A STUDY IN PHARMACY.*

NATURE'S PERCOLATION PROCESSES IN CONNECTION WITH THE FORMATION AND EXCRETION OF DEW, VERSUS ARTIFICIAL PERCOLATION.

BY JOHN URI LLOYD.

These experiments, seemingly afar from pharmacy, were instituted in 1879, by reason of the author's belief in the necessity for establishing differentiations between liquid movements of living plants, and extractive phases in pharmacy as applied to dead plants.

Intimately connected are Nature's sap circulation processes with the art of percolation, in which a selected menstruum, passing through coarsely comminuted or powdered organic tissues, abstracts therefrom certain desirable soluble constituents, while excluding others.

In Nature's laboratory we have the phenomenon of plant assimilation and excretion, complicated with the natural circulation of juices locked in, or passing through, cell and tissue complexities. The general distinction between the processes seems to be that in artificial percolation the liquid gravitates downward,[1] while in Nature's laboratory, the movement of sap is usually upward, a movement not due, wholly, to the force of capillarity.

Be this as it may, the incentive to the author's as yet unpublished studies[2] of menstruums and plant structures connected with percolation, have been largely stimulated by the many questionings inspired by this study of Nature's processes of percolation.

In these, the building and metamorphoses of multitudinous and diversified living structures have one marked distinction from artificial laboratory experiments in that a single liquid, water (plus dissolved materials), constitutes Nature's universal menstruum.

Oct. 19, 1879.—Preliminary Experiments to Discover the Proportions between Moisture Condensed from the Air, Evaporated from the Earth, and That Exuded by Vegetation.—Three factors seemingly need to be considered in this attempt, *viz.*, to establish processes to differentiate between:

(1) Moisture in the atmosphere.
(2) Moisture evaporated from the earth.
(3) Water exuded by vegetation.

Experiment No. 1.—The following arrangement was determined upon as adapted to preliminary experimentation: Three twelve-inch bell glasses, as shown by the accompanying cuts,

A, over the earth and growing young grass,
B, over the bare earth,
C, on a glass plate, all side by side (Fig. 1).

Into each was placed D, D, D, a dish of freshly burned calcium chloride. The experiments were conducted simultaneously, under as nearly identical conditions as possible.

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* Intended as a chapter in "A Study in Pharmacy," a continuation of "Precipitates in Fluid Extracts," *Transactions, Am. Pharm. Assoc.*, 1879 to 1885.

[1] A process for percolation *upward* has been experimentally tried.

[2] The present paper, following that of 1885, may be considered as the one that was prepared for, and should have appeared in, the Proceedings of 1886.

Result.[1]—A. Earth and grass together exuded 4.9 gr. moisture.
B. Bare earth beside the glass exuded 3.0 gr. moisture.
C. Bell glass over a plate gave 0.6 gr. moisture.

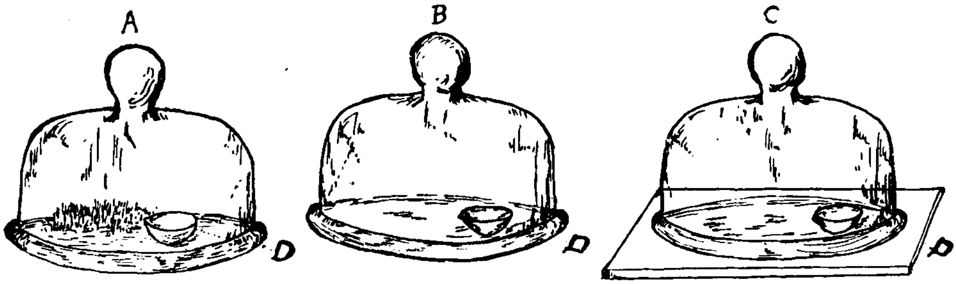

Fig. 1.

This gave 4.9 gr. − 3.0 gr. − 0.6 gr. = 1.3 gr. moisture yielded by the grass. The inner surface of all the bell glasses was dry when the dishes of calcium chloride were removed.

Experiment No. 2.—An attempt was next made to determine whether "dew" would have been deposited on the inner glass had no chloride of calcium been present. This seemed to be established in the affirmative as follows:

Chloride of calcium was removed from A. In half an hour moisture was condensed on the inner surface of the bell glass.

Same result followed with B.

The inner surface of bell glass C remained dry.

These indicated that the exhalations from both the earth and grass supersaturated the air, the excess of moisture being, when no calcium chloride was present, deposited as "dew" on the inner surface of the glasses A and B, but that there was not enough moisture in C to reach the dew point.

The details of the following experiments, designed to further study the problem, are as follows:

Experiment No. 3.—Over clump of grass under a bell glass.

Weight of watch crystal and chloride of calcium,	10 A.M.	127.30 gr.
	12 A.M.	132.20 gr.
	Increase	4.90 gr.

Thermometer, 10 A.M., 53°; 12 A.M., 56°.

No moisture on inner surface of bell glass.

The grass was now cut and weighed 12.60 gr.

Experiment No. 4.—At the time of making No. 3, a bell glass was placed on bare ground beside bell glass No. 3.

Weight of watch crystal and chloride of calcium,	10 A.M.	133.80 gr.
After exposure,	12 A.M.	136.80 gr.
	Gain of moisture	3.00 gr.

No moisture on the inner surface of the bell glass.

Experiment No. 5.—At the time of making Nos. 3 and 4, a bell glass was placed on a glass plate (beside 3 and 4).

Weight of watch crystal and chloride of calcium	136.80 gr.
After exposure	137.40 gr.
Gain of moisture	0.60 gr.

No moisture on inner surface of bell glass.

[1] Grain weights (gr.) were employed throughout, the metric system not having been adopted at the date of experimentation.

