äußeren Bedingungen als die übrigen Vertreter der Art. Dieses individuelle Leben ist es nun, welches dem Keimkomplex — von Befruchtung zu Befruchtung — eine besondere Färbung aufdrückt, und, ich möchte so sagen, den Ausgangspunkt der Kombinationen immer wieder von neuem verändert und verschiebt, so dass der noch nicht ausgenutzten Kombinationen kein Ende ist. In der wechselnden Stärke dieser individuellen Färbung sehe ich übrigens die Möglichkeit der Erklärung, warum ein Individuum, trotzdem es einer Vielheit entstammt, doch überwiegend die Züge eines der Ahnen tragen kann. In zweiter Linie denke ich mir, dass im Lauf der großen Zeiträume die ältesten Keimsubstanzen teils eliminiert werden, teils, wenn sie einen gesicherten Bestand für die eingeschlagene Entwickelungsrichtung bilden, Viele zu Einer, vielleicht vom höheren Rang, kondensiert werden. Im einzelnen kann ich das Gesagte nicht ausmalen und konsequent durchführen, ich wollte nur einigen Missverständnissen vorbeugen und ich glaube, dass folgender Ausspruch von Weismann den allgemeinen Sinn dessen, was ich im Auge habe, illustriert: „Die Ide eines Wurmes der Vorwelt können nicht unverändert heute das Keimplasma eines Elephanten zusammensetzen, auch wenn es ganz richtig ist, dass die Säugetiere von Würmern abstammen. Die Ide müssen sich seither unzählige Male umgestaltet haben durch Umbildung, Verkümmerung und Neubildung von Determinanten[1]." — Außer den genannten, relativ geringfügigen Änderungen im Keimbestand muss es notwendig langsam, aber andauernd wirkende, aus inneren, gleichsam zielbewussten Entwickelungsrichtungen entspringende Änderungen geben, und auf diese letzteren gründet sich die mannigfaltige Gestaltung der Lebewelt; Selektion legt, meiner Ansicht nach, nur die letzte ausgleichende und regulierende Hand. — Doch diese schwierigen Fragen würden mich zu weit vom Thema ableiten.

(Schluss folgt.)

The Desert Botanical Laboratory of the Carnegie Institution of Washington.

By F. E. Lloyd,
Member of the Staff.

The foundation of the Carnegie Institution of Washington by the generous endowment of Mr. Andrew Carnegie marked the beginning of the new era of scientific research in America. This was of course foreshadowed by the terms of the gift to science, and the results which have been attained in all fields of scientific activity since the latter part of 1902 have given grounds for the belief that, marked as the reward to knowledge has been, the

1) A. Weismann, Vorträge über Deszendenztheorie. Bd. II, p. 219.

future will see a normal but yet more rapid development of the Institution. This is assured by the appointment of Professor R. S. Woodward, formerly of Columbia University, a man of high scientific attainments and a keen appreciation of the function of science added to a remarkable gift of executive ability, as President, in the early part of 1905.

It is the purpose of this sketch to give an account of the work of the Carnegie Institution in the field of botany, aside, however, from that of the special Grantees, whose individual work, which has become known to botanists through the pages of the botanical magazines, has been carried on independently. I refer, in particular, to the Desert Botanical Laboratory. It will be of interest to trace briefly the historical development of the idea which culminated in the foundation and equipment of this particular branch of the Institution.

Among other advisory committees appointed during the first year of the existence of the Carnegie Institution, was one, naturally, on Botany. This Committee, consisting of Professor N. L. Britton, Professor John M. Macfarlane and Mr. Gifford Pinchot, with Mr. Frederick V. Coville as Chairman, presented a report embodying an extensive plan for the development of botanical research and containing a number of propositions of which one, which here interests us, was the following. "There should be established at some point in the desert region of the Southwestern United States a laboratory for the study of the life history of plants under desert conditions, with especial reference to the absorption, storage and transpiration of water." The report went on to point out that there existed up to that time nowhere in the world such a laboratory, although, as is well known, there were many laboratories in the humid regions of the earth. The economic importance in the long run, of such work, carried on under the freedom of the methods of pure science, were also pointed out[1]).

