THE WATER CYCLE

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Submitted to the faculty of the Graduate School
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fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 1960

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Report Approved:

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PREFACE

Examination of several current General Science and Biology text books revealed that the topic written on the "Water Cycle" was discussed in part, either from the biological point of view, or from the physical point of view. In all cases the discussions failed to answer some questions that would inevitably be raised by pupils when studying this cycle. Such questions as: What causes precipitation in the cycle? How does water rise in plants to the fartherest leaf of the tallest tree? What of the desert plants and the desert animals in the cycle? Some phases within the cycle are not completely understood by scientists. The pupil is made aware of these in this report in order that he or she would begin seeking the answers with their young and inquisitive mind.

The writer is indebted to Dr. Imy Holt for the loan of personal books and for his valuable guidance and suggestions; to Dr. Zant for his assistance in answering questions as to the form and shape of this report; to the National Science Foundation for the financial assistance that made this academic year of studies possible; to the members of the class for their ideas and constructive criticisms; and to Mrs. Alice M. Dyer, the writer's wife, whose understanding, faithfulness and encouragement helped to make this work a pleasure.

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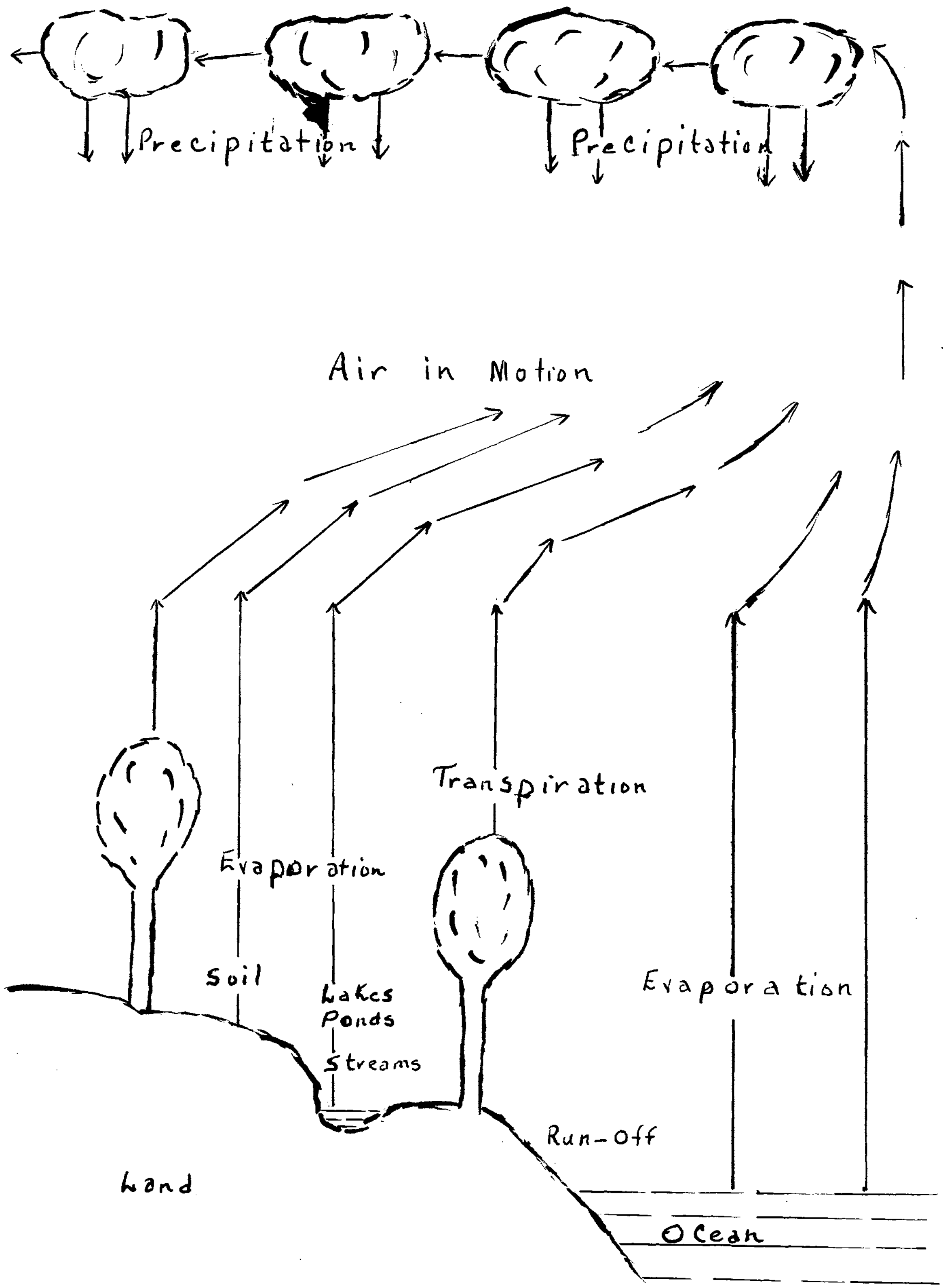

Fig. 1. The water cycle.

