Publications Committee

BULLETIN

OF

THE UNIVERSITY OF TEXAS

No. 194.

ISSUED FOUR TIMES A MONTH

SCIENTIFIC SERIES NO. 20 AUGUST 8, 1911

The Anatomy and Some Biological Aspects of the "Ball Moss," Tillandsia recurvata L.

By

Willie I. Birge

Formerly Graduate Assistant in Botany

PUBLISHED BY THE UNIVERSITY OF TEXAS

AUSTIN, TEXAS

Entered as second class mail matter at the postoffice at Austin, Texas

PUBLICATIONS

OF THE

UNIVERSITY OF TEXAS

The publications of the University of Texas are issued four times a month. They are arranged in the following series: RECORD, MINERAL SURVEY, GENERAL, HUMANISTIC, MEDICAL, SCIENTIFIC, REPRINT, UNIVERSITY EXTENSION, OFFICIAL, PRESS. For postal purposes they are numbered consecutively as Bulletins without regard to the arrangement in series. With the exception of the special numbers any Bulletin will be sent to citizens of Texas free on request. Communications from other institutions in reference to exchange of publications should be addressed to the University of Texas Library.

THE UNIVERSITY OF TEXAS RECORD has been issued from two to four times a year since December, 1898, and is now in its 10th volume. Its purpose is to preserve a record of the life and progress of the University, and for that reason it is of special interest to alumni, ex-students, and friends of the University. Upon request it will be regularly mailed, free, to any citizen of Texas. Address THE UNIVERSITY OF TEXAS RECORD, Austin, Texas.

The bulletins of the UNIVERSITY EXTENSION AND OFFICIAL series, consisting of Announcements of Courses, Catalogues, Regents' Reports, and administrative matter, will be mailed free to any one upon request.

The University still has for distribution copies of the following bulletins:

GENERAL SERIES

4. *Courses of Study in Law Pursued in the University of Texas*, by J. C. Townes, 16 pp. March, 1904.
7. *The Consolidation of Rural Schools*, by Una Bedichek and G. T. Baskett, New edition, enlarged by A. C. Ellis. 85 p., illus. November, 1907. 25 cents.
11. *What Should be Done by Universities to Foster the Professional Education of Teachers?* by W. S. Sutton. 24 p. 1905. 15 cents.
16. *A Study in School Supervision*, by Carl Hartman. 180 p. 1907. 50 cents.
17. *Religious Activities at the University of Texas*. 53 p., illus. August, 1909.

HUMANISTIC SERIES

5. *The Grotesque in the Poetry of Robert Browning*, by Lily B. Campbell. 41 p. April, 1907. 25 cents.
6. *The Beginnings of Texas*, by R. C. Clark. 94 p., map. December, 1907. 75 cents.

(Continued on inside back cover)

252-811-800-4954

BULLETIN

OF

THE UNIVERSITY OF TEXAS

No. 194

ISSUED FOUR TIMES A MONTH

SCIENTIFIC SERIES NO. 20 AUGUST 8, 1911

The Anatomy and Some Biological Aspects of the "Ball Moss," Tillandsia recurvata L.

By

Willie I. Birge

Formerly Graduate Assistant in Botany

PUBLISHED BY THE UNIVERSITY OF TEXAS

AUSTIN, TEXAS

Entered as second-class mail matter at the postoffice at Austin, Texas

TABLE OF CONTENTS

THE ANATOMY AND SOME BIOLOGICAL ASPECTS OF THE BALL MOSS, TILLANDSIA RECURVATA L.

Habitat and Hosts

Tillandsia recurvata, popularly called "ball moss," belongs to the *Bromeliaceae* or Pine-apple family, which consists largely of semi-tropical and tropical species. In the vicinity of Austin, *Dendropogon usneoides* on the lowland timber and *Tillandsia recurvata* on the upland timber form a characteristic feature of the landscape. (Fig. 1.)