This idea immediately bore fruit in the appointment of a second committee which was requested "to go to the arid lands of the west and make such further recommendations as might seem to them best" The gentlemen thus appointed were Mr. Frederick V. Coville and Dr. D. T. MacDougal, two persons eminently fitted to undertake the task assigned to them. Mr. Coville had, in 1891, been a member of the now famous Death Valley Expedition, and this, together with his other desert experience, gave him the basis for a ripe judgement. Dr. MacDougal was also in the position of an expert, having carried out a number of extensive excursions into the markedly desert regions of the Southwest United States.

1) Car. Inst. Wash. Year Book, No. 1, 1902.

In order to the carrying out of the work, these two gentlemen travelled together through all the typical desert areas which promised suitable conditions, and the results of their study of the problem were embodied in a Report published under the title of "The Desert Botanical Laboratory of the Carnegie Institution"[1]). This is a volume of 58 pages, illustrated by 29 full pages plates reproducing typical illustrations of the deserts visited, and five figures. This paper included, besides the final conclusions of the Committee as to the most suitable position for the laboratory, a large amount of scientific information pertaining to the character of the soils and meteorological conditions of the areas treated of. An extensive bibliography, compiled by Dr. W. A. Cannon, was also an important feature of this publication, and has served as a guide in laying the foundations of a special library of the literature pertinent to the work of the laboratory.

During the excursion made by the Committee, the deserts of Texas, northern Chihuahua and Sonora in Mexico, New Mexico and Arizona were examined, and the conclusion arrived at was in favor of the region about the city of Tucson, in Pima County, in the Southern part of Arizona. The later developments have, it would seem, amply justified the choice, one which involved a number of considerations. There should be a typical and abundant vegetation of a drought resistant character to constitute the materials for research. A too severe climate had to be avoided, and the laboratory must be near enough to a centre of population for social and practical reasons, and these the city of Tucson and the surrounding deserts offered. The appreciation of the people of the city was expressed in the practical form of subsidies of land for the site of the building and to serve as a preserve for desert vegetation, the installation and construction of a water system, telephone, light and power connections, and of a road to the site of the laboratory, about two miles distant.

The same committee was continued as a Directorate of the Laboratory, and the plans for the building were drawn up under their supervision. Upon completion, Dr. W. A. Cannon then at the New York Botanical Garden, was appointed Resident Investigator, and took immediate charge. During the first year investigations were carried on at the Laboratory by Dr. W. A. Cannon, Dr. D. T. MacDougal, Professor V. M. Spalding, E. S. Spalding, Dr. B. E. Livingston and Professor F. E. Lloyd, and these, with the exception of Dr. Livingston continued their work during the whole or a part of the following year.

These two years have to be considered as a period of testing

1) Car. Inst. Wash. Publication 6, 1903.

the various methods of promoting research by the Board of the Carnegie Institution, and at its close, a plan was proposed by the President, Professor Woodward, by which the resources of the Institution are henceforth to be used chiefly in forwarding the investigations in progress at the various special stations and laboratories which have been founded under its auspices, in contradistinction to the making of a large number of small special grants. Thus the Desert Botanical Laboratory becomes now the centre of a Department of Botanical Research, and the Directorship has been given to Dr. D. T. MacDougal, recently Assistant Director of the New York Botanical Garden, and a member of the original advisory committee.

The city of Tucson, near which the Laboratory stands, with a population of 15000 is situated in the valley of the Rio Santa Cruz, its position being central with respect to the deserts of California, Mexico, Texas, New Mexico and Northern Arizona, an area embracing 12° of latitude and 16° of longitude roughly speaking. With an elevation of 2,390 feet above sea level, it has a dry and bracing climate, and thought hot in the summer, still on account of the low relative humidity, not uncomfortable. The soil is a fine clay or "adobe" underlaid in most of the area by a hard pan of white material derived by the leaching out of the soil, and known locally a "caliche". Without doubt, wherever this caliche occurs it is a prominent factor in the determination of the character of the vegetation. Two miles to the westward are to be seen the out posts of the Tucson Mountains, rugged hills of volcanic origin. On the more gradual northerly face of one of these stands the laboratory, a building appropriately constructed of volcanic boulders. The style in simple and well adapted to the climate. The thick stone walls heat slowly, particularly as they are for the most part protected from the direct rays of the sum by a widely overhanging roof. This latter is so constructed as to form a large ventilatel air chamber, thus affording a protection against the intense insolation as well as affording comfort to the occupants by modifying the intense light.