CHAPTER I

INTRODUCTION

Of all the substances that are necessary to life as we know it on earth, water is by far the most important, the most familiar, and in most demand by living things.

"Darkness was upon the face of the deep."[1]

Before there could be ocean depths there had to be rain-and in the beginning there was no rain. Geologists tell us that the earth was at first a molten mass, probably enveloped in a cloud of hot vapor. In due course the earth's crust evolved, with a temperature below the boiling point. The cloud of vapor began to condense and gave birth to the rains. It is likely that those first rains were prodigious; the water must have come down in sheets continuously. There were floods beyond our present conception of the words.

In the meantime the earth in its cooling developed wrinkles, and these gave rise to mountains and valleys and plains. The floods poured into the valleys and inundated the low areas. Thus our oceans were born; vast expanses of clear unsalted water. Though the rainfall was tremendous, there was little erosion because there was no soil to erode. But the rock did gradually break down, and slowly but persistently

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[1]Genesis 1:2

they sent their minerals to the fresh-water seas and in due time changed them to brine.

It is assumed these cataclysmic changes took place in almost complete darkness. No sunlight was able to penetrate to the earth until that envelope of vapor had dissipated itself. When the light did reach the earth, a new phase in the course of events moved in; water began to rise again from the oceans in the form of vapor, causing a new kind of rain cloud to appear in the earth's atmosphere.

After eons went by, plants and then animals made their appearance first beginning in water and some making certain adaptions and moving to land.[2]

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[2]Joseph A. Cocannouer, Water and the Cycle of Life, (New York, 1958), p. 19.

CHAPTER II

THE PRECIPITATION NUCLEUS

The mystery of how rain forms in the clouds has been known less than thirty years. Yet the problem of making it rain, history tells us, was with the cave man.

Tor Bergeron Theory

In 1931, Tor Bergeron, a Norwegian meteorologist proposed an explanation that is widely accepted today. He suggested that rain drops are formed initially as snowflakes at high altitudes in supercooled clouds, that is, clouds in which the droplets do not freeze even though the temperature is below freezing. Previous knowledge of super-cooled clouds show that water has a higher vapor pressure than ice at the same temperature. It followed from this that if an ice crystal was put into a cloud of supercooled droplets, it would grow and the droplets would finally evaporate. And Bergeron reasoned that if a relatively few ice crystals were somehow formed in a supercooled cloud these crystals would rapidly grow into snowflakes. As they fell to lower altitudes they would melt forming raindrops.

The phenomenon of how the seeding ice crystals come to be formed in the clouds was not explained by Bergeron. This was a matter of exciting interest until further investigations and experimentations were made. The German scientist, Walter Findeison pointed out that "quite minute quantiatively inappreciable elements" such as certain kinds of dust particles, might initiate rainstorms, and that artifical control of the weather should be possible.[1]

Rain Making Experiments

Several years later, Vincent J. Schaefer and Irving Langmuir became interested in this idea of what caused rain and with the statement of Findeison postulation, proceded to investigate. In 1946 an experiment whereby supercooled clouds were made in a home food-freezer similar to those in the atmosphere were produced by merely blowing the breath into the freezer. In another observation the small propeller of an airplane, rotated in the clouds had ice formed on the leading edges. On the other hand an ice crystal did not appear in the clouds as such.

It had been postulated by other scientists that smoke and dust particles of various kinds might serve as nuclei for ice crystal formation. Shaefer tried all sorts of substances of this nature but still no crystals were formed.

One day the freezer was slow in cooling and to speed the rate of cooling, a piece of dry ice was placed in the box. To the surprise and delight of Shaefer the entire mass of supercooled cloud rapidly changed to a shimmering mass of

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[1]Bernard Vonvegut, "Cloud Seeding", Scientific American, 186, No. 1, 1952, pp. 17-22.

hundreds of millions of tiny ice crystals. Observation under the microscope showed them to be miniature six-sided snowflakes. In perfect accord with Bergeron's theory, when Schaefer blew his breath into this cloud of crystals the moisture formed a supercooled cloud as before but now the liquid droplets evaporated and condensed on the ice crystals in a matter of seconds.