Experiments Nos. 6 and 7.—Simultaneously with the foregoing, Experiments Nos. 6 and 7 were instituted to establish whether dew would have collected on the inner surface of the bell glass (Fig. 1, A and B explains the process) had there been no calcium chloride. The result was as follows:

No. 6.—Bell glass over clump of grass, paralleling Experiment No. 1, A; no chloride of calcium. In half an hour the inside of the glass was covered with moisture, which increased until 12:00 M.

No. 7.—Bell glass inverted over bare ground (Fig. 1B). In half an hour moisture covered its inside, increasing until noon.

Experiment No. 2 (Fig. 1C) had previously shown no moisture on bell glass over glass plate.

Summary.—These experiments were conducted simultaneously, and were in every way parallel as regards the temperature, time of exposure, etc.

In all, no attempt was made to locate the chief point or points of evaporation from the grass, the object being to differentiate between the moisture that earth, grass and air gave to chloride of calcium, under conditions recorded. It was also shown that when no chloride of calcium was present, moisture above the supersaturation point of air was deposited on the inner surface of the bell glasses A and B, but not on C, the one over the glass plate.

Establishing the Principal Excretory Points of the Grass.

These experiments, made in the summer of 1879, were resumed in the summer of 1880, with the object of establishing the principal excretory point, or points, of the grass. A double bell glass was now employed, the aim being to protect the inner glass from temperature changes, and keep it at as even a temperature as possible, above the dew point, thus preventing the air from unloading its moisture on the inner surface of the inner glass. The device is illustrated (Fig. 2), the results of the experiments follow:

Experiment No. 8.—August 1, 1880; bell glass large and high, placed at sundown over another, low glass (12 inch), which covered a clump of orchard grass (*Dactylis glomerata*).[1] Early the next morning the grass was covered with minute globules of moisture, the tip of each carrying a large globule. In four hours the moisture from the surfaces of the leaves had evaporated but the globules upon the tips had *increased* in size. These globules remained on the bell-covered grass all day; two hours of sunshine directly upon them.

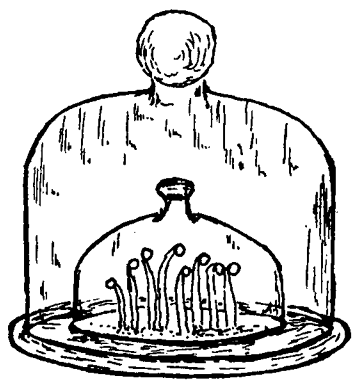

Fig. 2.

Explanation.—This illustrated that the grass not only excreted water from its tips (assuming that the globules were *excreted*) but that if evaporation were prevented, this "dew" remained even in the direct sunshine. As a familiar parallel, we have the dew-drop of grass in a shaded ravine long after it has disappeared from the hillside and crest, lingering even until the sunshine is directly upon it.

[1] Wherever the term "orchard grass" is used *Dactylis glomerata* is intended. The term "blue grass" always refers to *Poa pratensis*.

Grass Excretes "Dew-drops" in the Daytime.

The foregoing experiments (Nos. 1 to 7) indicate that if the air be saturated with moisture, evaporation from an excreting substance continues in the form of vapor that can be absorbed by calcium chloride. If there be an opportunity to condense the liberated moisture on a more adhesive (attractive) surface, such as glass, shown herein, at lower temperature,[1] but that if evaporation (No. 8) be prevented, water is excreted. Reasoning from the experiments tabulated, it was assumed that should the grass be surrounded with cold, still air, dew globules must form on the excretory tips, regardless of sunlight. This is established by the following experiment.

Experiment No. 9.—August 1, 1880, 11 A.M.: A tall narrow bell glass (Fig. 3) was inverted over a clump of orchard grass; day hot and close. The grass was dry, having been in sunshine three hours. Earth was now thrown up halfway around the outside of the glass, and on this ice-cold water was poured.[2] In one hour each blade of grass held a drop of dew upon its tip.

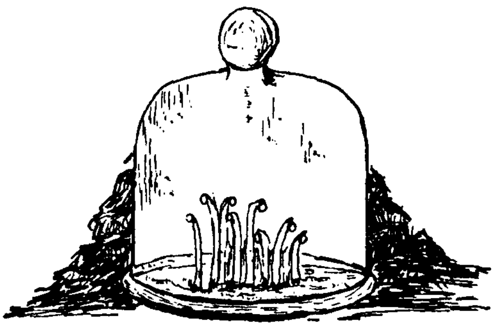

Fig. 3.

Fig. 4.

Experiment No. 10.—4 P.M.: A bell glass, low and flat, was placed over a porcelain dish that held lumps of ice, the dish being sunken in a bed of grass (Fig. 4). In a short time a drop of dew appeared on the tip of each blade.

Explanation (9 and 10).—These demonstrated that cooling below the "dew point" in a bed of stagnant air produced dew of excretion in the daytime. Grass in the same bed outside the bell glasses gave no dew before 4:45 P.M., my notes of the day being as follows:

Rain at 12 M. 6 P.M. warm, cloudy, still. At 4:45 drops of dew had started on the grass tips over the entire grass plot.

Stagnant Air.

The term "stagnant air" introduces a factor, which needs now be considered. Experiments Nos. 9 and 10 indicate that a bed of still, cool air within the earth belt (No. 9) and around the ice on the plate (No. 10) must become saturated in order that the water of excretion from the grass tips be not liberated as vapor. This involves problems governing natural dew conditions, the following experiments being

[1] I am presuming here to use a term expressive of the fact that different affinities prevail between surfaces of different substances. As yet only temperature distinctions have been considered, and these only are now to be kept in mind.

[2] The cut (Fig. 3) shows earth on the sides, front being removed.

made five days before those last (August 1st) recorded.[1] The experiments were made on a level door yard field of grass.

Experiment No. 11.—August 5, 7 P.M.; clear.