The original building was in the form of the letter L with the longer extension facing the north. At the present time an addition is approaching completion which doubles the capacity of the building. The main portion, facing the north is 126 feet long, two lateral wings extending southward from either end to a length of 36 feet. The new wing will be in part a glass house 20 feet long for experimental purposes. The breadth of the main portion of the building is 23 feet, of the wings 19 feed. The interior is suitably broken up into rooms, including a main general laboratory, offices, stock-room, photographic dark room, constant temperature chamber, cut into the rock below the level of the floor, and special laboratories. A deck for the mounting of meteorological instruments surmounts the roof. The interior finishing is in California Redwood. Fire places and lavatory render the whole a commodious and well equipped building large enough for some years to come.

The surrounding country presents features of rare beauty. To the northeast stands the range of the Santa Catalina Mountains, its rugged topography standing out in bold relief when the sun lies low in the heavens. Between, lies a low, level or gently undulating mesa for a distance of fifteen miles, covered chiefly with a uniform growth of *Covillea* (*Larrea*) *Mexicana*. In the water courses are a few cottonwoods (*Populus* sp.) giving way to mesquite (*Prosopis velutina*) on the adjacent flats and better watered rising ground. Here too is found a species of *Palo verde* (*Parkinsonia Torreyana*) another species (*P. microphylla*) of which is found affecting the rocky foot-hills. Interspersed with the greasewood or creosote-bush (*Covillea*) of the mesa are several species of *Opuntia*, among which a "Cholla" is the most conspicuous. This plant, and other closely recated species were formerly used by the Apache Indians as a means of torture, and it appears that they did not underestimate the effectiveness of these plants for this purpose. The penetration of the spines causes exquisite pain, and few botanists escape the experience at some time or other. The mountains themselves, on account of their elevation, offer a wider vertical range of vegetation, the higher ridges being the home of the pines and cedars. The main ridge, of which Mount Lemmon is the highest peak, is heavily forested with yellow pine (*Pinus ponderosa*) and Douglas Spruce (*Pseudotsuga*). Thus we may pass in a few hours journey on horseback from the vegetation of the desert mesa to the dense forest, where snow, on the northerly slopes at least, stands the whole year round.

To the east may be seen the Rincon Mountains, the most prominent feature being the bold rounded height of the Tanque verde. Further to the southward stand the Santa Rita Mountains, while at still greater distances rise to other ranges, all with great stretches of mesa lying between.

In the more immediate vicinity of Tucson the vegetation may be divided for the purposes of this description into two formations, that of the mesa, and that of the rocky foothills. I have already mentioned the leading plants of the former. The foothills bear a more varied flora, and perhaps the most characteristic of the region. It is here that we find the great cactus, *Cereus giganteus*, or saguaro. The columnar stems of this great plants stand in numbers overtopping the rest of the vegetation. The commonest shrub, or rather small tree is the palo verde (*Parkinsonia microphylla*) but we find intermingled with it a Celtis, a Lycium, and more notably, the Ocotillo (*Fouquieria splendens*). In the spring the whip like branches each bears a mass of scarlet flowers, and make a gorgeous show. Of the still smaller shrubby growths are, more prominently, the Franseria and an Encelia, both furnished with woolly leaves. The latter makes in the month of April a splendid mass of yellow flowers. These are of course supplemented by very numerous annuals and smaller perennials. Several species of cacti, in addition to the above are present. Two species of flat-stemmed *Opuntia,* and an arborescent type. *Opuntia versicolor*, a small *Mamillaria*, a small *Cereus* (*C. Fendleri*), with fine magenta flowers, and a barrel Cactus, *Echinocactus Wislezeni*, are the chief. Other localities afford numerous other species, but I have mentioned these few merely to suggest the richness and general character of the flora.