In regard to its distribution on the various kinds of trees, *Tillandsia recurvata* is almost cosmopolitan. In this locality it has been found in a flourishing condition on the following trees:

Cedar, Red, *Sabina Virginiana* (L.) Antoine
Cedar, Mountain, *Sabina sabinoides* (H. B. K.) Small
China-tree, *Melia azedarach* L.
Cottonwood. *Populus deltoides* Marsh
Crepe Myrtle, *Lagerstroemia Indica* L.
Elm, White, *Ulmus Americana* L.
Elm, Small-leaved, *Ulmus crassifolia* Nutt.
Forestiera, *Adelia pubescens* (Nutt.) Kuntze
Hackberry, *Celtis Mississippiensis* Bosc.
Hackberry, *Celtis reticulata* Torr.
Holly, *Ilex decidua* Walt.
Hop-tree, *Ptelea trifoliata* L.
Maple, *Acer saccharinum* L.
Mesquite, *Prosopis glandulosa* Torr.
Mulberry, *Morus microphylla* Buckl.
Mulberry, Paper, *Broussonetia papyrifera* (L.) Vent.
Oak, Black-jack, *Quercus Marylandica* Muench.
Oak, Live, *Quercus Virginiana* Mill.
Oak, Post, *Quercus minor* (Marsh.) Sarg.
Oak, White, *Quercus alba* L.
Osage Orange, *Toxylon pomiferum* Raf.
Peach. *Amygdalus Persica* L.

- Pecan, *Hicoria Pecan* (Marsh.) Britt.
- Persimmon, Mexican, *Brayodendron Texanum* (Scheele) Small
- Plum, *Prunus Americana* Marsh.
- Prickly Ash, *Fagara Clava-Herculis* (L.) Small
- Sycamore, *Platanus occidentalis* L.
- Walnut, *Juglans nigra* L.
- Wild China, *Sapindus marginatus* Willd.
- Willow, *Salix nigra* Marsh

In spite of its apparently wide distribution, *Tillandsia recurvata* shows a strong preference for those trees possessing deciduous foliage and rough bark. Such trees not only present a more accessible adhesive surface for the minute, hooked *comae* of the seeds, but it is also highly probable that there is sufficient moisture in their crevices to insure more ready germination of the seed. The smooth-barked trees, such as the sycamore, umbrella-tree, pecan and the willow, are rarely infected with *Tillandsia recurvata*. If, however, conditions suitable for germination prevail at the time of seed dispersal, it will soon establish itself upon these and even upon such unlikely substrata as old board fences, postoak fences, granite boulders and electric wire insulations.

The position of *Tillandsia recurvata* upon its host depends mainly on the direction of the prevailing winds and upon the relative light conditions. In this region of variable winds, it establishes itself upon all sides of the tree. Soon after the bursting of the capsules seed may be found clinging to the trunks, limbs, branches, and twigs of the trees and shrubs of the vicinity. Just what influence the factor of light has on the position of this *Tillandsia*, on its host, is an interesting problem. In the field it seems to prefer light, open places. The marginal trees of almost any closely standing infected group are much more heavily beset than the central ones. Conditions of medium light are more suitable for its successful growth than either dense shade or intense sunlight. Consequently, on deciduous trees in the open, the outer portions of the lower limbs of the central part of the crown are more densely covered with the moss than either the lowest branches or the terminal portion of the crown. On such an evergreen as *Sabina sabinoides*, which possesses a densely shaded crown, only the lower branches become infected with the "ball moss." The occurrence of heavy bunches on many of those limbs which have been entirely girdled by the cedar fungus, *Cyanospora*[2], probably gives rise to the current belief that the "ball moss" kills cedars and junipers.

There are two reasons why *Tillandsia recurvata* does not grow as well on the lower branches as on the upper ones: first, the suitable amount of sunlight is not available; and second, the atmospheric circulation of the lower stratum is so poor that it is impossible for the plant to obtain a sufficient amount of moisture for sustained and continuous growth. Frequently plants having their attachment on the lower side of the branch will grow up and around it in order to obtain a more suitable light adjustment.

Range

In order to determine the exact distribution of *Tillandsia recurvata* in the Southwest specimens were sent to the Superintendents of Schools of the counties on the supposed border line with inquiry as to whether or not the plant grew in that region. The resulting information together with personal observations was used in making the map showing its distribution in Texas. (Fig. 4.)

