HOW PLANTS FEED, RESPIRE AND LIVE

Dependence of the Organism Upon Light, Heat, Food, Air And Water.

LIFE-ACTION OF VEGETATION.

Work of the Roots, Stems, Leaves, Seeds—Objects of Home and School Gardens.

Somewhere in these articles it was said that all food of plant or animal is transformed sunshine. The statement may require elucidation. As is well known, a beam of solar light is composed of three kinds of rays—the heating, the illuminating and the chemical—each producing its own peculiar effects upon vegetation. Their combined influence upon the plant accounts, in fact, for all the varied phenomena which it exhibits.

PLANT LIFE AND SOLAR BEAM.

Plants show no signs of life except when under the heating rays of the sunbeam and the amount of the heat imparted pretty fairly measures the luxuriance of the plant's growth. The illuminating rays are of like importance with those that carry heat. In the dark, plant growth is checked, the leaves are deprived of green color, and the bulbs and fruits are tasteless and watery. Plants seeek the light, and will climb out of the cellar windows; while if confined in total darkness they speedily die. The solar light-beam causes the stomata, or breathing pores, to operate; but in darkness they close, and the plant suffocates. The chemical rays of the sunbeam, however, are of no less value to the plant. Under their action, the green parts of leaves have the power of decomposing carbon dioxide, of retaining the carbon, and of exhaling the oxygen in a nearly pure state. This process, as we shall see, is one of plant digestion and assimilation; while the breathing proper of the plant consists of taking in oxygen and of giving out carbon dioxid—a process that goes on at all times but is more noticeable at night, when the former process (assimilation) is suspended. Since, however, the amount of oxygen produced by plants is so much greater than the amount of carbon dioxid, the general effect of plant action is to fit the air for the support of animal life, by ridding it of the poisonous carbon dioxid and by supplying it with the life giving oxygen.

NATURE'S HARMONICS.

Only during the germination of seeds and the bursting of buds is more oxygen absorbed than is given off by the plant, and only then is more carbonic acid evolved than is taken in and destroyed. The consumption of oxygen and the production of carbon dioxid are greatly assisted by the absence of light, for the illuminating rays prevent the germination of seeds, and delay the bursting of buds, while the chemical rays hasten these processes. On the other hand the heat rays hasten the development of the reproductive organs of plants. And here we see a nice adaptation; for in the spring, when the process of germination is going on, there is a large excess of the chemical rays. As summer advances and the growth of additional vegetation is required the quantity of illuminating and heating rays increases relatively much faster than do the chemical rays, and the decomposition of carbon dioxid for the building of plant tissue goes on at an increased pace. But in the autumn, as plants approach maturity, and seeds are to be formed and fruit ripened, the illuminating and chemical rays boy diminish, while the heating rays are further increased. This extraordinary and curious instance of design in nature, has taught the horticulturist to cover seeds with blue glass when he wishes to force their development, for by cutting off the light and heat and transmitting only the chemical rays, he can hasten germination. Later, he uses yellow glass to hasten growth by a relative increase of the luminous rays; and still later by using red glass he hastens seed and fruit formation by admitting mainly the heat rays, while reducing the other kinds.

THE PLANT DEPENDENT.

How delicate and dependent, after all, is that interesting organism which we call the plant! It seems to be so tough and so prolific of life that it covers the earth with a carpet of vegetation in spite of neglect, ill usage, persecution, and climatic assaults; but in reality it is only nature's makeshift, the weeds, that do so. The plants which we prize as useful and profitable are produced with great artificial or natural labor, and are dependent upon the soil water, which they absorb, upon certain soluble salts which this water contains, upon the oxygen and carbon dioxid, which they take from the air and water, and upon sunlight, heat and good air. Deprive the plant of any of these, and it cannot live. So delicate, indeed, is the organism of the living plant that small and imperceptible amounts of coal gas in the air near broken gas mains will prove fatal to it; noxious gases of any kind seriously affect it, even when their amount may be so small as to escape chemical tests for them; while the relatively small proportion of really noxious gases in air slightly contaminated by smelter fumes, may completely poison the plant, without being sufficient in quantity to affect perceptibly the people who breathe this air. Witness the experience of Butte, with no living plants, grass, or trees, near, and of the damage to vegetation by the atmosphere surrounding our own smelter districts. The marvel is how lives so tender or things so fragile should be continued on the earth's surface with the amazing regularity and constancy which we actually behold.

WORK OF THE ROOTS.