The production of ice crystals were found to be due solely to the low temperature of the dry ice. A supercooled cloud cannot exist below the temperature of -38 degrees Fahrenheit. Ice crystals will form without the aid of dust or other foreign particles.

The results of this experiment encouraged Langmuir and Schaefer to try seeding some natural supercooled clouds with dry ice. They were successful in making snow, however, most of it melted before reaching the ground.

Examination of the structure of the snow crystal proved to be similar to the silver iodide crystal. The use of silver iodide for seeding supercooled clouds produced snow, but it was not as effective as dry ice. Silver iodide requires a cloud temperature of -26 degrees Fahrenheit or lower whereas dry ice is effective at any temperature.

Langmuir Chain Theory

The question now arises as to what happens in warm areas such as Africa, Northern Australia, or where the climate is hot and humid. The jungles of Africa have heavy rainfalls and no snows.

The Langmuir chain theory proposes that in a comparatively warm cloud, a water drop suspended in an updraft of a cumulus cloud, grows as it collides with fine cloud droplets. Eventually this drop becomes so large and unstable and finally disintegrates into several smaller drops. These drops in turn grow and divide by the same mechanism until the chain reaction fills the cloud with numerous large drops. The drops then fall as rain when the updraft ceases. This theory predicts that certain cumulus clouds can be made to produce rain by introducing into them a few drops of water of a specific size and shape to initiate a chain reaction.

In the experimental evidence of these demonstrations, to initiate any form of precipitation from a cloud, it is necessary that a nucleus conformable to a rain drop or snowflake be induced in a desirable cloud. Most rains begin with the formation of a snowflake in a supercooled cloud.[2]

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[2] Bernard Vonvegut, "Cloud Seeding", <u>Scientific American</u>, 186, No. 1, 1952, pp. 17-22.

CHAPTER III

INLAND WATERS PHASE

Water on land and in the soil is derived from the atmosphere and is directed by gravitational flow back to the ocean which is its stable reservoir.

"Inland waters" are bodies of water surrounded by land and are classified in five groups: (1) water running on land, streams and rivers; (2) seas, lakes and ponds that have outlets from which water flows; (3) seas and lakes that have no outlets; (4) water beneath the surface of the land; (5) bodies of water nearly surrounded by land, but connected with oceans that supply enough water to maintain them at sea level.[1]

The first four named classes are maintained entirely by water from the air which is obviously by evaporation, and the bulk of it comes from oceans. The fifth class receives its supply from its connective, the ocean.

There are three possible courses water takes when it reaches the earth: it may sink into the ground; it may run downhill, if there is any slope; or it may stand where it has fallen. The part that sinks into the ground may be absorbed by the roots of plants and given up in transpiration, which

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[1]Joseph A. Cocannouer, Water and the Cycle of Life, (New York, 1958).

will be discussed later. A part may leave the ground from a spring or well, or by seeping into a river or sea. A part may stay under ground for ages.

Surface Water

The water that runs on the surface may return to the ocean by streams and rivers; some may evaporate and some may join the ground water. Of the water that stands on level ground, as a pond or lake with no outlet, some will evaporate, some will sink into the soil. Under average conditions about one-third of all the water that falls on land will evaporate; a portion of this fraction will return to the ocean from which it originated, some by air, and some will fall again upon land. Nearly all the remaining two-thirds will flow back to the oceans by streams and rivers. The journey may take a few minutes, a few months or millions of years.

Ground Water

One great body of water which one does not see, but which is very important to all forms of life is called ground water. It includes all water from the time it sinks below the surface until it emerges from the ground. Joseph A. Cocannouer refers to this water as "Nature's inland sea".[2]

Water's work is not all done above the surface. It sinks below and percolates through the soil; and where there is

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[2]Joseph A. Cocannouer, <u>Water and the Cycle of Life</u>, (New York, 1958), p. 56.

rock, it moves through fissures and cracks. With the help of carbon dioxide picked up from the atmosphere and carried in solution, it dissolves limestones and creates caves hung with stalactites which may extend for miles.

When ground water encounters impervious strata of dense rock or clay which it cannot penetrate, it seeps along until it finds some outlet. Sometimes it flows under impervious stratum and cannot rise through it as it always goes downhill and may travel long distances, it may arrive at a level far below the point it went under the impervious layer and so be subjected to enough pressure to cause it to rise to the surface, or higher, if a well is drilled through the underlying strata. Such wells are called "artesian wells", and may produce a flow of many gallons per minute.

Most of the ground water leaves the earth through springs or seepage into river beds. These vary from the barest trickle to tremendous streams. Warm springs are the result of water rising from great depths, or are passing through a hot material close to the surface.