Thermometers A and B were suspended by a thread to a wire stretched between two posts six feet high, located between two brick buildings, thirty feet apart. Thermometer C lay on a clump of grass 4 inches in height. Thermometer D rested with its bulb in the surface of ground (Fig. 5). B was 40 inches high; A, 60 inches.

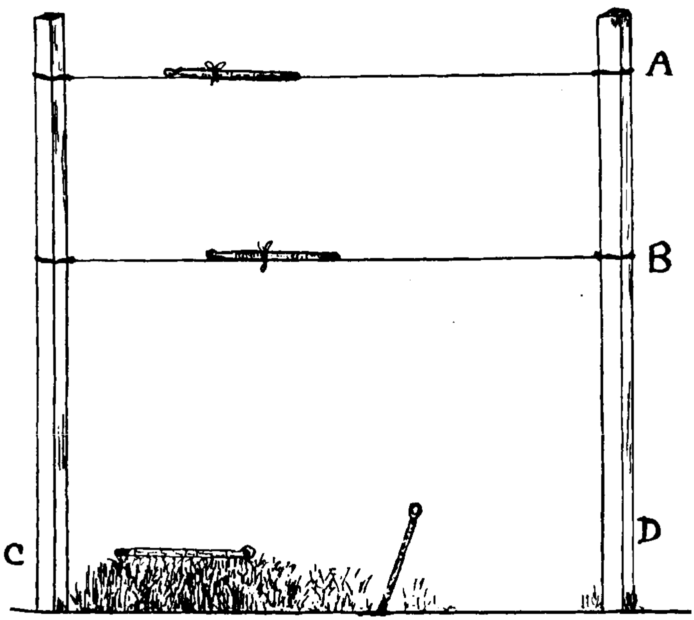

Fig. 5.

A, 60 inches high; thermometer on wire. C, Thermometer in grass, 4 inches above the earth.
B, 40 inches high; thermometer on wire. D, Thermometer on the ground.

	7:15 P.M.	8:00 P.M.	9:30 P.M.	10:00 P.M.
A (dry)	73°	68°	63° (dry)	62° (dry)
B (dry)	72°	66°	63° (dry)	61° (dry)
C* (dew)	70°**	62°	58° (wet)	58° (wet)
D	74°	72°	69° (wet)	68° (wet)

* Dew appeared on tip of grass.

** Dew appeared on thermometer.

Explanation (11).—These show that the dew point varied with the location of the thermometer, seemingly being dependent on temperature and "stagnant air." The high temperature of D needs to be restudied to discover if it be error of experiment[2] (see Experiments Nos. 12 to 19). A steady decrease of total tempera-

[1] Owing to my many business and other cares and few hours for recreation, I could not devote my whole time systematically to any one subject. In addition, favorable weather conditions were a necessity. To the foregoing I must plead a bit of selfishness that often led me, by the entrancement of thought, to make experiments in advance of the natural sequence. These facts will account for several date discrepancies.

[2] Mr. J. T. Lloyd informs me that this, in his opinion, needs no repetition. He states that in his travels in desert lands it was the custom when necessity required to scoop trenches in the desert sand and, wrapped in his blanket, sleep warmly during cold nights.—J. U. L., 1923.

ture is shown in the four experiments. These were repeated (12 to 19) to establish several questionable phases.[1]

Experiment No. 12.—August 6, 1880; clear. Arrangement same as No. 11, Fig. 5, Aug. 5th.

	7:00 P.M.	7:13 P.M.	8:00 P.M.	9:00 P.M.	9:30 P.M.	August 7th. 10:00 P.M.	4:30 A.M.
A	74°	73°	69°	67°	66°	65°	58°
B	73°	71°	67°	66°	65°	63°	57°
C	*69°	{65°	63°	62°	61°	61°	54°
D	75°	** }75°	74°	72°	72°	70°	66°

* Dew appeared on tip of grass (orchard grass).

** Dew appeared on thermometers A, D.

Experiment No. 13.—August 7, 1880; slightly cloudy at sundown, clear 9 P.M.; conditions same as before.

	6:30 P.M.	7:00 P.M.	7:30 P.M.	8:00 P.M.	9:00 P.M.	9:30 P.M.	10:00 P.M.
A	78°	75°	72°	68°	66°	65°	64°
B	77°	74°	70°	67°	65°	64°	63°
C	*72°	{67°	64°	63°	63°	62°	62°
D	78°	** }75°	75°	74°	73°	72°	72°

* Dew appears on tip of orchard grass.

** Dew appears on thermometers C, D.

Experiment No. 14.—August 9, cloudy; conditions same as last.

	6:30 P.M.	7:00 P.M.	7:30 P.M.	8:00 P.M.	9:00 P.M.	9:30 P.M.	10:00 P.M.
A	79°	78°	76°	75°	74°	74°	73°
B	77°	77°	75°	74°	74°	73°	72°
C	*72°	71°	70°	71°	70°	69°	69°
D	77°	77°	76°	75°	75°	75°	74°

* Dew appeared on tip of orchard grass.

Very cloudy entire evening, and heavy flow of dew from plants, but none on inanimate bodies. Rain at 8 P.M. for 20 minutes.

Experiment No. 15.—August 10, 1880; clear at sundown; conditions same as before.

	6:30 P.M.	7:00 P.M.	7:30 P.M.	8:00 P.M.	8:30 P.M.[c]	9:00 P.M.	9:30 P.M.[d]	10:00 P.M.
A	76°	73°	73°	70°	71°	71°	70°	68°
B	75°	73°	72°	69°	71°	70°	70°	67°
C	72°[a]	{67°	67°	67°	68°	68°	67°	64°
D	75°	[b] }75°	74°	74°	73°	73°	73°	72°

[a] Dew on tip of grass.

[b] Moisture on thermometers C, D.

