forms the backbone of Java, the intervening Sunda Strait being only fifteen miles across, the existing flora and fauna of Java are less like those of Sumatra than those of the latter are like those of Borneo. The biota of Java is, on the other hand, much more like that of the Siamese peninsula and northern India, and it is very interesting to find similar and apparently anomalous affinities shown as long ago as the Pleistocene and certainly before the submergence which gave the region its present physical geography.

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SPECIAL ARTICLES

SOME RELATIONS BETWEEN ROOT CHARACTERS, GROUND WATER AND SPECIES DISTRIBUTION

Observations on the root habits of desert shrubs indicate that the root-type of any species may be of importance in limiting the distribution of the species. This has been found to be especially clear in the case of plants having obligate tap roots, which, as a rule, are confined to relatively deep soils. Such shrubs as have a generalized root-system, on the other hand, have a wide local distribution, which may be correlated with the fact that the roots of these plants are capable of a large degree of modification in conformity with the pressure of the soil environment. But the rôle of the superficial type of roots, such as is typical of species with water storage capacity, is not so well defined. It is known that the fleshy cacti, for example, are most highly developed where the rainfall is a periodic one, occurring, perhaps, twice each year, but that these plants occur sparsely where the precipitation takes place once annually. Whatever may be the reason for this limitation, it is noteworthy that the larger mass of absorbing roots of species having a water balance lie within 10 cm. of the surface of the ground. The superficial soil layer is subject to the most intense desiccation, and, hence, carries moisture in sufficient amount for the use of plants for the shortest period only, so that plants depending on this stratum for moisture must either be short-lived or have the capacity of storing up water against the following period of drought. What the minimum absorption time of fleshy plants is, has probably not been determined, but it is evident, from their distribution, that the amount of available moisture in the superficial soils derived from a single rainy season each year is not sufficient. To put the case in another way, it is apparent that the general and local distribution of the fleshy cacti would be other than it now is, if such plants had another type of root-system, for instance, if there was an obligate deeply penetrating root-system, in place of the superficial one they now have. Such a change, were it possible, would, in the first place, limit the local distribution to flood plains or to other areas having deep soil, and, in the second place, it would permit a wider general distribution. This suggestion makes it evident that the root-soil moisture relation may be an important factor among those which determine the survival of a species.

Such observations as have been made on the root habits of trees indicate that in these large-bodied plants the root character may also be of importance among the factors which operate to influence their distribution.

It is now well established, at least for a portion of the Southwest, that there may be a very intimate relation between the occurrence of certain species of trees and the character of their roots, having regard to the depth at which perennial water may be found. Here trees occur along streamways, while the nearby upland may be treeless. The humidity of the two areas may not be very unlike, nor the rainfall, nor yet the temperature. The great difference, which is often striking, lies mainly in the soil conditions, particularly with regard to the depth to the ground water. On the bottoms the water table lies within reach of the roots of trees, while on the more elevated land it is far below them.

The depth to the level of ground water, or to the soil that is moistened from the water table, is usually not great. In the eastern portion of the United States, in lands of moderate elevation, water can commonly be obtained within 30–40 feet of the surface, while in the valleys the water lies at a depth of 15 feet, or less.[1] In the states of the middle west, as in Kansas and Nebraska, according to various sources, mainly the Geological Survey, the depth to ground water on the flood plains of streams varies from 10 to 40 feet, but the depth on the benches, valley sides and upland is from 60 to several hundred feet. A like condition is to be found in the more arid regions further west, while the more humid regions of the extreme West are similar, as regards depth to the water table, to the humid east. In rough and mountainous regions, the water reservoirs of whatever kind may be regarded as the physical equivalents of the water table of the more level country, and provide such plants, especially the trees, as penetrate to them, or to the soil moistened by them, with a perennial supply of water.

The various physical factors, climatic as well as those pertaining to the soil, which influence the distance to ground water, are, in the main, of significance in the physiological activities of the trees occupying an area. And, in addition to such factors, appropriate temperatures being assumed, the specific responses of trees to the water relation are to be considered. Chief among these are the water-retaining and water-absorbing capacities and adjustments, of which the root-ground water relation must be considered to be of great importance.

The general relations of trees to perennially moist soil, as indicated by the depth of the water table and by the distribution of trees and forests, and taken from a few widely separated regions, may be illustrated by a few examples.

