxis or leaf arrangement and floral symmetry there is thus a very close connection, and we might therefore be led to expect that they would always be in agreement; we might not unnaturally suppose, for example, that every plant with pentamerous flowers should have its leaves arranged on the $\frac{2}{5}$ plan, and *vice versa.* Although this rule holds good for many plants, it is very far from universal, and the numerous exceptions point to the conclusion that floral organs have more frequently retained the ancestral phyllotaxis than foliage leaves, which in many cases seem to have departed widely from the primitive arrangement. In other words, the hereditary tendency asserts itself much more strongly in the arrangement of the floral organs than in that of foliage; hence the importance assigned to the flower in every system of classification.

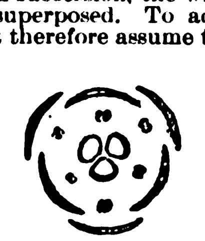
From cases of reversion like the flowering cherry, where the carpels are replaced by ordinary green leaves, we learn that a flower is simply an arrested branch or leafy shoot having its internodes undeveloped and its leaves modified to subserve the function of reproduction. The passage from vascular cryptogams to phanerogams involved, as was shown in a previous article (vol. xvii., p. 125), the arrest of certain structures belonging to the seed and pollen grain; it now appears that in the formation of the flower we have a further illustration of arrested development.

Excluding the Coniferæ and their allies, which are gymnospermous, all flowering plants have their seeds protected by closed carpels, and are on this account designated angiosperms. Plants embraced under this designation are either monocotyledons or dicotyledons, as the two great classes are called into which angiosperms are divided. To which of these classes a plant belongs can easily be ascertained from its flowers. Each whorl in the flower of a monocotyledon consists of three parts, or of a number which is a multiple of three. The flower of a dicotyledon, on the other hand, is made up of whorls each commonly composed of five parts, or a multiple of five; less frequently, as in the fuchsia and wall flower, of four, or a multiple of four. Besides this distinction, there is a difference in their floral envelopes; a monocotyledon has the sepals and petals alike; thus in the tulip both whorls of the perianth are colored or petaloid. Dicotyledons, again, have the sepals mostly green, the petals alone being gayly colored. The two classes are further distinguished by the characters of their vegetative organs; monocotyledons have parallel-veined leaves, endogenous stems and endorhizal roots; the leaves of dicotyledons are net veined, their stems exogenous, and their roots usually develop in exorhizal fashion. The first leaves of the dicotyledonous embryo arise in a whorl—they are the two opposite cotyledons; the subsequently formed leaves may arise either in pairs or verticils, but far more frequently they follow the $\frac{2}{5}$ arrangement. There is but one cotyledonary leaf on the embryo of a monocotyledon; in succeeding leaves the $\frac{1}{3}$ phyllotaxis prevails, though $\frac{1}{2}$ is not uncommon.

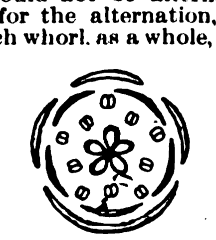
The persistence of these characters points to an early separation of the primitive angiosperms into two well-defined groups, having their leaves differently arranged. Although monocotyledons appear first in the geological series, it is by no means certain that they represent the earlier type. Pentamerous and trimerous flowers may have arisen independently after the separation of the two families, but the leaf systems they respectively represent should at least admit of reference to a common origin. The opposite and decussate arrangement some botanists, with good reason, regard as primary for dicotyledons; from it the $\frac{2}{5}$ and all other divergences occurring in this class can easily be deduced. The two opposite cotyledons favor this view, and the passage from the opposite to the $\frac{2}{5}$ arrangement may be actually observed in the artichoke, willow herb and other rapidly-growing plants. The $\frac{1}{3}$ type does not admit of direct derivation from opposite leaves, and this Henslow gives as the reason why it is never found among the foliage of dicotyledons; the 3-merous symmetry of such exceptional flowers as *Berberis* he regards as due to the breaking up of a high continuous spiral into groups of threes. The $\frac{1}{3}$ arrangement so characteristic of monocotyledons may have come from the opposite type in this indirect way, through an $\frac{8}{21}$ or more complex cycle; but it is much more probable that it arose by symmetrical decrease.

A hint of what was, perhaps, the condition in the common ancestral form is furnished by the herb paris, belonging to a family which has the closest relations with the Liliaceæ. The flowers of *Paris quadrifolia* are 4-merous; its leaves are reticulated and arranged in a whorl of four. We have in this undoubted monocotyledon a combination of monocotyledonous and dicotyledonous characters, with a phyllotaxis closely approximating to what, in all probability, was the primitive type in dicotyledons. It should not be forgotten, however, that in the phyllotaxis of fossil cryptogams and gymnosperms much diversity is found.

In Diagrams I. and II. the whorls are shown alternating; this is their normal position. Now, since foliage leaves develop in acropetal succession—that is, from below upward—the floral organs ought theoretically to do the same; but if they followed the strictly spiral succession, the whorls would not be alternate, but superposed. To account for the alternation, we must therefore assume that each whorl, as a whole, has



I. Monocotyledonous Type.



II. Dicotyledonous Type.

shifted its position, the displacement being equivalent to the rotation of a floral axis through half the angular divergence. The angular divergence itself is observed to change in some flowers; in aconite, for example, from $\frac{2}{5}$ in the calyx to $\frac{3}{8}$ and $\frac{8}{21}$ in the corolla and andrœcium. One or two of the Ranunculaceæ, such as *Garidella* and *Helleborus*, have the petals superposed to the sepals in strict accordance with spiral phyllotaxis, but this is rare in the floral envelopes. Where the andrœcium consists of numerous stamens, these are frequently arranged in a spiral manner, giving rise to superposed whorls. The sepals and petals of the buttercup arise in alternate whorls, but the stamens and carpels develop in spiral fashion like ordinary leaves. To this condition the name hemicyclic has been given. In the water lily order, Nymphaceæ, all parts of the flower follow the spiral order; this condition also occurs in the camellia, in the Magnoliaceæ and Calycanthaceæ, and is approached by several of the Ranunculaceæ. A significant fact in connection with the simplicity of the flower of the water lily is the circumstance that, nowithstanding its truly dicotyledonous embryo, the root stock shows the endogenous structure of the monocotyledonous stem.