CHAPTER IV

THE VEGETATION PHASE

It is common knowledge that water is absolutely essential to animal life, and that if it is withheld for a relatively short period from the organism, death occurs.

Water is just as essential to plant life and if a plant is deprived of water it will perish. One should consider the relationship of water to the life of a plant where the plant is an important factor in the water cycle.

Plant and Water

The absorption of water and solutes by living cells involves a group of complex processes which are still not completely understood. It is known, however, that the root hairs of plants, excluding parasitic plants such as mistletoe, are the chief absorbing structures of plants (Fig. 2).

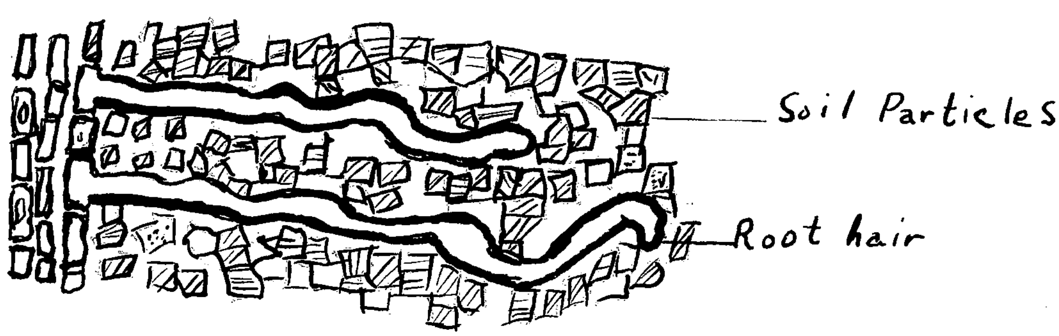

Fig. 2. Root hairs.

The absorption of water is initiated by imbibition. Absorption of water is the intake of nutrient solutes since this is by far the chief source whereby plants obtain their raw materials necessary for the manufacture of cellular substances.

There is experimental evidence which indicates that in very active tissue, such as a root hair possess; there may be more rapid uptake than could be explained simply by imbibition and osmosis, and that water movement may occur against a diffusion pressure gradient and that the oxygen supply may bear a direct relationship to water absorption.[1] Since oxygen supply is directly related to respiration, it appears that the energy released in respiration may be involved in the promotion of this active water absorption.

When a cell is in contact with water, the cell wall and the protoplasm absorb water by this process, which may be defined as soaking up a liquid by solid materials, especially substances in a colloidal condition. Cellulose, pectic substances, protoplasmic proteins and other organic compounds in plant cells have great powers of imbibition. Imbibing materials, if they are combined, exert considerable pressure as they absorb the liquid with which they are in contact and swell.

The process of diffusion is the physical phenomenon of osmosis. Diffusion is the spreading out of the molecules or ions of a substance through all the space which it can reach,

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[1]Harry J. Fuller, The Plant World, (3rd., New York, 1955), pp. 56-62.

from the space where they are more abundant to places where they are less abundant. It may be regarded as a tendency toward reaching an equilibrium for it results in the equal distribution within a given space of the diffusing particles.

The Rise of Water in Plants

This phenomenon is an amazing part of the water cycle. How does water reach the farthest leaves of the tallest Douglas fir tree of the Pacific Northwest? Some have been known to grow 400 feet tall. To reach the farthest leaf from roots beneath the ground water must travel a vertical distance of approximately 450 feet. Botanists have been puzzled over the problem for more than 200 years; even today the complete story of how water travels upward through plants is not fully understood.

Many wrong explanations have been postulated, and have enjoyed more or less wide acception. Yet as early as 1727, Stephen Hales, a versatile English clergyman and scientist, published his "Vegetable Statick". In this historic work, Hales laid the foundation for the science of plant physiology. The experiments and conclusions of Hales' are surprisingly modern. Of the two mechanisms that are now thought to account for the phenomenon, he did considerable work on one and at least hinted at the other.[2]

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[2]Victor A. Greulach, "The Rise of Water in Plants", _Scientific American_, October, 1952, p. 78.