[c] Clouded from southeast; very slight breeze arose from that direction.

[d] Clear again.

Experiment No. 16.—August 11, 1880; cloudy all afternoon.

	6:15 P.M.	7:00 P.M.[b]	7:30 P.M.	Clear. 8:00 P.M.	Clear. 8:30 P.M.	Clear. 9:00 P.M.	Clear. 9:30 P.M.	Clear. 10:00 P.M.
A	76°	74°	72°	72°	70°	69°	69°	69°
B	75°	73°	72°	71°	69°	68°	68°	69°
C	74°[a]	69°	68°	68°	67°	66°	66°	65°
D	76°	75°	74°	74°	72°	73°	73°	73°

[a] Dew on tips of orchard grass (C); cloudy and very still.

[b] Dew on thermometers C, D.

In the morning, 6 A.M., wind was blowing and it was very cloudy.

[1] Fig. 6 is marked "lost."

Experiment No. 17.—August 12, 1880; clear.

	6:30 P.M.	7:00 P.M.	7:30 P.M.	8:00 P.M.	8:30 P.M.	9:00 P.M.	9:30 P.M.	10:00 P.M.
A	78°	74°	72°	70°	69°	68°	68°	66°
B	76°	73°	70°	69°	68°	67°	67°	65°
C	*70°	66°	66°	67°	64°	64°	63°	62°
D	77°	76°	75°	74°	74°	73°	72°	72°

* Dew on tips of grass of all specimens.

Experiment No. 18.—August 13, 1880; clear.

	6:45 P.M.	7:00 P.M.	7:30 P.M.	8:00 P.M.	8:30 P.M.	9:00 P.M.	9:30 P.M.	10:00 P.M.
A	79°	76°	72°	72°	71°	69°	68°	66°
B	77°	75°	71°	70°	69°	68°	67°	65°
C	*68°	67°	64°	64°	63°	62°	63°	64°
D	78°	75°	74°	74°	73°	72°	72°	72°

* Dew on tips of grass.

Experiment No. 19.—August 14, 1880; clear.

	7:00 P.M.	7:30 P.M.	8:00 P.M.	8:30 P.M.	9:00 P.M.	9:30 P.M.	10:00 P.M.
A	79°	79°	77°	76°	73°	74°	72°
B	77°	77°	76°	75°	72°	73°	71°
C	*69°	68°	68°	68°	67°	66°	65°
D	77°	77°	76°	76°	75°	74°	74°

* Dew on tips of grass.

General Summary.—Experiments Nos. 1, 2, 3, 4 and 5 demonstrate that both the earth and vegetation exhale moisture, which, under the conditions named (chloride of calcium present), does not condense upon the inner surface of a bell glass inverted over them. The experiments show that during the time consumed, the air gave (Fig. 1) 0.60 gr., the earth (Fig. 2) 3.00 gr., and the grass (Fig. 3) 1.30 gr. moisture.

Experiments Nos. 6 and 7 (drawings lost) (no chloride of calcium present) demonstrated that the air thus saturated will deposit its excess of moisture over the inner surface of a glass bell jar, which moisture is properly (according to the dictionary definition) "dew condensed from the atmosphere." In these experiments no globule of water appeared on the tip of a grass blade.

Experiment No. 8 (Fig. 2) protected the inner bell glass from decrease of temperature, thus preventing the contained air from depositing its excess of moisture. As a result, the excretion of the grass, surrounded by supersaturated moist air, appeared as water globules at the point of liberation.

Experiments Nos. 9 and 10 (Figs. 3 and 4) demonstrated that by artificially cooling the stratum of air that surrounds the grass, the dew point is accompanied by water secretion from the grass, regardless of the time of day. We are thus (Experiments 1–10) shown that:

First, the excretion of moisture by growing vegetation is continuous.

Second, in unsaturated, stagnant air, this moisture is exhaled as vapor.

Third, if the air be saturated and stagnant, it appears as water, at the excretory point or points regardless of temperature or time of day.

Experiments Nos. 11–19 in a general way show that under the conditions present, the vegetation dew point of the seven experiments ranged between 69° and 74°, the average being $71^{1}/_{7}$°.

That when the stratum of air (Fig. 5C) to the height of the thermometer became supersaturated with moisture, water of excretion (dew of vegetation) appeared at the grass blade tips.

That not until the temperature had approximately fallen ten degrees, did the thermometers in the grass and on the ground get wet (moisture condensed from the atmosphere).

That this stratum of air at the dew point was then cooler than either the earth it rested upon or the air a few feet above. This difference was sometimes most marked, and, inasmuch as in a water-saturated atmosphere, decrease of temperature by evaporation is impossible, the phenomenon needs be explained by further investigation (see footnote, 2 page 411). Possibly, continuous occlusion of vapor from the surface of this stratum of air into the zone above permits evaporation sufficient both to keep stratum (Fig. 5C) at its low temperature and to cool the successive strata above.[1]

That the air above rapidly increased in temperature with height is shown by thermometers (Fig. 5A and B). But at no period did this air, in any experiment, contain enough moisture to wet the thermometers, regardless of the temperature.