Considerations like the foregoing make it clear that acyclic flowers, or those whose parts form a continuous spiral, represent a primitive type, upon which the hemicyclic condition of the buttercup is a slight advance. The passage from these to the regular alternating whorls of the eucyclic class involves a modification of the phyllotaxis for each succeeding whorl. Under the term cyclic are included all flowers whose parts occur in whorls, but some confusion has arisen from a lax use of the latter term. Some writers call any set of leaf organs a whorl which arise on the same horizontal zone of the axis—*i. e.*, which are produced at the same height, or what amounts to the same thing, at equal distances from the growing point; others restrict the term to circles in which the parts appear simultaneously. Sepals, as a rule, arise in succession; petals, for the most part, simultaneously. The calyx of the rose illustrates this successive character; its outermost and oldest sepal has fringes on both its edges which are free; so has the second sepal, which is placed at an angle of 144° to the first—*i. e.*, with a divergence of $\frac{2}{5}$. At an equal distance from the second stands No. 3, fringed on its outer edge only; No. 4 is similar, while No. 5, which completes the cycle, has no fringes, both its edges being overlapped by the other sepals. A corresponding order can often be traced even in the corolla—in the butterfly blossoms of Luguminosæ, for example, the large standard petal begins the leaf cycle, one of the keel petals completing it; and generally the æstivation of the flower—that is, the manner in which its parts are disposed in the bud before expansion—admits of explanation on the principles of phyllotaxis. The two examples just given illustrate respectively the quincuntial and vexiliary modes of æstivation. As early stages in the evolution of the blossom, then, we have to note: I. The spiral arrangement of the floral organs. II. Whorls due to the arrest of the internodes of the floral axis. III. Alternation, or a change in the orientation of each whorl disturbing the spiral order; and IV. Simultaneous whorls with synchronous development of parts, which still further obscures the original phyllotaxis.—*Knowledge.*

RAIN MAKING.*

By FERNANDO SANFORD, Professor of Physics, Leland Stanford Junior University.

I SHALL ask your attention this evening to the scientific principles which are involved in the condensation of atmospheric vapor, and to some of the attempts which have been made to produce this condensation by artificial means.

Since the change from atmospheric vapor to water involves a change of the physical state of the same substance from a gas to a liquid, it is important that we understand clearly the difference between these two physical states.

Both liquids and gases are undoubtedly made of very small particles called molecules. In a gas these molecules are not held together by any force, but each molecule is a perfectly independent body, free to move in any direction without reference to any other molecule, except as its motion may be interfered with by colliding with another. Under all known conditions these gaseous molecules are actually in rapid motion, each one moving at its own rate and in its own path, unaffected by any known force except gravitation. Each molecule will, accordingly, move in a straight line until it collides with another molecule. When two molecules collide, their direction of motion will be changed according to the angle of collision, but on account of their high elasticity they rebound with the same force with which they collide, and the sum of their motions will be practically the same as before. Hence, no number of collisions between the molecules themselves will ever bring them to rest.

If confined within solid walls, they strike against these walls and rebound from them just as they do

* A lecture given before the students of the Leland Stanford Junior University, March 6, 1894.—*Popular Science Monthly.*

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from each other. In doing so each molecule exerts a pressure upon the wall during its time of contact, and the sum of these pressures is the whole pressure of the gas upon the walls of its containing vessel.

These walls are likewise composed of similar molecules, but held together by some unknown force, and it is the surface layer of these molecules which must bear the shock of the molecular bombardment of the gas. Accordingly, the molecules of the solid walls, while not free to be driven about from one place to another, like the gaseous molecules, are nevertheless set in vibration; and since they cannot lie as close together while in vibration as they could at rest, the solid mass of the walls is made to expand. By measuring the amount of this expansion we can determine the energy of the molecular bombardment. By letting the vibrating molecules of the solid or the gas come in contact with the parts of our skin to which certain special sense nerves are distributed, we feel the sensation of heat, and we are accustomed to say that the expansion of the solid or the gas is due to heat. The total measure of the energy which any mass of matter has on account of the motion of its molecules is determined by the amount of heat—*i. e.*, molecular motion—which it must give to other bodies before its molecules can come to rest. The higher the temperature of the mass, the more heat or the more molecular motion it has.

The atmosphere is, in general, made up of two different kinds of molecules. These molecules are, of course, very small—so small that no possible magnifying power can ever bring them into view. Their size is, in fact, so small as compared with the length of a light wave that no image of one could be produced by reflected light. Still, there are several independent methods of calculating their approximate size, and, since these different methods lead to fairly accordant results, we may assume that their approximate size is known. According to Lord Kelvin's computation, if a drop of water were magnified to the size of the earth, its molecules would become larger than shot and smaller than cricket balls, perhaps about the size of marbles. They are so close together in the air that the number in a cubic inch is represented by the number ten raised to the twenty-third power. Being so close together, and being at the same time in rapid motion, they must have frequent collisions, and, according to Maxwell's calculation, a molecule of air at ordinary temperatures would have seven or eight hundred thousand millions of collisions in a second of time. While these figures, both for size and number, can convey no definite meaning to us, they may aid us in picturing to ourselves the tremendous agitation which is constantly going on within our atmosphere or within the mass of any other gas.

Within the body of a liquid the conditions are similar, except that here the molecules are so close together that they cannot be said to have any free path at all, and are, accordingly, in a state of perpetual collision. They are not, as in a solid, held to any definite position with reference to the surrounding molecules, but are hindered by a force called cohesion or capillarity from escaping from the liquid altogether. What the nature of this force is, is not known, but it is evidently a pressure of some kind exerted upon the molecules tending to push them closer together.