A successful theory must explain: (1) the origin of rather large forces. To raise water 450 feet requires a pressure or tension of about 210 pounds per square inch neglecting friction. Friction between water and the walls of the tubes which conducts it may call for almost as much force again, making the total 420 pounds per square inch; (2) the speed of the ascent and the volume of flow of water in plants. Water in some plants rises at the rate of almost 150 feet per hour. A date-palm tree in a desert oasis may need to raise as much as 100 gallons of water a day to make up for losses from transpiration; and (3) the explanation must satisfy the facts of plant anatomy and physiology. The upward flow of

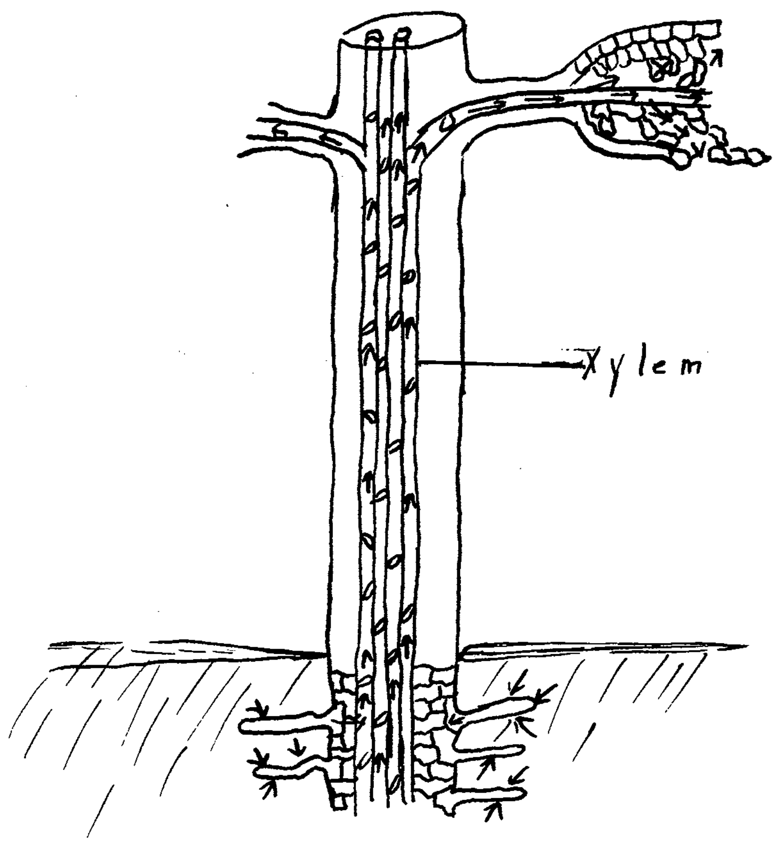

Fig. 3. Water from soil to the leaves.

water in plants takes place in the xylem, or woody tissue, (Fig. 3). Throughout the xylem are many dead cells consisting only of cell walls and central cavity. It is through these cavities that water passes.

Many carefully performed experiments have proven the forces are not due to capillary action as some biology texts relate. Capillary action is effective over a short distance.

Hales proposed that the rise of water in plants some of the time is due to root-pressure. He found that plant roots sometimes develop pressure due to their osmotic absorption of water from the soil, and suggested that this pressure accounted for the rise of the liquid in the stem. This, of course, could not be the full answer as Hales himself recognized. The greatest value of this pressure is far too small to raise water to the tops of trees; moreover some plants develop no root pressure at all. Finally this mechanism could not elevate water nearly as far as the sap sometimes rises in trees.

The only theory that seems to meet all the requirements was proposed by H. H. Dixon in 1895, an Irish plant physiologist, and his co-worker J. Joly.[3] It is variously called the cohesion theory, the transpiration stream, the transpiration-cohesion tension theory and the Dixon theory. The original author Victor A. Greulach cited that "shoot tension" should be added which is probably more accurately discriptive and

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[3]Victor A. Greulach, "The Rise of Water in Plants", Scientific American, October, 1952, p. 78.

which is comparable to the term root pressure. The theory turns on an over-looked quality of water itself -- its cohesion. If water is enclosed in a thin air-tight tube, and does not contain too much dissolved gas, it has a great tensile strength. Under the proper conditions such a column of water can withstand a pull of 5,000 pounds per square inch. Plant sap does not have quite as much cohesion as water, but its tensile strength has been measured at 3,000 pounds per square inch. Such a pull could theorethically lift a column of sap to a height of 6,500 feet, surely enough to account for the rise of sap in the tallest trees.

The sap, then is capable of being pulled up. What pulls it? The force comes not from high pressure below, but low pressure above -- the low diffusion pressure of water in the cells of leaves and other living parts of the shoots. As water is lost from the leaf cells by transpiration, or is used up in photosynthesis, digestion or growth, a water deficit is created in these cells. The resulting drop in their diffusion pressure causes the water to move inward from the liquid in the xylem by osmosis, and thus the entire water column, which is continuous from the leaves down to the roots is pulled up. This in turn increases the difference in diffusion pressure between the root water in the tissues and soil water, and water diffuses rapidly into the roots.