Conclusion. Air influenced by moisture tends to form strata of varying densities, the same being governed by temperature and air motion. Under the conditions named herein, over a flat lawn between brick buildings, where escape of the heavy air was impossible and air stagnation prevailed, there was no perceptible air current. However, the greater gravity of the lower moisture-saturated stratum and the supply of dew of vegetation should theoretically make interesting air movements on a grass-covered hillside, in sloping valleys, or across the crest of a "hog-back ridge," where opposing valleys head. In these directions the following researches apply:[2]

Some of the Influences of Dew. The foregoing experiments (Nos. 1–19) show how dew excreted from grass, uniting with vapor of earth, produces a thin stratum of cold, supersaturated, moist air. This air should, theoretically, on an incline, flow downward as does water. With the object of investigating this premise the grassy slopes of Eden Park, Cincinnati, were sought in August 1881, in the *afternoon*. Here a sun-bathed grassy valley gave near the same temperature, top to bottom. Immediately after sundown decrease of temperature began, more rapidly at the bottom. Within a moderate time, dew of excretion sprang from the tips of the grass blades in the lowest part of the valley. Up the hill-sides, the dew successively crept. Cold was the air at the bottom, warm at the top of the hill. It was evident that a sheet of cold air, caused by evaporation of earth and vegetation, at sundown began to slip down the hillside. This was verified by pouring muriatic acid on spots of the lawn, and placing moistened

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[1] Experiments not herein recorded, indicated to me that very sharp lines of demarcation separated zones of air under such conditions as these. They even approach the lines of demarcation between immiscible liquids. See Proceedings of Am. Pharm. Assoc., 1879–1885, "Precipitates in Fluid Extracts."

[2] So entranced was I by this phase of my study, that only by severe force of will power could I bring myself to its abandonment. So far-reaching did this subject of "dew" appear, as to lead me to accept that its influence on conditions governing life of animals reaches far beyond such restrictions as govern its presence as water alone. But, my investigations being a part of a study of plant pharmacy, and the relationships of water movements within the plant so intimately connected with percolation and pharmacy processes, I was forced to turn to other phases of plant juice movements, excretion and secretion.

blue litmus paper above and below it. The current was ever toward the bottom as shown by the reddening of the paper. Finally a lake of supersaturated air filled the valley and extended above the hill crest.[1]

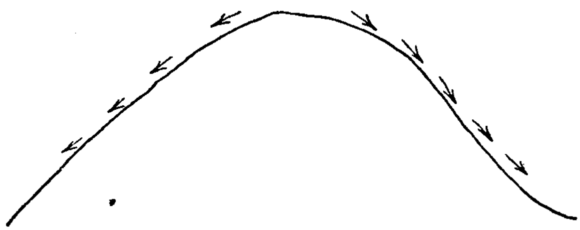

Fig. 7.

Fortunately, the great grass-covered ridge that separates the waters of the Kentucky and Licking rivers, crested by the Lexington Pike, furnished every possible phase of hill crest, slope, valley-head and deep valley. As a summary of these further experiments and observations on the influence of dew, I may conclude as follows:

Evening. Given any herbage-covered ridge, evaporation of excreted water therefrom, after sundown, cools the surface earth layer (see Fig. 5). This, when vegetation is very active, may even, on a hill crest, start water globules soon after sundown. This sheet of cool air seeks an

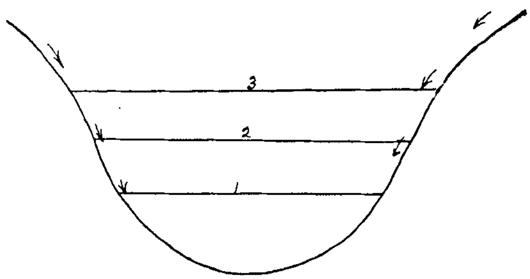

Fig. 8.

Lines 1, 2 and 3 represent successive air lakes (strata of vapor) within which vegetation successively, from below upward, is dripping with water of excretion.

equilibrium, flowing down the slopes into the valley-heads, thence to the bottom, where an air lake is formed. This motion seems distinct from *wind*.[2] It is a displacement process that may be imperceptible as an air current. Every growing bit of vegetation contributes its share of vapor. When a stratum is saturated, water, as *Dew of Vegetation*, exudes from pinnate leaves, from the tips of grass, as well as from the points of plant excretion generally. The blade of grass

[1] Thinking that I must be demented, park care-takers and unresponsive Cincinnati observers received with ridicule, approaching hostility, my invasion of public grounds and my experiments. Hence I transferred them to the valleys and meadows of Northern Kentucky, that bordered the Lexington Pike. Here, one is free to be "crazy," providing he shoots no one, and even then it is give and take. The Eden Park location is now the "reservoir."

[2] In reading these notes I recall that a strong wind prevails under these conditions in the valley slopes of Cayuga Lake near Cornell University. J. T. L.

sparkles in its own "dew." The tall tree in the deep valley finally moistens the earth from its topmost bough, with its own dripping water of excretion. The total amount of water thus excluded is enormous each dew-breeding night.[1] This movement may be shown by diagram No. 8.

Morning. When the sun rises, the hill crests first are warmed. The topmost surface air rises, the dew of the crest disappears. Suction of the upward air movement reverses the direction of the sheet of air—it turns back. Upward the arrows now point, the air lake of cold, saturated air, fog and mist is sucked dry. Currents of air are produced, usually wind arises, the lake of supersaturated vegetation exhalation becomes cloud fogs where conditions favor.

The drip of water from leaves and herbage ceases as the air drawn from above replaces that which is night-saturated. Sunshine, accompanied by air currents, breaks through the trees and shrubs into the interstices of the grass, the moving

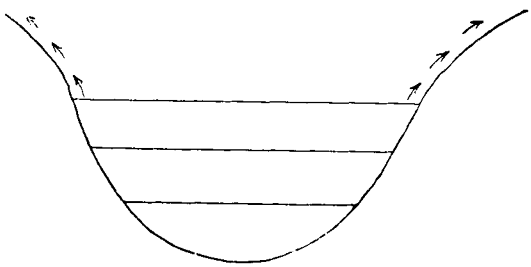

Fig. 9.

air shakes from their settings the dew-drop tears of the growing herbage. Vapor of plant excretion in the unsaturated air now replaces water tears. Excepting in the darkest recesses of the grass-banked valley, the dew of the night is gone.