A fringe of delicate root-hairs surrounds each rootlet of the plant. These hairs are single cells, elongated, from the growing root, and filled with cell sap and protoplasm. Among the soil particles, these delicate threads find or make their way. Wherever they come into contact with moist earth, and that is practically everywhere, a singular result follows: these hairs drink in or absorb the moisture that may be clinging to the soil particles. They do this by reason of a peculiar process called osmosis.

HOW THE ROOT DRINKS.

Sunshine vibrates through soil moisture and brings into liquid form (solution) the food of plants, which is then borne in capillary currents to the root fibers, whence it is further carried, also by the power of sunshine, into the stems and leaves above. In what way?

When dry prunes or raisins are put into water, they swell; osmosis is said to have taken place. When juicy fruits are covered with sugar, they shrivel; here, too, a contrary osmosis has occurred. Pfeffer used a porous clay cell lined with a mebrane. He found on filling it with a solution of potassium nitrate and then placing it in pure water that the water flowed into it until it pressed outwards with a force of three atmospheres—a force equal to the weight of a column of water 100 feet high. This is the force which presses outward in the case of the swelled bean or prune. The flow always takes place from the thinner into the thicker liquid, and occurs whenever the two are separated by a porous membrane. The liquid whose molecules are small enough, passes through the most rapidly, causing an accumulation within and a pressure outwards. So, in any plant cell, as in the leaves where water is being consumed as food and is evaporating or being changed into some other substance, the removal of these molecules from the solution, for the sake of growth, leaves space unoccupied, diminishes pressure from within ontward, and causes a flow of molecules from other cells lower down in the stem to make good the loss in the leaves due to the selective absorption of growth.

WHY WATER SEEKS THE ROOTS.

As the root cells have their pressure reduced by the flow toward the place in the leaves where the water is being used, they drink in more of the water surrounding the soil grains. If this water contains nitrates and growth is going on in the leaves above, this means that nitrogen is being changed into seeds and fruits for the use of man. Still more water is drunk in by the roots to make good the loss that occurs at the places where the leaves are manufacturing the nitrogenous foods. Each food substance travels somewhat independently of the others. If evaporation should cease, these currents would continue to flow only as long as the plant substance is more dense than the plant food in the water at the roots. The selective power of plants is explained by this consumption of those kinds of particles which the leaves are changing into plant tissue.

Any substance may be taken in by the root, but if the plant does not use that substance, the currents are soon saturated with it and no more of it can be received or carried. The plant is not overloaded with the kinds not used because no more of them can come in; but of the kinds which it uses, more continues to arrive as fast as the plant picks out these materials for its own substance. Removal of these food particles by placing them in the tissue, reduces the relative saturation of that substance in the current, and more of it comes in from the root to supply the place of the food removed, causing an upward flow, the force exerted by which we then term root-pressure.

WORK OF THE STEMS.

We may demonstrate this upward root pressure by cutting off the stem of a vigorous, growing sunflower, just above the ground, and by fitting over it first a rubber and then a glass tube filled with water. Before many hours, the ascending sap will cause the water to rise in the tube. The common nettle will thus sustain a column of water 10 feet high. The sap goes upward, not between the bark and the wood, as commonly supposed, but through the young wood. A piece of corn stalk or celery put into a colored solution, and cut off after a few hours, shows the coloring matter in dots corresponding with the stringy parts of tough celery and with the small wood bundles of the corn stalk. It is root-pressure from below, and the osmotic force due to evaporation above, that cause the sap to ascend through these woody bundles, which, as veins and veinlets, reach to all parts of the leaf surface.

WORK OF THE LEAVES—BREATHING.

Quite as wonderful, in fact, as the work of roots and stems, and much more impressive as to its visible results, the work of the leaves next claims our attention. The plant must breathe; and, like the animal, it must breathe oxygen. It does so chiefly by means of the leaves which are its lungs. Oxygen is constantly absorbed by the delicate parts of plant foliage, and even by the roots and the seeds, but especially by the stomata of the leaves. Stomata, or breathing pores, are small openings in the epidermis of leaves and soft stems, to allow the passage of air and other gases. Two guard sells open or close the gate to the stomata as the conditions of the atmosphere may require. The pores are usually most numerous on the under side of the leaves. Their number to the square inch varies from 200 on the leaf of a mistletoe to 160,000 on the leaf of a lilac, so that they are very small. As the air enters, the oxygen passes into the leaf cells, and unites with carbon there, forming carbon dioxid, which is then exhaled, in a manner resembling the respiration of animals. A growing plant may absorb an amount of oxygen equal to its bulk in 24 hours.