This area has the appearance of an irregular triangle with its apex touching north latitude 31°, and included between the ninety-eighth and ninety-seventh meridians, and with its eastern and western sides cutting the Rio Grande at Brownsville and Del Rio respectively. Its northern range is determined by the cold of the winters. Eastward it follows the curve of from twenty to thirty inches of rainfall, although it ocasionally crosses this into the area receiving over twenty inches of rainfall in the hilly uplands of Goliad and Victoria counties. South and east of the latter, *Tillandsia recurvata* extends along the coast and the water courses into Mexico. The basal portion of the triangle extends for a considerable distance into the warm, semi-arid portion of northeastern Mexico. There is, however, in the southern portion of this area a small region having only ten inches of rain-fall, in Maverick and the western portion of Dimmit County, in which *Tillandsia recurvata* is not known to occur. The western extension of the "ball moss" may be represented by a line drawn from Bell County, north latitude 31° to Del Rio in the lower portion of Val Verde County. Practically the only exception in this western extension occurs in Kerr County, where it is probably too high for the successful growth of the "ball moss." It is quite evident that *Tillandsia recurvata* demands a semi-arid rather than a swampy environment to which Small[8] in his *Flora of the Southeastern United States* entirely confines it. In the southwestern portion of the boundary or the region of less rain-fall the "ball moss" is in many cases confined entirely to the river valleys, while in regions of more rain-fall it makes its most luxuriant development on the timber removed from the streams.

General Characters

Ball formation

If viewed from a distance, *Tillandsia recurvata* seems to enshroud the smaller branches and the dead limbs of the oaks and elms of this vicinity with a dusty gray swathing. Upon closer examination these sheaths are found to be made up of heavy, stiff rosettes composed of from twenty to sixty individual plants. The latter arise as lateral shoots from the primary leafy stem, and are attached to the substratum by from one to four short holdfasts.

The stem appears to merge insensibly into the leaf. In the young seedling it is confined to the narrow zone lying between the growing point of the new leaf and the root constriction. As has been previously stated, this manner of branching results in the formation of "balls" from a single plant. As new plants are constantly being formed in the axils of the leaves of the primary stem, the lowermost and consequently the oldest leaves of the plant, become smothered. This dying out of the lower leaves results first in the elongation of that portion of the stem included between the growing point and the holdfast, and second in the complete separation of the individual plants from each other. Figures 50 and 51 represent a series of plants showing the manner of "ball" formation in this species.

Leaves

The leaves of *Tillandsia recurvata* are awl-shaped near the apex. Beginning near the middle of the leaf, a shallow groove arises on the upper face which deepens and widens as it nears the basal portion until the sheathing base overlaps the base of the opposite leaf (See Fig. 52). The numerous scales which cover the entire leaf are especially large near the base of this concave groove. This is probably due to the fact that this part of the leaf is so constructed as to hold minute drops of water for a short time; consequently, there is need for a greater abundance of absorbing organs in this portion. The stomata (Fig. 15) occur just beneath the wings of the scales over the entire surface of the plant. It is quite doubtful as to whether the guard-cells in Tillandsia species function in the work of transpiration. Billings[1] and Mez[4] in describing a closely related species, *Tillandsia usneoides,* conclude, "that the guard-cells have lost their power of functioning, this power having been transferred to certain cells of the subjacent parenchyma which operates the passive guard-cells, thus opening and closing the stoma." The fingerlike processes of such cells are quite common in *Tillandsia recurvata,* and, as the guard-cells are cuticularized and rigid, it is probable that the latter do not function.

Flowers

Soon after the spring rains in April the formation of the flower is begun, and by May 29th the buds can be seen protruding from the axils of the leaves. After this the flower pedicel elongates rapidly and the corolla becomes colored. By June 14 the first open flowers appear. The long pedicel, bearing from one to two small flowers, may be regarded as a reduced terminal inflorescence. Each inflorescence is subtended by a scale-covered bract. The members of the cycles are arranged in whorls of threes (Ca 3 Co 3 S 6 P (3)). The petals are of a delicate lavender color. The tri-carpellate ovary is superior. It is quite probable that the flowers are self-pollinated, as the anthers are pressed by the corolla tube against the tip of the style.

Fertilization follows closely upon pollination. The ovary elongates rapidly, and the pericarp becomes thickened and impermeable to water. By the last of August the organization of the fully developed embryo is practically completed. The fruits remain in a dormant condition until about the first of February, when the capsule splits longitudinally into three valves and the seeds are liberated. Germination begins immediately if conditions are favorable.

The Holdfasts

Schimper[6] called attention to the fact that the *Tillandsia* species are not dependent on the root systems for nutriment. The holdfasts merely attach the plant to its substratum. The anatomical structure of the roots is in conformity with this function. They are short, tough projections which end in flattened disc-like knobs. (See Fig. 15.) While they may penetrate into the soft outer bark to the depth of a sixteenth of an inch, in no case have they been found entering as far as the *cambium.* Apparently all that is necessary is a firm anchorage. In one instance a holdfast of a small plant was found which had followed a worm-eaten course for more than an inch to reach a firm substratum. The result of a number of experiments on roots shows that, although they may elongate slightly when first placed in soil or damp sand, the holdfasts do not function as true roots. In the majority of cases in which plants were planted in moist soil the roots decayed in a few weeks' time.