Stand, any still summer evening, on the great ridge that for fifty miles stretches southward from Covington, Ky., toward Lexington. In the evening, each ravine head begins an invisible river of water-saturated air, that, increasing in size and depth as from the summit it widens and deepens, flows all night long down into the valley, where is produced a lake that when chilled below the dew point, or when mixed with various strata of air, of other temperatures, becomes a fog bank.

Comes now the morning, back turns the river current, the lake is sucked dry. Then, all day long across the ridge where heads the valley, the wind blows.[2]

THE DEW OF VEGETATION.

Rivers and Lakes of Air-Saturated Currents. In the preceding pages it is shown that water of plant excretion must be accepted as a factor of the "dew" problem. Whoever cares so to do can study the phenomenon in the manner presented, or by other, perhaps better, suggested processes. Possibly there is no easier

[1] Do not accept that water excretion ceases in the day or in windy weather. Then even *greater activity* prevails, but the water escapes as vapor and is blown away.

[2] Such idealistic conditions prevail constantly during the summer in the *locality cited*. However, sun-bred air currents and air movements from afar often sweep the whole country over in wind deluges that obliterate such as this. These interferences, however, do not disturb the "dew" excretion, which continues either as vapor or as water.

and more conclusive method than of watching the grass tips on a still day, as evening closes down. To see the dew globule spring into place, to fall and be again replaced, seemingly is all that needs be necessary unless the "Natural Fallacies of Observation" prevail.[1]

In the preceding chapter, the term "air river" and even "lake" has been used. This implies *much water*, and when connected with such as "dew supersaturated air" is either an extravagance or an assertion that needs be established.

In establishing this point, several problems such as temperature changes, moisture that under decreased temperature would be dew were no vegetation present, and other intruding phases of thought, are to be considered. In this object (amount of water excreted) the following series of experiments were instituted.[2]

DETAILED EXPERIMENTS ON WATER EXCRETION OF GRASS.

Experiment No. 20.—August 11, 1879. Two-inch watch crystals severally weighed were, at different heights, hung by strings over a grass plat, 8:30 P.M. (see Fig. 5).[3]

10:00 P.M.	(A.)	(B.)	(C.)
	60 inches	40 inches	4 inches
	no dew	no dew	0.34 grain dew

Experiment No. 21.—Simultaneously, at same heights others were suspended, over a gravel walk six feet from No. 1.

10:00 P.M.	(A.)	(B.)	(C.)
	60 inches	40 inches	4 inches
	no dew	no dew	no dew

Morning was cloudy with some wind. Dew had evaporated from C. This experiment showed that at 10:00 P.M. the air over the gravel walk, six feet from the supply of water (dew drop), had not become saturated to the dew point, nor at A and B.

Experiment No. 22.—Watch crystals hung on strings over the grass, 7:00 P.M., August 12th, to 6:00 A.M., August 13th, collected condensed moisture as follows:

	10:00 P.M.	6:00 A.M.
(1) Top, 60 inches from grass............	Dew 00	2.14
(2) Middle, 40 inches from grass..........	Dew 00	2.55
(3) Bottom, 10 inches from grass.........	Dew 0.96	3.22
Crystal over gravel walk 10 inches from walk	Dew 00	1.96

Explanation.—This shows that at 10 P.M. moisture of adhesion had collected only on the glass 10 inches from the grass; none on the glass over the gravel walk 10 inches from the ground, but at 6 A.M. had been deposited increasingly (1, 2 and 3) from below upward.

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[1] "A Study in Pharmacy," pp. 58–63. Published for private distribution.

[2] The original notes, deposited in the Lloyd Library, give weights of glasses and calculations therefrom. A summary of results only is here deemed necessary. In this publication many detailed experiments were illustrated in order to establish that the fallacy of observation was an unavoidable factor in experimentation. It may be largely summarized as errors due to the personal equation.

[3] Adhesion distinctions of different materials are pronounced. Surface conditions from smooth to rough also need to be considered.

Experiment No. 23.—Watch crystals on wires, 7 P.M., August 13th, to 6 A.M., August 14th; clear.

No.	Aug. 13.	Dew. (A.)	Aug. 14 6 A.M. Morning dew. (B.)	Clear, Aug. 15 6 A.M. Dew. (C.)	Cloudy Aug. 18 6 A.M. (D.)	Clear Aug. 19 6 A.M. (E.)	Clear, fog all night Aug. 22 6 A.M. (F.)	Clear, slight fog Aug. 23 6 A.M. (G.)	Clear, slight fog Aug. 24 6 A.M. (H.)
1—60 in. high	10 P.M.	00	3.63	0.86	0.15	1.90	9.47	5.00	7.85
2—40 in. high	10 P.M.	00	5.02	0.90	0.24	3.33	10.37	5.41	5.65
3—10 in. high	10 P.M.	0.62	7.23	2.16	0.94	5.23	11.85	5.94	7.92
4—10 in. gravel walk	10 P.M.	00	1.07	0.68	Not weighed	4.70	Not weighed	Not weighed	Not weighed

Explanation.—This (No. 23) shows that at 10 P.M. water of adhesion had collected on the glass 10 inches from the grass (0.62) but none on those higher. The glass 10 inches over the gravel walk was dry.

After this, all glasses collected moisture, heaviest from below upward, excepting the glass nearest the gravel. The eight weighings (A to H) were quite uniform. The decrease in cloudy weather (D) as well as the marked increase on the foggy nights (F, G and H) are important. The exception (60 inch H), 7.85, was fact, not error of weighing. These experiments, together with No. 9, are deemed sufficient to establish that under the conditions governing these experiments, dew of condensation is greater over herbage than over the bare ground, and that even the "moisture condensed from the atmosphere" is partly mothered by vegetation. And yet, in one experiment, No. 24, August 16, 1880, the earth exhaled enormously as contrasted with moisture from a few blades of grass:

Experiment No. 24.—August 16, 1880, 8 P.M., to August 17th, 6 A.M.