TABLE I

PER CENT OF WATER FOUND IN SOME COMMON PLANT LEAVES

Kind of Leaf	Percentage of Water	Kind of Leaf	Percentage of Water
Cabbage	86	Pumpkin	80
Tomato	84	Corn	77
Cowpea	82	Apple	60

Loss of Water from Plants

All living matter is composed of protoplasm and a large amount of water is necessary for it to function properly. The younger, the more vigorous, the more impressionable, the more active and the more rapidly growing protoplasm is, the more water it contains. For example, the tip on the base of rapidly young growing regions of a corn plant is composed of 92 to 93 per cent of water, most of which is directly associated with protoplasm which completely fills the cells of these portions of the plant. Comparably speaking, the flesh of a ripe watermelon does not contain any more water percentage wise.[4]

Water is located in the vacuole to maintain the normal condition of turgor essential for the growth of cells and for

[4]Edwin C. Miller, Plant Physiology, (New York, 1938), pp. 407-505.

the erectness of the plant. Of course the amount of water varies in different parts of the plant and depends also on the type and condition under which the plant is examined. Table I contains a list of plant leaves and the per cent of water normally found in them.[5]

Material translocated in a plant moves from cell to cell in a watery solution.

Experimental data show that a plant does not utilize very much water for the formation of organic compounds. It is necessary for proper chemical reactions to take place.

A normal corn plant reaching the height of 10 to 12 feet and producing a good yield of grain, had including the stem, leaves, grain cob, and roots a moist weight of 2,707 grams. The weight of the dry matter was 835 grams. This means that the water needed for vacuoles of the cells, protoplasm and for the translocation of materials, did not exceed this amount. It is believed that 250 grams of water is an ample amount to take care of all the chemical reactions in a corn plant for a season. Based on these figures, a corn plant would need only 2,122 grams (approximately 2 1/5 quarts) of water during an entire growing season. It is a known fact that a corn plant would need more than 2 1/5 quarts of water over an entire growing season for proper growth. One corn plant was observed to remove 54 gallons of water from the soil over a growing season. This is approximately ninety-eight times

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[5] Ibid.

more than is needed for cell vacuoles, translocation, protoplasm, and chemical combination.

What then happens where a condition of this nature prevails, that a corn plant need such a large supply of water during a growing season? The use of the corn plant in this report is an indication of what happens in other plants to a more or less degree. An enormous amount of experimental data supporting basic facts have been compiled.

The topic concerning water for the vacuoles of the cells, for translocation of materials, for protoplasm and chemical combination was given in order that a comparison may be made with the information to follow. All contribute to the completion of the water cycle.

Now to answer the question: Why does a plant need a large supply of water during its growing season?

A plant is continuously losing water from its stem and leaves by transpiration and by guttation which necessitates a supply of water in the soil at all times.

Transpiration is the loss of water in the form of vapor from the stem and leaves of living plants. Practically all the water that is lost by plants escapes in this manner and the greater per cent is lost by the leaves. This process goes on at all times, except possibly when the air is saturated with moisture during or immediately following rains. The quantities of water lost by transpiration are often very great. It has been determined that a single sunflower plant during a growing season of approximately 140 days loses about

145 pounds of water by evaporation from the aerial portions, an average daily loss of more than one pint of water. A single corn plant has been found to lose by transpiration over 50 gallons of water (more than 400 lb.) during its life span of 100 days. An acre of corn plants, transpiring at the same rate evaporates into the air over 300,000 gallons (about 1,200 tons) of water in 100 days. A single full-grown large apple tree has been found by calculation to lose 1,800 gallons of water in a growing season of six months. The tremendous amount of water vapor transpired from extensive masses of vegetation affect air temperature, increases the moisture content of the air, and thus influences the frequency and quantity of rainfall.

About 90 per cent or more of the water which evaporates from leaves passes out into the air through the stomata; the remainder of the water vapor lost diffuses outward through the cuticle of the epidermal layers, Fig. 4. The former type of transpiration is termed "stomatal", the latter is "cuticular transpiration".