In southern Arizona, in the vicinity of the Desert Laboratory, the distance to the water table, or to perennial ground water, is various. On the bajada, water is to be obtained at a depth of 70 feet, or over, while on the flood plains of the streams it lies from 15 to 35 feet beneath the surface. There is practically no arboreal flora on the bajada, but along the streams, and on their flood plains, occur ash, cottonwood and mesquite, the latter often forming an open forest of trees ranging as high as 40 feet, or more. The mesquite may be taken to illustrate the relation between trees of the vicinity and the depth to perennial water supply.

The mesquite is the most widely distributed tree of the Tucson region, occurring not only on the flood plains of streams, but on the higher bajada as well. The form of the species, however, when growing in such diverse habitats is quite unlike, since apart from the flood plains it assumes the form, not of a tree, but of a shrub. There is a close association between the dual habit of the mesquite as noted and the depth to the water table, which is also shown by a variation in the development of its roots.

The root-system of the mesquite is an extremely variable one. It may penetrate the ground deeply, or it may extend widely and lie not far beneath the surface of the ground, or, again, it may be of rather limited extent and of a generalized character. The first type of root is probably most characteristic of the tree form, and the last of the shrub form of the species, while the second arrangement may be connected either with the tree or the shrub habit. On the flood plain, roots of the mesquite as a tree have been seen to penetrate to a depth of 15–24 feet, or to the level of the water table. Under especially favorable soil conditions, as where it is fairly homogeneous and easily penetrable, the roots may attain a greater depth.

A comparison of the distribution of the tree form of the mesquite with maps which give the water table depths indicate that the species becomes a tree, soil conditions favoring, where the ground water does not lie deeper than 50 feet. On the other hand, where the water table is at a greater distance, or is otherwise not available, the shrub habit is assumed, with characteristic generalized root-system.

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[1] Crider and Johnson, "Water Resources of Mississippi," U. S. Geological Survey, Water-Supply and Irrigation Paper No. 159, 1906.

An extension of observations on tree distribution, as related to the depth of perennial water, to regions outside of southern Arizona, gives interesting, if not entirely conclusive, results. A comparison of the depth to ground water of the Coastal Plain of Texas, as given by Taylor,[2] with the tree distribution, as given by Bray,[3] for example, offers important suggestions in the present connection. In general, it may be said, that the stream bottoms of the Coastal Plain support a hardwood forest, which also extends over such upland as has a fairly shallowly placed water table. Such of the deciduous trees as are marked xerophytes, for example, the post oak, occur on dry ridges where pines of various sorts are also to be found, and where the depth to permanent water is considerable. Of these trees, the root habit of the long-leaf pine is known. This species has a long tap root which penetrates to a great depth and which renders the species in a measure independent of surface conditions of soil and moisture. In the more arid southern portions of the Coastal Plain, where the water table lies below 50 feet, chaparral is characteristic of the upland, and, along the streams, where the water table is less deep, forests occur.

Northward from Texas, as well as westward from the Coastal Plain of the state, are to be found conditions analogous to much already noted for southern Arizona and the Coastal Plain. That is, other things being equal, trees and forests, especially deciduous forests, are limited to areas where the depth to the water table is not great. Thus, in Kansas and Nebraska, the deciduous forests are mostly confined to the flood plains of streams, while the adjacent upland is treeless.

As one examines other regions (reference is made more in particular to those that are semi-arid) he finds forests confined to such areas as are underlain by ground water not beyond the attainment by the roots of trees.

Although it is not practicable at present to give in detail the relation of tree roots to the water table in the more humid regions, enough is known to justify the belief that often there is a very intimate relation between the two, according to Bowman.[4] For example, the level of the ground water is said always to be lower in a forested tract. The same writer states that the greater supply of moisture for trees is derived from deeper lying sources, *i. e.*, than which supplies shallowly rooted plants. The roots, also, which supply the moisture, descend to a point a little above the surface of the ground water. If the level of the water table changes greatly, the trees suffer either from lack of moisture, or from poor aeration, according as it is lowered or raised. The variation in depth to the ground water, however, does not affect trees having superficial roots, or at least roots which do not attain it, and such species are well adapted for growth where the water table is high, or the upper soil is shallow. The ecological importance of this is apparent, and may be illustrated by a single example. Rossmässler[5] mentions trees which are characteristic of two habitats, of which one is rough and stony, and the other is underlaid by an impervious clay. Oaks and pines form a mixed forest in the first habitat, and of these the oaks at least have deeply penetrating root-systems. In the second habitat there is only *Picea*, since the soil depth prevents such root development as is characteristic of the other species.