ASSIMILATION.

But carbon dioxid is likewise "breathed" in by the leaves; and whenever these have green coloring matter (chlorophyll) present and the sun is shining, the carbon of this gas unites with watery substances in the leaf and forms starch, while the oxygen is thrown off. This process, by means of which the plant is chiefly built up, since plants consist mainly of carbon, is the main form of plant digestion and assimilation. During the day, when this process is more or less active, much oxygen may be given off; during the night, when this process ceases, the effect of respiration is to give off small quantities of carbon dioxid. The starch formed in the leaves during the daytime is changed into sugar and is carried at night into the roots, tubers, or stem, or stored in the thickened leaves, for future growth.

TRANSPIRATION.

A third process carried on by the leaves is transpiration, the means by which the plant gets rid of its surplus water. The plant absorbs water in much greater quantity than it needs, in order to secure the proper amount of dissolved food substance. This water evaporates from the surfaces of leaves and green stems. Thousands of minute pores aid this process also; and these stomata open in moist and close in dry weather, to regulate the amount of transpiration.

WORK OF FLOWER AND SEED.

The work of the flowers in securing cross-fertilization and of the seeds in getting disseminated and planted, was treated in earlier articles and requires no further statement now, especially since the botanies generally deal with it. But the work which the school and the larger community may do in plant cultivation may be referred to here. This kind of work is becoming very popular.

THE GREAT WORLD'S FARM.

Just when a part of the aristocracy of inherited wealth had once more begun to believe as they did just before the French revolution, that farming was the appropriate vocation of the horned-handed toiler, that science was the domain of the pale student, that shopwork was for the masses, and that "society" was the true and eminent domain of the "400" who constitute in every considerable community, the principal aggregation whose chief occupation is gossip, slander, scandal, card parties, ice-cream, and other dangerous messes,—just then, we say, it happened to become quite generally known that the whole world is one great farm; that the winds and the waves, in their work upon the rocks take part in it; that the birds and the beasts, in their ordinary modes of life, help along the great industry; that the world's true nobility of great men and women take a hearty interest in this larger farm; and that the only creatures who really hinder its beneficent operations are the insects, the fungi, the bacteria, and the human parasites who consume without helping to create the annual product of the world's great garden.

In general, for both home and school the state normal recommends a procedure something like that which is outlined below, both as a means of keeping in touch with nature in its most easily understood, most interesting, and most profitable aspects, and as an educational process of the highest value to teachers, to students, to literary workers, and to all others whose vocation tends to keep them indoors.

HOME AND SCHOOL GARDENS.

The work in home and school gardens should comprise the care and culture of plants, with daily observation of the vegetative processes of living forms. As a laboratory, the garden at home and at school may be employed to demonstrate the effects of careful tillage on the cultivated species. The subject matter of the lessons falls into two groups: (1) The rearing of the species cultivated for purposes of decoration about the home and the school—a work that will be aided by a spirit of refinement due to aesthetic motives. The aim here is to arouse in the students the desire to cultivate and the capacity to enjoy these forms of natural beauty; and this can be done only by having them work at it.

(2) Experimental growing of the useful grains, fruits, and other plants that constitute the main food and wealth of the nations. This work should be prompted by a desire to teach the pupils something of the world's greater processes of agricultural industry, and to direct those practical tendencies which all normal children possess, toward sharing in the world's work.

IN NATURE'S GARDEN.

The field work in nature's garden should comprise a personal acquaintance with the wild plant, and a knowledge of the service it performs in the field, forest, canyon, desert, etc. This object will be attained chiefly by voyages of exploration, to be taken by both teacher and pupil, with the view of discovering in the wild flowers those aspects and properties which justify scientific interest. The result of this kind of work is that it leads to practical application of the teachings of nature, and makes possible the appropriation or domestication of her products. This work has likewise two aspects: (1) the collection, study, and preservation of the more showy or artistic of the wild species; and (2) acquaintance by observation with the more unique or striking forms of the native flora—the "wonder" species with which the arid west so plentifully abounds.

Hitherto these articles, about 25 in number, have not been signed. It was thought sufficient to indicate that they emanated from and represented a certain phase of the work done in the state normal school. The writer now deems it proper to acknowledge their authorship, for he wishes to assume any possible responsibility that may attach to the statements which they contain. This addition of the writer's name was not suggested by any one connected with the university.

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