Notwithstanding this force, the molecules of the liquid are in rapid vibration, and at the free surface of the liquid they are being continually bumped off by the molecules below them. When this happens they become free gaseous molecules, and move off in straight lines under the impulse of the force which set them free until they come into collision with other molecules.

At the surface of separation between water and air the conditions are accordingly as follows: The surface layer of water molecules is held down by the force called cohesion, but the individual molecules of this layer are being continually bumped off by the vibrations of the molecules below them. Some of these free molecules are undoubtedly driven back by the bombardment of the air molecules above them, so that they escape much more slowly into the air than they do into a vacuum, but those which once escape into the air are knocked about by the air molecules and by each other until they are pretty evenly distributed throughout the air. After a time they become so numerous in the space above the water that, in their irregular excursions between their collisions with other molecules, they begin to strike the surface of the water, and then, under favorable conditions, they penetrate into the liquid and are held fast. This process continues until finally as many molecules enter the water as escape from its surface, and then, while a constant exchange is taking place between the liquid and gaseous molecules, the average number in the space above the liquid remains constant. This space is then said to be saturated with vapor molecules. The number of molecules required to saturate this space is the same whether the space already contains air molecules or not, but, on account of the number of water molecules which are beaten back by the air molecules, it takes much longer for the space to become saturated when it is already filled with air than it does when there are no other molecules in it. The air molecules, however, hinder the vapor molecules from striking the surface of the water as often as they prevent them from leaving the surface, so they do not influence the total number required to produce saturation.

When the point of saturation has been reached, an increase of temperature—*i. e.*, an increase of the molecular vibration of the water—causes the molecules to be driven off faster than before. It also causes the gaseous molecules to strike the surface of the water oftener than before. But an increase of temperature means a corresponding increase of vibration of all the molecules; and, since there are very many more liquid than gaseous molecules in the same volume, the total increase of molecular vibration corresponding to a given rise of temperature will be much greater for the liquid than for the gas, and a correspondingly greater number of molecules will be thrown off at the surface of the liquid than will be returned to it. Accordingly, the higher the temperature, the more molecules are required to saturate the space above the water. In fact, the amount of water vapor required to produce saturation of the atmosphere under the conditions above mentioned is more than twice as great at 80° F. as at 50° F.

On the other hand, lowering the temperature of the liquid and vapor by a like amount lessens the number of molecules given off from the liquid surface more rapidly than it lessens the number striking upon the surface. Accordingly, we say that raising the temperature increases evaporation; lowering the temperature increases condensation.

Now, it happens that this same force of cohesion may hold water molecules upon the surface of most solid bodies as strongly as upon the surface of water itself, and in many cases even more strongly. Accordingly, if a solid body of this kind be placed in the atmosphere, the same exchange of water molecules will take place between its surface and the air as between a water surface and the air. In fact, as soon as a layer of water molecules is formed over its surface, it becomes a water surface. Accordingly, if a solid particle be placed in an atmosphere saturated with water vapor and the temperature be lowered, the water molecules will accumulate upon its surface faster than they are driven off, and we say that a precipitation of dew is taking place upon it. The air is accordingly said to reach its dew point when it reaches its point of saturation.

There are other substances which hold fast in a different way the water molecules which strike upon their surface. These substances form either chemical compounds or solutions with water, and in this way remove the water molecules from the places where they strike to the interior of the compound or the solution. Sulphuric acid is a good example of this class of substances. If a vessel of sulphuric acid be placed in a receiver filled with water vapor, the acid holds fast all the water molecules which strike its surface, and sends off no other water molecules to replace them. Since all the water molecules in the receiver will in time come in contact with the acid surface, they will ultimately all be held in a liquid form by the acid. Accordingly, a receiver of moist air can be changed to dry air by allowing it to stand for a sufficient length of time over sulphuric acid.

There are very many other substances which, like sulphuric acid, have the property of condensing the water molecules from a space which is not saturated with them. Such substances are said to be deliquescent, or to gather moisture from the air. Common salt and caustic potash are good examples of deliquescent substances.

There is still another method of producing condensation. If an inclosed space contain water vapor enough to bring it to the point of saturation, and if the volume of the space be decreased without changing the temperature, more molecules will strike upon a given surface of the containing walls than when the volume of the gas was greater. Since the temperature remains the same, the same number of molecules will be driven off from a given surface of these walls as before. There will, accordingly, be a condensation upon the walls, which will continue until enough gaseous molecules have been removed to make the exchange again even.

These are the three known methods of changing water vapor to the liquid form—viz., by lowering the temperature of the vapor and the other bodies in contact with it until the point of saturation has been passed, by compressing the vapor until there are enough molecules in unit volume to produce saturation, and by allowing the vapor molecules to strike upon some surface which will immediately take them into solution or into chemical combination. I know of no other method by which water vapor, or any other vapor, can be changed into the liquid form.

The conditions necessary for the precipitation of the aqueous vapor from the atmosphere are, then, as follows:

(1) The air must contain enough molecules of water vapor to more than saturate it, and must contain at the same time either solid or liquid bodies upon which these vapor molecules may be held fast by cohesion; or (2) the air which does not contain enough water vapor to saturate it may come in contact with solid or liquid substances, which combine with or dissolve the water molecules which strike upon them.

This latter condition can manifestly play no important part in atmospheric precipitation. The only condition under which such substances could cause condensation above the earth's surface would necessitate their distribution throughout the atmosphere, and if they were so distributed, they would constantly absorb the atmospheric vapor until, loaded down with it, they would sink to the earth, and there would be a condition of perpetual rainfall.