The Structure of the Stem

The general structure of the stem of *Tillandsia recurvata* with the exception of the secondary ring of sclerenchymatous fibers surrounding the vascular axis, is very similar to that described by Billings[1] for *Tillandsia usneoides.* The central vascular cylinder is made up of a number of fused bundles composed of thick-walled sclerenchymatous cells surrounding isolated groups of thin-walled phloem. (Fig. 5.) A layer of spongy tissue several cells thick surrounds the vascular axis and loosely connects it with the secondary ring of fibers. The latter serves to give additional rigidity to the stems and is also composed of large sclerenchymatous cells. (Fig. 6.) The cortical layer is composed of exceedingly large parenchymatous cells.

The Structure of the Leaf

General Structure

A detailed examination of a section of the living leaf near its center shows the cylindrical outline with the inner grooved or "tank" edge (Fig. 8). The cuticularized epidermal cells possess very thick walls and are scarcely half the size of the adjacent parenchyma. With the exception of the scales, the epidermal cells, the water storage cells, and the vascular bundles all of the leaf and stem cells contain chlorophyll. The walls of the water-storage cells are minutely pitted.

The number of vascular bundles in the leaf varies from one near the end to eight in the basal region. Each closed bundle is surrounded by thick-walled sclerenchymatous cells. Differentiation into bast, sieve cells and tracheides takes place at an early stage in the germination of the seedling. The sieve cells have large perforations in their walls, thus permitting a more rapid translocation of elaborated food. Only three or four *tracheides* occur in each bundle. These may be readily distinguished in a cross section tested for lignified walls by their thick, deeply stained walls (Fig. 9). The bast fibers are characterized by homogenous walls with very evident middle *lamellae*.

The chlorophyll bodies of *Tillandsia recurvata*, accepting the terminology used by Billings,[1] show the microplasts or individual chlorophyll bodies as minute, oblong bodies. They are usually found massed into megachloroplasts (Fig. 7). A single cell may show several of these either in the process of formation or of disintegration. The microchloroplasts move with an oscillating movement through the cytoplasm and occasionally even enter the vacuoles. Direct sunlight seems to have the effect of massing the chloroplasts. Plants were placed in the dark and their leaves sectioned later to see what effect the absence of light might have on the distribution of the chloroplasts in the cell. Such sections showed even distribution throughout the cell. Leaves of plants growing in a densely shaded portion of the greenhouse for eighteen months also showed an even distribution of the microchloroplasts throughout the cell. With the exception of the above-mentioned regions microchloroplasts as well as the ordinary chlorophyll bodies are found in all of the vegetative cells.

Scales

Another important accessory structure of the leaf is the scale. It originates in much the same way as the scale of *Tillandsia usneoides.* According to Billings, each scale develops from a single epidermal cell, the early divisions of which occur while the young leaves and stem are included within the leaf sheath (Figs. 12 and 13). Four cells result from transverse divisions. The three lower cells form the stalk of the scale, while the upper cell by successive divisions forms the three rows of the crown of the scale. There are four large cells in the inner, eight smaller cells in the intermediate, and sixteen in the outer group of plate cells. The cells of the last row after dividing repeatedly elongate to form the slender colorless cells of the wing of the scale (Figs. 10, 11, and 14). As has been stated elsewhere the scales cover the entire surface of the plant with the exception of the holdfasts, the flower pedicel, and the petals.

Mineral salts and other inorganic particles probably become incorporated into the tissues as fine dust particles which collect between the wings of the scales and the epidermis of the leaf, and which are carried in solution into the cells of the leaf. According to Mez,[4] 355.27 mm. of the surface of the living plant will absorb 35.172 mg. of water through its scale membranes. The difference in the gross gain by spraying and atmospheric moisture (42.37—35.17 mg.) gives the amount of absorption by the tissues as 7.20 mg. for 205 minutes of spraying. Enough moisture is absorbed in this time to keep the plant, under normal conditions, for thirty-eight hours, which is far beyond the next fall of dew.