An important phase of the study of the relation of roots to the water table lies in observing the range of variation under natural conditions. Specialized roots, such, for example, as were mentioned at the beginning of this note, are, generally speaking, not capable of great variation. Hence, plants with this character of a root-system, and for this reason only, may have sharp bounds placed on their distribution. On the other hand, generalized root-systems are often variable to a high degree, and, corresponding to this fact,

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[2] U. S. Geological Survey, Water-Supply and Irrigation Paper No. 190, 1907.

[3] U. S. Dept. Agric., Bureau of Forestry, Bull. No. 47, 1904.

[4] "Forest Physiography," p. 42, etc., 1911.

[5] "Der Walde," p. 31, 1881.

the species bearing generalized roots may have a relatively wide distribution, occurring in widely different habitats. Cowles[9] gives an interesting example of the relation between root variation and species range. The red maple grows in swamps and also on dry grounds. The root character of the tree on the two habitats is very unlike. In the swamps the tap root is not largely developed, but the laterals are prominent, while in the dry situation the reverse is the case, the tap root being the leading characteristic of the root-system.

The problems which deal with the presence of trees are primarily physiological and have mainly to do with the absorption and conservation of water. Each of these capacities varies with the species. Of the root relations that of the root-water table is of prime importance, owing to the fact that the soil horizon, tapped by the roots of trees, derives, by capillarity, from the level of ground water, its perennial supply of moisture. In the semi-arid regions probably the roots of most trees attain to the perennially moist soil, sometimes to the water table itself, at least for a portion of the year, and, in the more humid regions, the roots frequently do so. In both regions, certainly in the former, wherever such is not the case, a variety of factors, which need not be discussed in this place, are of greater importance in the survival of the species than the water table depth, although the character of the root-systems may still be of much, possibly of definitive, importance.

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INORGANIC COLLOIDS AND PROTOPLASM[1]

BREDIG[2] has shown that inorganic colloidal solutions, such as silver, platinum and gold, may act as catalyzers in certain chemical reactions, such as the reduction of hydrogen peroxide to water, and while chemists have studied the problem of the action of catalyzers from this standpoint, biologists have signally avoided attempts[3] to determine whether the activities of the enzymes of the organism can be imitated by these inorganic catalyzers. It must be remembered in any such examination that, as Ostwald[4] has demonstrated, along with others, enzymes of any nature are incapable of instigating a reaction, but their function is solely that of modifying the Guldberg-Waage mass action equation for a given instance, either accelerating or retarding a reaction already in progress. Therefore, we should not expect to find a striking modification of the actions or of the structure of any organism, if any effect were obtained by the application of inorganic "enzymes."

In a series of experiments, I attempted to determine whether colloidal platinum and a colloidal gutta percha[5] gave evidence of any effect upon simple organisms, such as protozoa and single-celled plants. Platinum black was obtained by the use of the house current, reduced to about 70 volts, passing it through a lamp-board, the current delivered to water which had been glass-distilled, the electrodes being of platinum, according to the Bredig method.[6] In order to be certain that the solution was desirable for experimentation, it was examined over a Zeiss dark-ground con-

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[9] "Text-book of Botany," Vol. 2, Ecology, p. 506.

[1] Presented in abstract form to the Columbia University Biochemical Association and outlined in the *Biochemical Bulletin*, II., 1, 1912.

[2] "Anorganische Fermente," Leipzig, 1901.

[3] Benj. Moore (in "Recent Advances in Physiology and Biochemistry." L. Hill, Edt. London: Edward Arnold, 1908; Chapter 4, p. 122) mentioned having performed injection experiments with platinum sol on animals, but he gives no details; he obtained negative results. Autolysis has been shown to become accelerated under the influence of colloidal metals. (See Ascoli and Izar, *Biochem. Zeitschr.*, Bde. 5, 7, 10, 14 and 17; also Doerr, same journal, Bd. 7.)

[4] "Uber Katalyse," *Vortrag auf d. Ges. d. Naturf. u. Arzte*, 1901.

[5] Professor Henry A. Perkins, of the Jarvis Physical Laboratories, Trinity College, prepared this solution after the formula which he used in the laboratory of Professor Perrin at the Sorbonne, and I am indebted to him for the kindness.

[6] *Zeitschr. f. angew. Chemie*, 1898, p. 951.