	Weight, gr.
A—Glass over a sheet of rubber resting on the ground, a dish of $CaCl_2$ within, gave 6 A.M.	168.74
8 P.M.	168.00
Moisture from air	0.74
B—Glass over ground, 6 A.M.	182.70
8 P.M.	169.45
Moisture from air and earth	13.25
	0.74
Moisture from earth	12.51
C—Glass over rubber, through which are projected a few blades of grass, 6 A.M.	200.70
8 P.M.	185.60
Combined moisture of earth, air and grass	15.10
Moisture from earth and air	13.25
Moisture from grass	1.85

Explanation.—This shows that the earth here excreted 12.51 gr. moisture, the grass 1.85.

Experiment No. 25.—August 15, 1879; 12:00 M.

Two thermometers placed side by side in the shade, on grass 3 to 4 inches long; both registered 75°. Glass shade was placed over one. In a few moments it registered 77° and remained from two to four degrees above the other, while the glass shade covered it.

The shade was then raised two inches and a current of air from a fan thrown under it, both thermometers being in the air current. The temperature of each fell to 76°.

Both thermometers were now placed beneath the shade, No. 1 on the grass, 3 inches above ground, No. 2 suspended near the top of the shade, 4 inches above No. 1.

(1) 83°
(2) 85°

Explanation.—These results show that temperature increased when the air was confined, and that it varied according to location within the receptacle.

Experiment No. 26.—August 15, 1879; 12:00 M. (shade).

Bulbs of thermometers were wrapped in top part of young caladium leaf—Nos. 1 and 3.

Beside them another thermometer (No. 2) was suspended.

In a few moments Nos. 1 and 3 = 78°, and No. 2 = 80°.

The leaf of No. 1 was then tied against a stick, and the stalk cut off. In a short time the leaf wilted. Then the mercury rose until it stood nearly as high as No. 2. The leaf-enclosed thermometer (No. 3) registered lower than Nos. 1 and 2. See following tables.

(Shade.)	12:00 M.	1:00 P.M.	1:30 P.M.	2:00 P.M.	2:30 P.M.	3:00 P.M.	3:30 P.M.
(1)	80°	81°	79°	84°	81°	79°	81°
(2)	80°	81°	79°	85°	81°	81°	81°
(3)	77°	78°	78°	81°	79°	79°	79°
	4:00 P.M.	4:30 P.M.	5:00 P.M.	5:30 P.M.	6:00 P.M.	7:00 P.M.	9:30 P.M.
(1)	82°	81°	79°	78°	77°	74°	72°
(2)	83°	82°	80°	79°	78°	75°	73°
(3)	81°	80°	79°	78°	77°	74°	71°

Experiment No. 27.—August 15, 1879; 12:30 P.M.

Bulb of thermometer (1) wrapped in oleander leaf under surface out (exposed).

Bulb of thermometer (2) wrapped in oleander leaf (severed from tree) under surface out.

Bulb of thermometer (3) exposed to air.

Bulb of thermometer (4) wrapped in oleander leaf, upper surface out.

	1:00 P.M.	2:00 P.M.	2:30 P.M.	3:00 P.M.	3:30 P.M.	4:00 P.M.
(1)	75°	75°	76°	76°	77°	78°
(2)	75°	79°	80°	80°	81°	84°
(3)	80°	82°	82°	81°	82°	85°
(4)		79°	80°	79°	80°	(82°)
	4:30 P.M.	5:00 P.M.	5:30 P.M.	6:00 P.M.	7:00 P.M.	9:30 P.M.
(1)	79°	77°	76°	76°	73°	72°
(2)	82°	81°	79°	79°	75°	73°
(3)	82°	82°	79°	79°	75°	73°
(4)	81°	79°	77°	76°	74°	72°

These experiments illustrate that, under the conditions herein stated, varying temperature prevailed within distances but slightly separated. They show that in these cases active vegetation reduced the temperature; that in this case an exposed under surface of oleander was in daylight cooler than the upper surface; that a leaf excised from the plant became about the temperature of the surrounding air. Taken together, the indications are that activity of evaporation prevailed herein in daytime from the under leaf surface, but that at night, perhaps due to surrounding vapor-saturated air, differences of temperature are (9:30 P.M.) nearly equalized.[1]

[1] This experiment should be repeated with oleander as well as other forms of vegetation. It is an interesting opportunity and is presented as a text I have never followed to a conclusion. I hesitate to even record it other than as a suggestive text that in a broad sense, or even repetition, may lead to very different conclusions.

Establishing the Place of Water Excretion.

The foregoing general experiments seem to show conclusively the importance of vegetation in dew production, as well as prove that vapor is eliminated under certain conditions and water under others. The following line of experiments was instituted to locate accurately the principal points of water excretion and to establish the amount excreted.

Experiment No. 28.—Capillary glass tube placed through a sheet of wax in one end of glass tube, and its expanded end against tip of orchard grass projected through wax (Fig. 10).

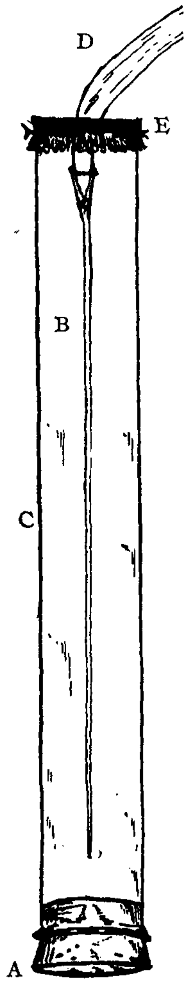

Fig. 10.

A—Cork in end of glass tube.
B—Capillary glass tube.
C—Glass tube.
D—Blade of orchard grass.
E—Sheet of wax over end of glass tube.