For the general precipitation of atmospheric vapor we must accordingly depend upon the condensation due to cohesion. Of this form of condensation, dew is the simplest illustration. During the day the earth and the solid bodies upon its surface are raised by the sun's radiation to a temperature higher than that of the surrounding air. So long as this is the case the atmospheric vapor will not condense upon them, even if the air be cooled to the point of saturation. In the night the same substances which absorbed the sun's heat fastest now radiate it fastest and soon become colder than the surrounding air. As soon as they are cooled to the temperature of saturation of the surrounding air the vapor molecules begin to condense upon their surface.

Now, the condensation of water vapor in the air above the surface of the earth is dependent upon exactly the same conditions as the formation of dew. It used to be thought that, as soon as the air was cooled to or below the dew point, the molecules of water vapor in the air would come together and form drops of water. In 1880 Mr. John Aitken, of Scotland, began a long and very thorough series of experiments upon the condensation of water vapor from the air, and the same line of experimentation has been carried still further by Robert von Helmholtz and by Richarz in Germany. These experiments have all shown that vapor condensation within the body of the air only takes place upon the surface of dust particles which are floating in the air. Indeed, Robert von Helmholtz found that when the air was carefully freed from dust particles it could be cooled until it contained ten times the amount of vapor necessary to saturate it without any condensation taking place within the body of the air. Aitken thought that he had found one exception to this, and that in the case of a sudden shock upon the walls of the containing vessel, when the air within was oversaturated, precipitation would take place; but Robert von Helmholtz found that this apparent exception was due to the dust particles given off by the walls of the vessel at the time of the shock. Since this fact has been experimentally established, Lord Kelvin has shown mathematically that, from the known laws of surface tension in water, it would be impossible for a globe of water consisting of only a small number of molecules to hold together at all. The same calculation has been made by Robert von Helmholtz by means of a formula developed by his illustrious father. According to these calculations, the smallest sphere of water which could hold together at 0° C. would be 0·00015 millimeter or 0·000006 inch in diameter. Since this is 7,500 times the diameter of a water molecule as computed by Lord Kelvin, the smallest drop of water which could be held together by cohesion at this temperature would contain not less than four million millions of water molecules. At 40° the smallest possible water sphere would have a diameter about twice as great, and would accordingly contain eight times as many molecules.

(*To be continued.*)

THE

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lots the boom began, which has not, to all appearances, ceased as yet. The act creating Cook County became a law January 15, 1831, and the county was organized in March of the same year. The first post office was established in 1831. Two taverns received town licenses, and all the charges were fixed by law, dinner being 37½ cents. A bridge was built over the South Branch, between Lake and Randolph Streets. The white citizens contributed $286.20, while the Pottawatomies were mulcted in the sum of $200. This first bridge across the Chicago River was only taken down in 1840. The first drawbridge was thrown across the river at Dearborn Street in 1834, and then began that merry war between the north and south sides which has not ceased at the present day. The Internal Improvement act was passed in 1837, a period of wild inflation, in which millions were wasted. Soon the times became hard, and years of struggle followed.

Probably no city in the world has been visited by such a disastrous series of fires as Chicago, and no reference to the history of the city, no matter how short, would be complete without some mention of the terrible fires which have scourged the city. The long series of fires was inaugurated by a fire in 1834 in which the damage was $1,200. On September 19, 1835, the first volunteer fire department was formed. The terrible fire of 1871, the worst fire of which we have any record, not excepting the London fire of 1666, entailed a loss of $200,000,000. The fire started at what is now 137 De Koven Street, and raged terribly for two days, burning from Fullerton on the north to Twelfth Street on the south and from the Lake as far as Halsted Street. The fire began Sunday, October 7, 1871. Only last year a series of fires began which have succeeded in reducing the magnificent Fair buildings to a mass of ruins. Last week two fires destroyed over $2,000,000 worth of property. The fires, bad in themselves, have, however, done much to increase the beauty of the streets, for the city which rose like the phœnix from the ashes of 1871 was entirely different from the city which was destroyed.

Our other illustration is a view of the State Street of to-day, one of the busiest streets of the great inland metropolis. At intervals rise the many-storied office buildings which are not inaptly christened "sky-scrapers." All day long the clang of the cable car gong is heard, and even in the evening the streets are crowded with pedestrians. Looking upon this busy scene, it is not difficult to believe that we are in the heart of a great city whose manufactures and wholesale trade have risen from $20,000,000 in 1850 to $1,409,000,000 in 1891. For our illustrations we are indebted to the St. James's Budget.

CAVE EXPLORERS BURIED FOR EIGHT DAYS.

NOT long ago the German journals gave an account of the truly lamentable expedition of a party of explorers who became prisoners underground through the rising of the waters of a stream that cut off their retreat.

The following are some authentic data in regard to this adventure, which, after threatening to be tragic, fortunately terminated in the delivery of the unfortunates who were in jeopardy.

The terrible eight days that six members of the Society of Cavern Explorers, of Gratz, and a sixteen-year-old collegian passed in the Luegloch, near Semriach, were due to an accident that the party met with through culpable thoughtlessness.

The sole motive of the enterprise undertaken was to get ahead of another society that explores caves, and with some little scientific spirit, too. Despite the warning of the curate of Semriach, Mr. Gasparikz, who knew all the dangers of the Luegloch, the seven imprudent explorers entered the latter on the 29th of April without taking even the most elementary precautions.

The ravine which leads into the cavern is traversed by the brook of Lueg, a thin stream of water ordinarily, but which increases formidably in rainy weather in consequence of the affluence of all the waters of the vicinity.

The stream enters the cavern at the point, A (Fig. 2), and at a few steps further along the hole that it has formed in the rock as a passage for itself becomes so narrow that it is impossible for one to advance without stooping or even crawling. Twenty steps further on this very narrow passage widens out into a sort of hall or antechamber, B. If one continues to follow the bed of the stream for thirty feet more, he reaches a passage, *d*, that has a slight slope and that it is necessary to traverse by creeping. This passage debouches in the Faeltzmann chamber, C, and then in a series of other chambers which join one another in a straight line. At the entrance of this passage the stream disappears in an excavation leading toward *c*, and the arrangement of which had not as yet been explored.