The distributional relations of this vegetation may be indicated in a general way by the following data, kindly supplied to me by Professor V. M. Spalding. Within the boundaries of the Laboratory reservation there are 146 genera and 195 species of these genera, 70 are world wide in their distribution, while 34 are common to N. and S. America, 19 of these following the Cordillera north and south. Of the lot, 28 are limited to Arizona and adjacent territory, or extend along the mountains of western N. A. Of the species, 163 are restricted to their speculiar area in Arizona and adjacent territory. 13 ware idely distributed in n. A., 7 are common to N. and S. America, while only three, aside from introduced weeds, are found in the eastern and western hemispheres.

The whole area of ground which pertains to the Laboratory covers 860 acres, all of which is now fenced in and thus protected from damage by animals. The area includes a stretch of mesa cut by a "wash" that is a small stream bed usually dry, excepting during heavy rains, and, for the major portion, of the volcanic foothills on which the building stands.

I append a summary of the work which has thus far been carried on at the Desert Botanical Laboratory by those who have been officially connected with it during the period up till the present time.

Dr. MacDougal has been engaged in field work and explorations in the American deserts for the U. S. Government and for the New York Botanical Garden since 1891. Since, his connection with the Desert Laboratory he has cooperated with Mr. F. V. Coville in a general geographical study of the North American Deserts, and has devoted special attention to the arid regions about the head of the Gulf of California in which opportunity has been taken to make some general comparisons betwen the mesophytic vegetation of the delta of the Rio Colorado, and the adjacent deserts. One of the most interesting generalizations obtained set forth the fact that plants with storage organs for water were given highly characteristic of arid regions in which the total precipitation occurs within a very short period each year, these structures being noticeably absent from plants of regions which receive a scant rainfall redistributed in small quantities throughout the year.

Dr. W. A. Cannon came to the Desert Laboratory as Resident Investigator in the autumn of 1903 and since then has been engaged on studies on the transpiration and the structure of the desert plants in the vicinity of the Laboratory. Some of the results of the studies on transpiration may be briefly presented.

By a method perfected at the Laboratory[1]) the transpiration of plants was observed at different seasons while they were growing undisturbed in their habitats. Among other things it was learned, other things being equal, that a marked acceleration of rate took place with an increase in the available water supply. This was noted in leafless as well as in leafy forms, and in the latter with or without an increase in the area of the transpiration surface. The variation in rate between seasons of extreme drought and seasons of rain was very marked particularily in leafy forms. In *Fouquieria splendens*, for instance, the ratio was 1 : 32. But in the leafless plants it was much less. The highest rate noted for the leafy condition of the leafy forms of typical desert perennials was quite as high as the rate of the desert annuals or of such mesophytic plant as the sugar beet. The minimum of the former, however, is probably much more than that of the latter class.

In addition to work on independent plants some observations were made on the transpiration of the parasitic Phoradendron and its hosts. The rate of transpiration of the mistletoe is frequently greater than that of the host. The studies show, however, that the rate may be a variable one, being higher near the main stem of the host than more remote from it. That is, the variation may be associated, as is the case in the independent plants, with the variation in the water supply.

Under a grant from the Carnegie Institution Dr. B. E. Livingston spent the major portion of the summer of 1904 at the Laboratory, studying the moisture conditions of the soil and atmosphere, under which desert plants are obliged to exist during the summer season. A summary of this work may be given as follows. 1. The deeper soil layers of the hill on which the Laboratory stands contain at the end of the dry season, and thus probably at all times, a water content adequate to the needs of those desert plants which are active through the months of drought. This con-

1) Bull. Torr. Bot. Club, 32 : 515. 1905.

servation of soil moisture is largely due to the high rate of evaporation and the consequent formation of a dust mulch. It is partly due to the presence of rock fragments and of a hard pan called caliche.

Desert forms show an adaptation to existence in dry soil, being able to exist in soils somewhat dryer than those needed by plants of the humid regions. This adaptation is however comparatively slight, and cannot be considered of prime importance.

The downward penetration of the water of precipitation is slow through the adobe soil itself, but comparativlely rapid on the whole, on account of the presence of numerous oblique rock surfaces along which the flow is not markedly impeded.