Weight,	8 P.M.	1.80
	6 A.M.	2.56
		0.76

Rain in the afternoon; very warm and close. Dew appeared on tips of grass 6 P.M.; thermometer 78°. This is exceptional. It was very cloudy until 9 P.M.; then clear.

Experiment No. 29.—August 18, 1880.

Two vials prepared with wax over the top and tip of grass through the wax (see Fig. 10).

(1)	Surface of leaf painted with collodion	8 P.M.	0.50
(2)	" " " " " "	6 A.M.	0.54
			0.04

Experiment No. 30.—August 5, 1880.

Two watch crystals filled with $CaCl_2$; one placed in a beaker and tied over with sheet rubber. Time, 7 P.M. to 7 A.M.

Weight of watch crystal, etc., 7 P.M.	138.70
Weight of watch crystal, etc., 7 A.M.	139.30
	0.60

Experiment No. 31.—One watch crystal placed in beaker, tied over with rubber, and blade of orchard grass stuck through rubber. Time, 7 P.M. to 7 A.M.

Weight of crystals, etc., 7 P.M.	158.60
Weight of grass blade, 0.83	
Weight of crystals, etc., 7 A.M.	160.45
	1.85

Explanation (Nos. 30 and 31).—Experiment No. 30 shows that 0.60 gr. moisture was contained in the air; No. 31 that a blade of grass weighing 0.83 gr. excreted, in 12 hrs., 1.85 − 0.60 = 1.25 gr. moisture, or twice its weight.

Experiment No. 32.—Watch crystals filled with $CaCl_2$. No. 1 in beaker glass of air, No. 2 in beaker glass with one blade of grass stuck through rubber; both glasses covered with sheet of rubber. Time, 7:30 P.M. to 7 A.M.

(1)	Crystal after exposure	147.49
	Crystal before exposure	146.90
		0.59

(2)	Crystal after exposure	162.25
	Crystal before exposure	161.00
		1.25

Weight of grass blade, 0.50.

This (32) confirms No. 31, a blade of grass 0.50 gr. excreting 0.66; more than twice its weight. 1.25−0.59 = 0.66 gr. moisture.

Experiment 33.—August 5, 1880.

Watch crystals of chloride of calcium in beaker glasses from 7 P.M. to 9 A.M.

(1)	Tied over with rubber, 9 A.M.	146.63
	7 P.M.	146.00
		0.63
(2)	Tied over with rubber through which blade of orchard grass projected	
	9 A.M.	162.13
	7 P.M.	159.60
		2.53

Weight of grass blade, 0.93.

Experiment No. 34.—Watch crystal of $CaCl_2$ in beaker glasses from 7 P.M. to 7 A.M.

(1)	Tied over with rubber, 7 A.M.	141.50
	7 P.M.	140.24
		1.26
(2)	Tied over with rubber through which blade of orchard grass projected	
	7 A.M.	198.90
	7 P.M.	196.76
		2.14

Experiment No. 35.—Watch crystal of $CaCl_2$ in beaker glasses, from 8 P.M. to 7 A.M.

(1)	Tied over with rubber, 7 A.M.	136.7
	8 P.M.	135.8
		0.9
(2)	Tied over with rubber through which blade of orchard grass projected	
	7 A.M.	186.33
	8 P.M.	184.10
		2.23

Experiment No. 36.—Crystals of $CaCl_2$ in beaker glass tied over with rubber and blades of grass through each. 8 P.M. to 7 A.M.

(1)	Orchard grass and beaker, weight, 7 A.M.	194.50
	weight, 8 P.M.	191.44
		3.06
	Grass 2.18.	
(2)	Wire grass and beaker, weight, 7 A.M.	138.33
	weight, 8 P.M.	136.20
		2.13
	Grass 1.06.	
(3)	Air in bell glass over plate of wax, 7 A.M.	120.27
	8 P.M.	118.84
		1.43

Explanation.—In this experiment the orchard grass (1) excreted $^1/_3$ more water than the wire grass, but it weighed twice as much. See Experiment No. 37.

Experiment No. 37.—Watch crystals of $CaCl_2$ in beaker glasses tied over with rubber and blade of grass through each. 7 P.M. to 7 A.M.

(1)	Orchard grass, weight, 7 A.M.	176.50
	weight, 7 P.M.	173.58
		2.92
	Grass 0.94.	
(2)	Orchard grass, weight, 7 A.M.	123.40
	weight, 7 P.M.	120.64
		2.76
	Grass 1.32.	
(3)	Air in glass over plate of wax, 7 A.M.	136.62
	7 P.M.	136.26
		0.36

Explanation.—These two blades, differing in weight by $^1/_3$, excreted practically the same amount of moisture—one twice, the other three times its weight.

Experiment No. 38.—Watch crystals of $CaCl_2$ in beaker glasses tied over with rubber, a blade of orchard grass through each. 7 P.M. to 7 A.M.

(1)	Weight, 7 A.M.	173.30
	Weight, 7 P.M.	171.84
	Grass 0.65.	1.46
(2)	Weight, 7 A.M.	135.43
	Weight, 7 P.M.	132.80
	Grass 0.95.	2.63

Explanation.—These two blades of grass excreted moisture—one twice, the other three times its weight.

Experiment No. 39.—Watch crystals of $CaCl_2$ in beaker glasses tied over with rubber. 7 P.M. to 7 A.M.

(1)	Oleander leaf through it,	7 A.M.	185.80
		7 P.M.	182.26
			3.54
(2)	Orchard grass,	7 A.M.	138.03
	Grass 0.61	7 P.M.	136.32
			1.71
(3)	Over wax,	7 A.M.	111.68
		7 P.M.	111.48
			0.20

Explanation.—The oleander leaf (weight not given) excreted twice as much moisture as the grass blade.

(To be concluded next month.)