THE DEVELOPMENT OF THE MEGASPORANGIUM

The archesporial cell arises as a single hypodermal cell, and may be readily recognized by its granular, deeply staining cytoplosmic contents and by its relatively large size (Fig. 18). The primordia of the inner integuments at this stage, appear as slight rounded projections on each side. The *archesporium* gives rise by a tangential transverse division to a parietal cell and a primary sporogenous cell. Figure 19 shows the parietal cell with two complete nuclei. Billings[1] in describing the embryology of a closely related species, *Tillandsia usneoides,* states that "the parietal cell is not present." In *Tillandsia recurvata,* however, the cutting off of the parietal cell occurs in all of the early stages of development of the *megasporangium.* Immediately after this cell is cut off the megaspore mother-cell enters into a resting condition in which it remains for four or five days without dividing. During this time the cell elongates and the inner and outer integuments become quite distinct (Fig. 20). The division of peripheral cells places the megaspore mother-cell three cells deep before its first division occurs (Fig. 20). As a result of the succeeding division a row of four faculative megaspores is produced, the innermost one of which is destined to become the embryo-sac (Figs. 21, 22, and 23). Soon after their formation the disintegration and absorption of the three upper cells of the tetrad begin and continue until all traces of them have disappeared (Fig. 24).

Material collected June 1st shows that the primary nucleus has already divided and the daughter-nuclei have migrated towards each end of the elongated embryo-sac (Fig. 25). As the result of the subsequent, simultaneous divisions four nuclei are produced in the antipodal and four in the micropylar end of the embryo-sac (Figs. 26 and 27). The lowermost of the nuclei of the upper end of the sac shown in Figure 27 is the micropylar polar nucleus, which has commenced to migrate towards the antipodal polar nucleus. These nuclei, almost equivalent in size, meet just below the center and to one side of the embryo-sac and fuse to form the primary endosperm nucleus (Figs. 28 and 30). The three remaining antipodal nuclei, which are much smaller than those of the micropylar end of the sac, soon sink into the pocket-like projection of the lower end of the embryo-sac and become surrounded by definite cell-walls (Fig. 28). The nuclei of the synergids soon take up a position slightly above and to each side of the egg, from which they are readily distinguished by their deeply-staining, granular, cell-contents and by their wedge-like shape (Fig. 29).

POLLINATION AND FERTILIZATION

Pollination takes place in the vicinity of Austin between the 18th and 21st of June. Sections of material collected three days after pollination show that the pollen-tube has pushed through the micropyle and pierced the wall of the embryo-sac. Upon entering the sac the globular end of the pollen-tube either passes directly over the synergides, in which case it discharges its contents very near the egg, or it enters between the egg-cell and one of the synergids pushing the former to one side of the sac and completely crushing the other synergid (Fig. 29). In case the former case prevails, the synergids persist for a considerable period during the early stages of the formation of the embryo (Fig. 40). The tube nucleus is quite small and round. The male nuclei are small and oblong, and are usually discharged a little in advance of the tube nucleus. Nuclei of vermiform shape were not observed. Figure 29 shows one of the male nuclei fusing with the nucleus of the egg-cell. The second generative nucleus which passes to the primary endosperm nucleus becomes slightly enlarged and more spherical in shape (Fig. 31). Simultaneous double fertilization of the egg-cell and the endosperm nucleus is common. The two polar nuclei may or may not show complete fusion before fertilization takes place, although the former condition is the usual one in this species.

THE ENDOSPERM

After fertilization, the egg-cell secretes a cell-membrane around itself and enters a resting period of some five or six days duraiton. During this time rapid multiplication of the free endosperm nuclei takes place. Figure 32 shows the nuclei resulting from the first and second division of the primary endosperm nucleus. Occasionally one of the nuclei resulting from the first division migrates to the micropylar end of the sac before division takes place. Soon after this, young endosperm nuclei in groups of four or more and in close contact with each other may be found in the antipodal and micropylar ends of the sac (Fig. 33). A section through a more mature embryo-sac frequently shows as many as twenty nuclei lying close together and embedded in the dense wall-layer of cytoplasm. The thin and much more vacuolate character of the cytoplasm of the central portion of the embryo-sac is propably one of the causes of the massing of the nuclei near the periphery. Soon after the segmentation of the fertilized egg, free endosperm nuclei line the walls of the entire sac. The nuclei then lay down cell-walls, and the cells, especially in the chalazal region, become filled with a dense cytoplasmic content. When the embryo is mature the endosperm is reduced to a small cap of tissue, which is completely absorbed as germination proceeds.