By the middle of the summer rainy season all of the soil excepting the first few centimeters is sufficiently moist to allow germination and of growth most plants. The surface itself is often wet for several days at a time during the period of summer rains.

The seeds of *Fouquieria splendens* and of *Cereus giganteus* fail to show any special adaptation to germination in soils dryer than those needeed by seeds of such mesophytes as *Triticum* and *Phaseolus*. Immediately following germination the seedlings of desert plants exhibit a slow aerial growth but an excedingly rapid downward elongation of the primany roots so that these should soon attain to depths where moisture is always present in adequate amount for growth.

The high moisture retaining power possessed by the soil of the laboratory hill holds near the surface much of the water received from single showers, and offers excellent opportunity for the rapid absorption of this by such shallow rooted forms as the cacti.

The saps of *Cereus*, *Echinocactus* and *Opuntia* exhibit osmotic pressure no higher than those commonly found in plants of the humid regions.

The effect of air currents in increasing evaporation and transpiration rates is so great that reliable measurements of transpiration cannot be made in closed chambers.

By means of a new method, involving a newly devised evaporimeter, a physiological regulation of the rate of transpiration was shown unquestionably to exist in the forms studied. This regulation appears to be most probably due to stomatal action responses.

The regulation of transpiration seems to be controlled by air temperature, the checking of water loss beginning to be effective between 79° and 90° F., and the check being removed between 75° and 80° F.

The ratio of transpiration rate per unit of leaf surface to evaporation rate per unit of water surface is termed relative transpiration. Relative transpiration is reduced by the regulatory response from unity in the high periods to from $^1/_{12}$ to $^1/_{16}$ in the low periods.

Professor V. M. Spalding began his work at the Desert Laboratory in the autumn of 1903, having received leave of absence from the University of Michigan for this purpose. He undertook an investigation of the biological relations of certain desert shrubs which exhibit a wide range of adaptibility, retaining more or less pronounced mesophytic habits, but capable of surviving extreme drouth and usually classed as typical xerophytes. The success of these plants in resisting infavorable conditions, though manifestly due in large measure to the perfection of their arrangements for preventing excessive transpiration, is also to be attributed to a remarkable combination of favorable structures and habits. The close relation existing between rate of transpiration and available soil moisture was demonstrated in the case of various species in accordance with results previously obtained by Aloi and Feruzza, and experiments to determine the relation relative efficiency of several methods of supplying water to the roots of the same plants have been carried out with definite results. In 1904—1905 Professor Spalding, under a grant from the Carnegie Institution. conducted an investigation regarding the absorption of water and water vapor by the leaves and shoots of desert plants. It was found that different species differ widely in their capacity for subaerial absorption. It does not appear that this is of direct physiological importance, though it may become an advantage indirectly by preventing excessive transpiration, and may even result in leaf formation, as was shown by Lloyd in the case of *Fouquieria*. This work has been continued through the early part of the present year during which a more comprehensive study, including certain habitat relations of plants growing in the vicinity of the Desert Laboratory, had been in progress.

F. E. Lloyd spent two summers at the Laboratory which were occupied in a study of the physiology of stomata, and this work is now being continued in residence. The plants examined in particular are the *Ocotillo* (*Fouquieria splendens*) and a verbena (*V. ciliata*). It has, in the first place, been found possible to preserve stomata in their natural form so that the size of the openings may be studied with great exactitude. The result of the work may be summarized as follows, all statements applying to both plants except when otherwise mentioned.

The rate of transpiration is not controlled, except perhaps with in broad limits, by the size of the stomatal openings. Very marked changes in the rate either increasing or decreasing it, may occur without any a preciable change in the stomata. It is therefore to be concluded that in these plants the stomatal mechanism hardly be regarded as regulatory of transpiration in the sense of certain previous students.

This conclusion is strengthened by the results of experiments on wilting, which in Verbena, show that, not only does an opening of the stomata previous to wilting, as held by Leitgeb and Fr. Darwin, fail to occur, but the closure actually lags behind. Thus the teleoligical significance of stomata on this score may very seriously be called into question.