The seven explorers had got as far as the Faetzmannshoehle. Unfortunately for them, not only had the stream become swollen, but had also carried along some trunks of trees and some branches, the accumulation of which stopped up the channel of discharge, *c*, and caused a local inundation. So when the seven imprudent explorers, warned by the water that was entering the Faeltzmannshoehle, were desirous of returning, the passage that they had traversed a short time before was no longer practicable and their retreat was cut off.

The unfortunates were obliged to remain buried thus for eight days and a half. Through tin boxes filled with food that were thrown at hazard into the stream and that the latter carried to them, they fortunately received enough sustenance to prevent them from dying of hunger while awaiting the hour of delivery, which was long. The work of rescue, however, was particularly difficult, and it was not till after the arrival of a detachment of military pioneers, sent by order of the Emperor, that it could be pursued methodically and with any rapidity.

In order to widen the passage, it was necessary to employ dynamite. Thanks to the rapidity of the rescuers, it finally became possible at 3 o'clock in the afternoon of May 7 to enter into communication with the unfortunates, and soon afterward the student, Rodolph Haidt, the prisoner who had suffered the most from his eight days' captivity, was brought out into the open air.

When they saw that their retreat was cut off by the water, the explorers penetrated the interior of the mountain to a distance of about 2,000 feet. But here they found themselves arrested by a perpendicular fissure. Fatigue, moreover, had got the better of their first apprehensions, and they slept soundly during the first night. It was not till the next day that they realized the horror of the situation, and one can easily imagine what their existence must have been up to the moment when the explosion of the first dynamite cartridge apprised them of the approach of the rescuers. It is to be hoped that this adventure may serve as a lesson to those too numerous novices who embark upon such excursions without any precaution and often despite the prudential advice that is given them.—Revue Universelle.

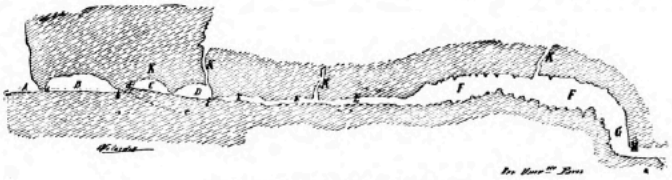


FIG. 2.—SECTION OF THE CAVE.

A, entrance; B, first chamber; C, Foltzmann chamber; D, Oswald chamber; E, gallery of stalactites; F, stalactite chamber; G, Tartarus; *a*, *b*, passageways; *c*, drainway; *d*, passageway; K, unexplored parts.

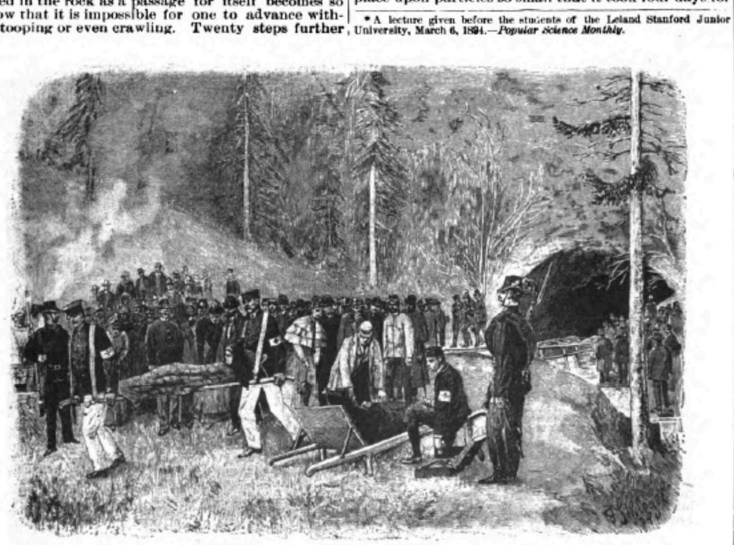


FIG. 1.—RESCUE OF THE EXPLORERS OF THE LUEGLOCH CAVE.

[Continued from SUPPLEMENT, No. 971, page 15526.]

RAIN MAKING.*

By FERNANDO SANFORD, Professor of Physics, Leland Stanford Junior University.

AITKEN found that dust particles of microscopic size were sufficient for the nuclei of condensation, and R. Von Helmholtz showed that condensation could take place upon particles so small that it took four days for them all to settle through still air to the lower side of a horizontal glass tube about one inch in diameter.

Aitken counted the number of these dust particles in different samples of air by first diluting the air with two hundred times its volume of air which had had its dust particles removed by being drawn through water and then saturating the air with water and cooling far below its dew point and counting the number of water drops falling upon a given area until all the dust particles were carried down. He found the number of dust particles to vary from 34,000 per cubic inch in pure air taken from the top of Ben Nevis to 88,346,000 per cubic inch in air taken from a room near the ceiling, and nearly 500,000,000 per cubic inch in the flame of a Bunsen burner.

The number of these dust particles in the air determines the character of the precipitation. If the dust particles are very numerous, each one becomes a nucleus for the condensation of water vapor, but only a small quantity of water will be condensed upon each one; hence the formation of the fine drops which constitute fog. If the number is smaller, as it is likely to be at a greater distance above the earth, each nucleus may receive a larger quantity of water, and a cloud may be formed. If they are few, or if the total amount of condensation is great, the drops which are formed become heavy enough to fall to the ground and rain is produced. If the nuclei are very few, rain may fall from an almost cloudless sky.

It is well known that as we ascend above the earth the temperature falls about one degree Fahrenheit for three hundred feet; consequently, while the air at the surface of the earth may be far above the dew point, the air at a few thousand feet above the earth may be cooled below the dew point. The height of the clouds always indicates the distance above the earth at which the air is cold enough for condensation to begin. The clouds, being made up of these little dust particles surrounded by water, are heavier than the air, and are slowly settling toward the earth, but as fast as the little drops settle into the warmer air, the rate of evaporation from their surface is increased, and before they have settled far the water has been evaporated off. Hence, at a given time, over an area of uniform temperature, the lower surfaces of the clouds are all at nearly the same distance above the earth.