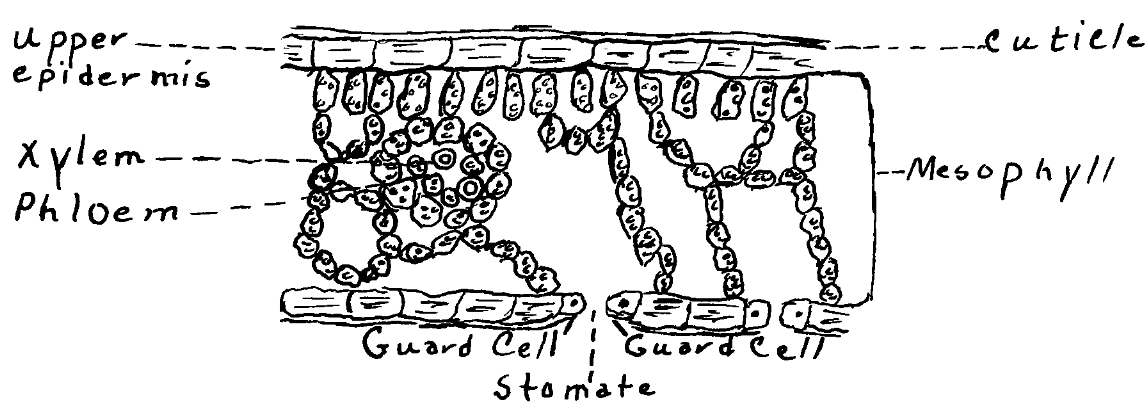

Fig. 4. A cross section through a flat leaf showing internal structure.

The actual conversion of liquid water into water vapor does not occur at or through the stomata, for the latter are merely holes in the epidermal layers of the leaves. Liquid water passes into vapor from the wet walls of the mesophyll cells of leaves at the places where such walls are exposed to the intercellular spaces of the mesophyll. A water vapor collects in these spaces, it moves outward through the stomata into the external air, in accordance with the laws of diffusion.

Transpiration proceeds more rapidly during the day than at night, chiefly because the stomata of most plants are open widest during the day and also because the environmental factors which prevail during the day favors rapid evaporation of water. At night, when the stomata are partially or wholly closed and when temperatures are lower than during the day, the rate of transpiration is considerably less than that during the day.

The principal external factors which influence the rate of transpiration in plants are light, temperature, wind velocity, humidity, and soil factors.

Transpiration is more rapid in bright light than in diffused light or in darkness, partly because certain light rays raise the temperature of leaf cells and thus increase the rate at which liquid water is transformed into vapor, partly because bright light causes the opening of stomata.

A high temperature favors more rapid transpiration, not only because evaporation occurs quickly in warmer air but also because warm air is capable of holding more water vapor than cold air. The rate of transpiration at moderate or low temperatures is markedly less than it is when the surrounding air is high.

The evaporation of water is reduced when the external atmosphere is humid, for the differences in water vapor concentration in the inner spaces of leaves and in the outside air is so slight that the outward diffusion of molecules from leaves is very slow. The rate of transpiration is roughly proportional to atmospheric humidity; thus the drier the air, the more rapid the rate of evaporation from the leaves.

Where there is no breeze, the motionless air near transpiring leaves becomes very humid and as a result, the rate of water evaporation decreases. Moving air currents continually bring fresh, drier masses of air in contact with leaf surfaces and thus maintain a high rate of transpiration.[7] However, the rate of transpiration is not directly proportional to wind velocity for closure of the stomata frequently begins when the wind velocity exceeds 25 to 30 miles per hour and the transpiration rate is lowered at high velocities.

The rate of transpiration is indirectly influenced by soil temperature, solute concentration of the soil solution and the water content in that they affect the rate at which roots absorb water. If plants cannot absorb water readily, the rate of their absorption is correspondingly low. If

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[7]Harry J. Fuller, The Plant World, (3rd ed., New York, 1956), p. 200.

water is more easily absorbed the transpiration rate is higher.

The internal factors regulating transpiration is stomatal behavior. It might seem at first consideration that plants can control to a large degree the rate of water evaporation from their leaves by closing their stomata, for these apertures are easily regulated by their surrounding guard cells. However, the stomata of plants are singularly ineffective in reducing water vapor loss for so long as the leaves are turgid and are exposed to light, their stomata remain open. Only when leaves begin to wilt or the guard cells lose their turgidity are the stomata completely closed.

Desert Plants (Xerophytes)

The colloidal material in protoplasm holds water very tenaciously, and when transpiration has proceeded for some time at a rapid rate the water-retaining power of these colloids frequently causes a marked decrease in transpiration rate. Many desert plants, such as various species of cacti and acacias, have mucilaginous, gummy material in large quantities in their tissues. These substances are colloidal in nature and are especially effective in retaining water against various drying forces. The tubers of a desert gourd were found to be able to retain a part of their water for almost seven years after being up-rooted and placed in a laboratory shelf to dry.[8]

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[8] Harry J. Fuller, The Plant World, (3rd ed., New York, 1956), p. 201.