Numerous experiments have shown that, under constant conditions and in the total absence of light, the curve of transpiration shows at about 6 A. M. a maximum which apparently must be interpreted in terms of habit, that is as „eine von äußeren Einflüssen unabhängige Periodizität", thus giving support to Unger, Sachs and Sorauer. This periodicity may not be interpreted as supposed by Fr. Darwin and C. C. Curtis, to be dependent upon stomatal movements.

The stomata of the plants studied are found to be devoid of chlorophyll, and this has been found true of a very considerable number of others. Contrary to the general supposition, these stomata are quite as active, or indeed more so than in some instances, as those possessing chlorophyll. This fact, led the writer to examine with great care the daily course of stomatal activity, with respect not only to the movements, but also to the conditions of the contents of the guard cells. It was found that the maximum opening occurs in the summer at nine A. M. and continues till twelve M. The stomata then close slowly during one to three hours, and remain almost closed till sunrise on the following day. Further light is thrown upon this procedure by the behavior of the contents of the guard cells in *Verbena*, in which the amount of starch is observably variable. The maximum starch content is to be found during the night and till sunrise. At this time the starch begins to undergo depletion, until it is reduced to a minimum at from nine till 11. 30 A. M. according to the time of the year, the higher temperatures hastening the depletion. Very soon the reverse takes place, and the amount of starch again increases. This occurs in the dark, and at both ends of the spectrum separately, and also in the absence of Carbon dioxid. The stimulus of light seems however to be necessary to the opening of the stomata. We are thus able to differentiate two distinct processes, mechanical and nutritive, and to follow these separately. In addition to the starch content there is present a certain times an oil[1]) presenting, in some regards an inverse action to that of the starch. It is present in

1) Oil has of course been observed by various students in the guard cells of stomata.

minimum amounts in the early morning, but increases materially during the period in which the starch is being depleted. After the maximum amount is reached, it again disappears, and at night none is present. Its behavior in the dark and in the absence of CO_2 is not yet fully understood, and there is collateral evidence that this substance is not concerned in the intimate physiology of the stoma, at any rate as regards the movements. The evidence thus afforded indicates that the physiology of the guard cell is distinctly different from that of the chlorenchyma cells[1]). The guard cell plastids are secretory but not a carbon-assimilative (photosynthetic) and the movements result from enzymatic activity stimulated by light and controlled by temperature, a view outlined, but hardly supported by convincing evidence, by F. G. Kohl, and finding collateral evidence in the work of Green upon the relation of enzymes to the various lights.

The evidence may not here be enlarged upon, but it may be asaid that it throws considerable new light upon the old and vexed question of stomatal physiology.

It may be added in conclusion that the research, the bare outlines of which have been given above, indicate in general the trend which the work to be carried out at the Desert Laboratory will be made to take in the future.

K. Escherich, Die Ameise, Schilderung ihrer Lebensweise.

Mit 68 in den Text gedruckten Abbildungen. 8°, XX und 232 S. Braunschweig, 1906. Verlag von Fr. Vieweg und Sohn.

Unsere Kenntnis der Lebensweise der Ameisen ist in den letzten Jahrzehnten durch zahlreiche in- und ausländische Forschungen so erheblich vermehrt worden und das allgemeine Interesse für dieselben hat sich zugleich so sehr gesteigert, dass eine knappe, übersichtliche Zusammenfassung derselben dringend erwünscht war. Sowohl dem Naturforscher, der, ohne selbst Ameisenbiologe zu sein, doch die Ergebnisse dieser Wissenschaft kennen lernen will, als auch dem gebildeten Laien wird daher die vorliegende Schrift Escherich's über die Ameise sehr willkommen sein. Sie hat die Aufgabe, die einer solchen Schrift gestellt werden muss, die Forschungsresultate gründlich, allseitig und in übersichtlicher Kürze zusammenzustellen, in wirklich vortrefflicher Weise gelöst. Dass in manchen Punkten noch Ergänzungen oder Verbesserungen für eine neue Auflage angebracht werden können, ist bei einer so umfassenden Arbeit selbstverständlich. Auch die Ausstattung der Schrift Escherich's ist durchaus zweckentsprechend.

---

1) The chloroplasts offer a constant and close check upon the conditions of the starch content of the guard cell plastids.