How, then, shall rain be produced in the great unbounded atmosphere? There are but two ways. Either the total quantity of vapor in the atmosphere must be increased or the temperature of the air must be diminished. It is probably safe to assume that there are, under all ordinary circumstances, a sufficient number of dust particles in the air to form the nuclei for condensation, so that no artificial provision need be made for these.

So far as I am aware, no enterprising rainmaker has yet proposed a method of increasing the total moisture of the air to any appreciable extent, though some of them have attempted this on the small scale, probably in the vain hope that if they touched the button, nature would do the rest. This, by the way, has been the one claim upon which all these pretenders have based their arguments. They have steadfastly and with unanimity asserted that if a little condensation could be started in one place, it would at once spread out in all directions, like the benign influence of the little homeopathic pill. How a rainfall started in this way is ever to stop as long as any aqueous vapor remains in the air, they have not condescended to tell us. This question has not, so far as I know, ever been raised by the results of their incantations.

As a matter of fact, every drop of water taken from the air decreases the number of vapor molecules remaining, and, consequently, lowers the temperature of the dew point. Likewise, every free molecule which is brought to rest by striking against a solid body gives up its energy of motion to that body and increases the total energy of its molecular vibration, so that a body upon which water molecules are condensing is having its temperature continually raised, and it must be continually giving off heat to surrounding bodies, or it will soon be warmed above the temperature of condensation. In the case of the dust particles of the atmosphere, they must give off this acquired heat to the molecules of the air which come in contact with them; hence the condensation of moisture from the air raises the temperature of the air. There are, accordingly, two reasons why heat must be continually taken from the air in order to keep up condensation. The temperature of the dew point is being continually lowered by the loss of vapor molecules, and the temperature of the air is being continually raised by the amount of heat which these molecules lose when their motion is stopped.

In the formation of rain by natural causes this continuous decrease of temperature is provided by ascending currents of air which carry the water molecules upward into continually cooler and cooler regions. These ascending currents of air may be caused by mountain ranges, which deflect upward the winds that blow against them, by the expansion of the air over a heated area of the earth's surface, and possibly by other agencies not yet understood. In the case of our California storms, these ascending currents are usually persistent for several days, frequently moving across the whole continent. They are marked upon our weather maps as areas of low barometric pressure. Whenever there is an area over which the barometric pressure is less than the normal, it is an indication of

* A lecture given before the students of the Leland Stanford Junior University, March 6, 1894.—*Popular Science Monthly*.

an ascending current of air, and wherever there is an ascending current of air there is a probability of rainfall, though, if the air be very dry, it may not be carried to a sufficient height to be cooled below its dew point.

On the other hand, wherever there is an area of increased barometric pressure, or of high barometer, it is an indication that there is a descending current of air over that area; and since air which is settling toward the earth is continually having its temperature raised, no precipitation of moisture will occur over an area of high barometer.

The simultaneous weather observations conducted by the government enable us to locate these regions of ascending and descending currents, and long observation has enabled us to predict their probable path across the continent, and it is upon these data that the weather officers base their predictions of future weather. Since these areas regularly travel from west to east, we in California receive much shorter notice of their coming than do the people farther east, and the weather predictions issued from our local bureau are proportionally more liable to error than are those issued from stations beyond the mountains.

And now as to the possibility of producing rain by artificial means. It is never safe to say what things are possible and what things are impossible to man. What the future may bring forth no one can tell. At the present time, however, there is no evidence to show that even the smallest local shower has been produced artificially. Further than that, it is safe to say that no method of producing artificial rain has yet been publicly proposed which suggests to one familiar with the scientific principles involved even a possibility of success. That such attempts have received the official recognition and the financial support of Congress is only another evidence of the gross ignorance of scientific principles which is prevalent among our so-called educated men. That some of the men who advocate these wild schemes are honest in their motives cannot be questioned, but that all the professional rainmakers are conscienceless fakirs is scarcely more questionable. That many of them are able to submit testimony as to the efficacy of their system is equally true of every patent medicine fraud and electric healing quack who has ever swindled an ignorant public. As an illustration of the value of testimony of this kind, let me give you a local example.

I will read from the San Francisco *Examiner* of February 2, 1894:

He Produces Rain at Will.

HIGHLY SUCCESSFUL EXPERIMENTS OF THE VISALIA RAINMAKER—HEAVY SHOWERS AT PIXLEY.

HE SELECTS THE DRIEST SECTION OF FRESNO COUNTY, WHERE RAIN SELDOM FALLS, AND BY THE USE OF CHEMICALS CAUSES LOCAL DOWNPOURS ON TWO SUCCESSIVE DAYS—MANY OTHER TESTS MADE.

Visalia, February 1.

A week ago Wednesday Frank Baker, of Visalia, an amateur rainmaker, went to Pixley for the purpose of producing rain. Before he left he informed the *Examiner* correspondent that he intended to produce rain within seven days, and he kept his word. On Tuesday and Wednesday a local rainstorm occurred in the vicinity of Pixley amounting to 0·35 to 0·45 of an inch.

Mr. Baker returned to this city this morning in jubilant spirits. He is now satisfied beyond a doubt that he can produce rain by means of his appliance. He proposes to visit Pixley every two weeks, and is sanguine that he will be successful in his experiments.

During the months of April and May he proposes to put forth his best efforts in order to thoroughly drench the soil. The residents of Pixley are well pleased with Baker's experiments, and they propose to assist him in conducting his future operations.

THEY VOUCH FOR HIS EFFICIENCY.