The structural modifications of many species of plants growing in desert soils of low water content frequently conserve water. Plants which grow in such regions in soils of scanty available water content and which possess structural feature which reduce transpiration are termed xerophytes. One should distinguish them from hydrophytes (plants growing in water) and the mesophytes (land plants growing in soils with moderate amounts of available moisture). Among the characteristic structural features which conserve water are: heavy layers of cutin on leaves and stems, reduced numbers of stomata, stomata sunken in cavities below the surfaces of leaves, abundance of water storage tissues and the reduction in size of or absence of leaves. Some xerophytes (Fouquieria splendens, Ocotillo) produces leaves during the rainy season and drop them as soon as dry weather begins.[9]

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[9]Gayle Pickwell, Deserts, (New York, 1939), p. 43.

CHAPTER V

DESERT ANIMALS AND WATER

Generally the eater of plants (herbivors) have no serious water problem, for they secure their water from the juices of the plants they eat. This applies to desert snails which when green plants are scarce, seal themselves in their shells with a mucous film until water comes again. The Crested Lizard, Chuckwalla and the Desert Tortoise also get their water by eating succulent herbs where and whenever they can find them.

But those eaters of such plant products as dry seeds or dead and dry wood have the most trying problem of all and the most amazing method of solving the water problem. The animals such as the Larvae of the Powder Post Beetle, the Big Desert Kangaroo Rat, the Desert Antelope Ground Squirrel and perhaps the Mohave Pack Rat, use water from metabolism.

Animals that eat other animals let the victims solve their water problem for them. Thus, a Red Racer may swallow a Whiptail Lizard that is so hopeless as to run into the Racer's burrow. The Racer at once is supplied with water from the juices of the Whiptail. The Whiptail had secured its water from insects. The insect had secured water from plants.

Large flesh eaters such as coyotes and foxes are water spendthrifts as are human beings, so they must go to water holes or desert streams from time to time.

The Desert Tortoise stores its excess water in two tanks on the inner surface of its shell.

SUMMARY

Conclusive evidence supports the theory that for precipitation to take place, whether it is rain, sleet, snow, hail or any combination, the origin requires a nucleus, and the supercooled clouds are the best possible source for the formation of a nucleus.

Vincent J. Schaefer and Irving Langmuir were successful in producing snow by seeding clouds with dry ice and also with silver iodide crystal. The theory in the use of dry ice is that the clouds are cooled to a temperature at which they cannot exist, a nucleus is created and once a single nucleus is produced, then millions are created. Silver iodide crystals have a structure similar to that of snow crystal; therefore, they can be used to seed a cloud which has a temperature of -26 degrees Fahrenheit or lower.

Once precipitation has taken place and most of the water falls to the ground, then the inland waters become the next link in the water cycle. Under average conditions, about one-third of the water that falls evaporates and part of that third returns to the ocean by way of the air and the other falls again on land. Lakes, streams, rivers which may be called surface water and that that sinks below the surface until it emerges from the ground, take up most of the remaining two-thirds.

A large quantity ground water is absorbed by the root hairs of vegetation and sent back through the stem and transpired through the leaves.

The rise of water in plants is not completely understood by scientists, but the theory support the fact that the rise is due to a combination of forces. Cohesion, root pressure, low diffusion pressure of water in the cells of leaves and living parts of the shoots are some of the forces responsible for the rise of water in plants.

Vegetation is an essential link in the water cycle. Much of the precipitation that returns to the atmosphere gets there by way of plants. It is a known fact that plants absorb well over the amount of water needed for metabolism and growth. This excess water is transpired through the leaves and other living parts of the shoot. The physiology of the leaves is of such nature that environmental conditions regulate the transpiration.

"THE WATER CYCLE" AS A UNIT IN JUNIOR AND SENIOR HIGH SCIENCE

Junior high science pupils could study the water cycle as a unit on weather. Efforts should be made to show the relationship between all phases and that each phase is either directly or indirectly dependent on the other. A good opportunity affords itself here for the introduction of new terms and principles which can be utilized in advanced science courses. The ability of the above average student can be capitalized on by assigning special reports on weather, single experiments, demonstrating certain principles involved in the cycle.

Senior high science pupils whether in biology or general science have a rich opportunity to build on the already established fundamentals and principles studied.

In a general science class, individual pupils or groups can be assigned to study and make reports in the following fields; meteorology, geology, biology, and physics. Meteorology would take in weather, including all forms of precipitation. Geology would be a study of all ground and surface waters. Biology would be a study of plants and animals in the cycle role and physics would enlarge on all known forces within the cycle.

Each group or individual should make use of charts and demonstrations whenever possible to give clarity and understanding to their report.

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