He brought back with him the following letter:

"This is to certify that it rained 0·35 to 0·45 of an inch at Pixley on the 30th and 31st of January. We gentlemen here vouch for the truth of the same; that it is a local rain of fifteen to twenty miles in extent, and that it was brought about by the Baker process.

"J. J. Kelly,
"Charles S. Peck,
"W. M. Jackin,
"L. E. Smith,
"J. T. Austin,
"John W. Harper."

Now, it is not my purpose to impugn the veracity of the gentlemen whose names are signed to this certificate. I know none of the gentlemen. I do not question the only point in the statement to which the gentlemen could possibly subscribe of their own knowledge. You will observe that the certificate includes three separate statements: (1) That it rained in Pixley on the 30th and 31st of January; (2) that it was a local rain of fifteen to twenty miles in extent; (3) that it was brought about by the Baker process. Manifestly, the only one of these statements to which the gentlemen could have subscribed of their own knowledge is the first.

Fortunately for the settlement of questions of this character, we have the use of data collected by the Weather Bureau. When I read the above article I at once wrote to Mr. Pague for the maps issued by the Weather Bureau for January 28 to 31 inclusive. He kindly forwarded them to me, and the following data were compiled by me from them:

On the map of Sunday, January 28, 5 P. M., an area of low barometer is shown with its center west of Vancouver. The weather was reported cloudy and rainy north of the Oregon line. The weather forecast was "rain in northern California." Twelve hours later, Monday, January 29, at 5 A. M., the storm was central over northwestern Washington. I quote verbatim from the predictions printed upon the map: "The conditions this morning are favorable for rain over California from the Tehachapi Mountains northward by Tuesday morning, and possibly will extend southward Tuesday afternoon or night."

At 5 P. M. of the same day the map shows a storm area extending from British Columbia to southeastern California, with its center near Keeler, about ninety miles east of Pixley. Here the storm center remained for thirty-six hours, while the storm was gradually breaking up over its northern part, as shown by the three following maps, and not until the map of Wednesday morning is there an indication of an eastward movement of the storm, while as late as 5 P. M. of Wednesday, January 31, rain was reported at Keeler. During Monday and Tuesday light rains were reported over nearly all parts of the State, and on Tuesday it rained at Pixley.

From these data we see that the local rainfall produced by the Baker process at Pixley was part of a storm which extended over a large part of British Columbia, over Washington, Oregon, California, Utah, Nevada, and Arizona, and which had its center for thirty-six hours within ninety miles of Pixley, and that the weather forecasts sent out from San Francisco on Monday morning at 5 o'clock predicted rain for the region about Pixley for Tuesday afternoon or night. As a matter of fact, it rained at Pixley on Tuesday night, as had been predicted by Mr. Pague thirty-six hours before.

I have referred to this special case, not because it differs in any essential particular from other well-authenticated cases, but because one typical example which any one can verify is worth a great amount of generalizing, and because this particular instance has been so prominently mentioned by the press of the State.

And now I wish to say a few words about the methods of some of the best known of the professional "rainmakers." For most of the following data I am indebted to a paper read by Prof. Alexander Macfarlane, of the University of Texas, before the Texas Academy of Science.

Powers.—In 1870 Mr. Edward Powers, of Delavan, Wis., published a collection of statistics in a volume entitled "War and the Weather." By means of these statistics he seeks to establish the remarkable fact that battles are followed by rain. He does not prove that battles are necessarily accompanied by rain, or that a day of battle is followed more quickly by rain than a day of no battle. Having, however, apparently convinced himself of the value of his argument, he at once adopted the universal American expedient of proving his claim, and petitioned Congress for an appropriation to make a suitable test. Two hundred siege guns which lie idle at the Rock Island arsenal were to be taken to a suitable locality in the West, and one hundred rounds to be fired from them in each of two tests. The estimated cost of the experiment was to be $161,000. He does not tell us how the molecular vibration caused by the sound and heat of the firing is to lessen the molecular vibration of the air and cause the vapor molecules to come to rest.

Probably the distinction between a scientist and a crank could not be shown more clearly than in a comparison of the methods of Aitken and Von Helmholtz with the methods of Powers. The former spent years working in private and at their own expense to find, if possible, some explanation of the mystery of condensation. The other wished an appropriation of one hundred and sixty thousand dollars from the government in order to test his visionary hypothesis.

Ruggles.—In 1880 Daniel Ruggles, of Fredericksburg, Va., patented a process for producing rain. The invention, as described by Mr. Ruggles, consists of "a balloon carrying torpedoes and cartridges charged with such explosives as nitroglycerin, dynamite, guncotton, gunpowder, or fulminates, and connecting the balloon with an electrical apparatus for exploding the cartridges."

This is another scheme for lowering the temperature of the air by heating it.

Dyrenforth.—It is probable that the name of Mr. Dyrenforth is better known in connection with attempts at artificial rainmaking than that of any other man. As a result of the agitation of Mr. Powers, Congress voted two thousand dollars to make a preliminary test, and the inquiry fell to the scientists connected with the Department of Agriculture. They reported that there was no foundation for the opinion that days of battle were followed by rain, any more than days of no battle. It was then that Mr. Dyrenforth came forward with Ruggles' plans and offered to make some tests. Through the influence of Senator Farwell, an additional appropriation of seven thousand dollars was placed at his disposal for a series of practical tests, which were made at Midland, Texas, in August, 1891. A further government appropriation was expended in tests at San Antonio, Texas, in November, 1892.

Mr. Dyrenforth's plan seems to have been to imitate as nearly as possible the conditions of a battle. His explosives were ranged in a line facing the advancing clouds. Shells were fired into the air at frequent intervals. Dr. Macfarlane states that the "general" and his lieutenant even wore cavalry boots.

In addition to these warlike demonstrations, cheap balloons containing hydrogen and oxygen mixed in the proper proportions for forming water were sent up, and the gases were exploded by means of a time fuse attached to the balloon.

At the time of making the San Antonio tests, November 25, 1892, the record of the weather office in San Antonio at 8 P. M. gave the temperature of the air at 72° F. and the temperature of the dew point as 61° F. Dr. Macfarlane makes the following calculations upon a cubic mile of the air under the above conditions: to cool down the cubic mile of air to the dew point would require the abstraction of as much heat as would raise eighty-eight thousand tons of water from the freezing to the boiling point. To cool it eleven degrees more would require the abstraction of the same quantity of heat again. This would cause the precipitation of twenty thousand tons of water, which spread over a square mile would give 1·4 pound per square foot or 0·27 of an inch of rain. The amount of heat which the twenty thousand tons of water vapor would give off to the particles upon which it would condense would raise a hundred thousand tons of water from the freezing to the boiling point, and this would also have to be taken from the air in order to allow the condensation to continue. According to this computation, enough heat would have to be extracted from the air to raise two hundred and seventy-six thousand tons of water from the freezing to the boiling point in order to produce a rainfall of about a quarter of an inch over an area of a square mile. This two hundred and seventy-six thousand tons of water would cover the same area to a depth of more than six inches. Accordingly, in order to produce a rainfall of a quarter of an inch under the conditions mentioned, enough heat would have to be taken from the air to heat a body of water covering the whole area to a depth of ninety feet through one degree Fahrenheit. To accomplish this purpose Mr. Dyrenforth proceeded to raise the temperature of the air still higher by means of heat-producing explosives.

Under these conditions eight balloons, a hundred and fifty shells, and four thousand pounds of rosellite were fired off. No rain appeared. One balloon exploded within a black rain cloud, but failed to produce any precipitation. On the following Wednesday, with a clear sky, ten balloons, a hundred and seventy-five shells, and five thousand pounds of rosellite were exploded, and the sky remained clear. On the following night the remaining stock of explosives were fired off, regardless of consequences, to get rid of them.

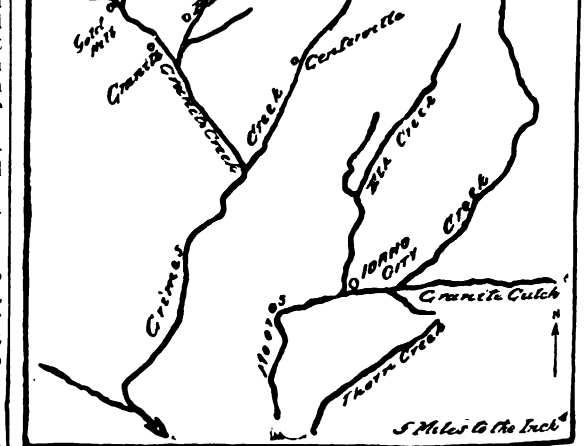
At the time of this national *fiasco*, another patented plan of rainmaking was published, and it was reported that Senator Farwell liked it even better than the concussion plan. It proposes to send up liquefied carbonic acid and to set it free in the portion of air from which it is desired to precipitate the rain. The carbonic acid in vaporizing and expanding must take heat from the surrounding air sufficient to set its molecules vibrating in the gaseous form. Unquestionably we have here the proper kind of an agent for producing rain. The only question to be considered is one of finance. Prof. Macfarlane estimates that one pound of carbonic acid in taking the gaseous form at 72 F. would take up enough heat to change sixty-eight pounds of water by one degree Centigrade. To cool the cubic mile of air formerly considered sufficient to make a rainfall of a quarter of an inch would accordingly take four hundred and six million pounds of carbonic acid. This could probably be purchased in quantities of this magnitude at one dollar a pound, making the expense of a rainfall of a quarter of an inch, not counting anything but the carbonic acid, about six hundred thousand dollars per acre. This would make artificial climate even more expensive than the genuine California article.

I have now endeavored to give you in as brief a space as possible a simple statement of the problem of rainmaking as it appears to one with an elementary knowledge of physics, and to give a brief statement of some of the methods of the men who, without any scientific knowledge, have intentionally or unintentionally imposed upon the public. The examples which I have quoted are only the prominent ones. There are many impostors whose names are but little known who are proposing to furnish rain to large sections of country for a suitable financial consideration. And it is only surprising that the number is not larger. The business offers special inducements to men who are accustomed to make a living by swindling their fellow men. No capital and no business training is required. The only thing necessary is to contract to furnish rain to as many different sections of country as possible. Then, if it rains over any of these areas, collect the pay. If it does not rain, the experiment has cost nothing. The system has all the advantages of the traditional gun loaded to kill if it is a deer, but to miss if it is a calf.

THE BOISE BASIN IN IDAHO.

By J. B. Hastings.

The Boise Basin covers an area of 400 square miles, through which flow three large creeks, Moore's,



SKETCH MAP OF BOISE BASIN, IDAHO.

Grimes and Granite, and many tributaries, and along these are the auriferous gravels. The placers of the district were formerly famous; they yielded in six years after their first opening, from 1864 to 1870, over $40,000,000 in gold. The deposits were not distributed over the whole country in an anomalous manner, as is sometimes conceived, but as elsewhere, along the stream beds and bars connected therewith. The accompanying sketch map gives a general outline of the region. That the gold in the gravel was derived from the veins, and that again from a source deeper than the inclosing granite, is shown by the absence of gold from gulches which do not tap any lodes. Were the gold distributed through the granites in sufficient quantity to allow its concentration in the vein fissures as we now see it, there would also be found deposits in gulches through granitic areas only, the erosion having been great. The country rock of the whole basin and beyond it is light gray, typical biotite granite, with few accessory minerals, and usually deemed part of the Idaho Rocky Mountain archean area; while not differing to any extent mineralogically through the district, it does so in hardness. Probably the free dom with which it disintegrates about Idaho City and elsewhere, forming low rounded hills and flat broad gulches, has suggested the name, "Basin."

The placer deposits on Grimes and Granite creeks are ordinarily distributed stream and glacial debris,

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