THE DEVELOPMENT OF THE EMBRYO

As previously stated, the egg-cell remains dormant for a week or more after fertilization. The embryo-sac, however, increases to at least three times its original size. Material gathered on June 29th showed the unsegmented egg-cell, while that gathered two days later showed several stages of the young embryo. The fertilized egg divides by a slightly oblique, transverse wall (Fig. 40). The upper cell becomes the first or basal suspensor cell and does not undergo division until a later period. Figure 40 represents the segmented embryo and the synergids still intact. A transverse division of the apical cell results in a pro-embryo of three cells (Fig. 42). The terminal cell, which is destined by its subsequent divisions to give rise to the cotyledon, divides obliquely (Fig. 43). A subsequent differentiation of the tissue derived from the middle cell results in the formation of the stem and root-tip, and of a part of the suspensor. The first division of the middle cell is longitudinal. Figure 44 shows the octant. In the following stages of the embryo, the dermatogen, originating first in the region of the cotyledon, differentiates progressively towards the root. The first division of the enlarged vesicular basal cell is shown in Figure 46. The upper cell of the suspensor gives rise by transverse division to a cell which in turn divides longitudinally, thus making in all four cells derived from the original basal suspensor cell, while the new basal cell remains in an undivided condition until the embryo reaches maturity (Figs. 47 and 48).

The first indication of the differentiation of the various parts of the embryo is shown by slight constrictions which appear between the region destined to become the stem and the cotyledon and also between the former and the root (Fig. 47). Subsequent growth and differentiation of the tissues of the region of the cotyledon just anterior to the point of origin of the stem-tip results in the formation of a sheath which in the mature embryo and in the germinating seedling completely surrounds the growing point of the stem (Figs. 35-38). Before any differentiation in the external form occurs the disintegration of the cellular contents of the zone of tissue lying between the root and stem takes place. These cells soon become devoid of nuclei and probably serve as loose connective tissue between the stem and the holdfast. In embryos gathered August 29th, the organogeny appears to be complete. The embryo does not, however, reach its full size until about the middle of September.

THE MATURE SEED

The mature seeds are especially well adapted for wind dispersal by means of the pappus-like comae or long, colorless, barbed hairs which arise from the outer integument and are attached to the seed-coat at the chalazal end. When the capsule splits, the comae serves as a sort of a half-open parachute which carries the seed through the air. The barbs of the nodes are also useful in attaching the seedlings to the substratum.

The seed-coat is impermeable to water and very thick. In fact, it is impossible to section embryos six weeks old without first removing the seed-coats.

GERMINATION

When the seedling begins to grow, the intercellular matrix, which is of a rich, dark brown substance, is broken up and a loose net-work of cells is left surrounding the entire embryo. The leaves push through the top of this coat, but it is not until the end of the second year that it is completely outgrown. Together with the *comae*, it serves as a means of holding the plant to the substratum when there is no other kind of attachment possible, as the holdfasts do not function until a much later period.

From the cotyledon there arises a structure which from its function and scuttle-like form may be called the sheath or scutellum. This sheath originates from the cotyledon near the central portion of the embryo, and surrounds the stem apex. Figures 35-38 show the appearance of the sheath in surface view and in section. The cotyledon of the germinating seedling is at least twice as long as the remaining portion of the embryo. Its cells are rich in food content. Dense masses of starch granules and oil globules occur throughout the cytoplasm. The scales are developed soon after germination, first in the region of the primary leaf-stem and afterwards on the cotyledon and sheath. The cotyledon frequently persists through the end of the second season.

The seeds germinate shortly after their dispersal, which takes place in the vicinity of Austin between January 1st and February 10th. Young seedlings were found in the field within seven days after the liberation of the seeds from the seed pod. A number of experiments were tried to determine the time necessary for germination and the percentage of mature embryos. Of the seeds planted on damp wood, mud, garden soil, sand, and on culture media the majority germinated within three to five days. About eighty-five per cent of the seed contained mature embryos. Seedlings and young plants showing all stages of growth can be readily found at all times of the year. If the conditions are favorable for germination at the time of the bursting of the pods, the seeds frequently germinate within the capsule. This viviparous condition is not at all rare in this species of *Tillandsia*. Figure 52 shows an old capsule containing twenty-five two-year-old plants. A similar condition has recently been reported by Harshberger[2] for *Tillandsia tenuifolia L.*

THE DEVELOPMENT OF YOUNG PLANTS AND "BALL" FORMATION

The young seedling grows very slowly. At the end of the first year's growth it is about one centimeter in length. The second leaf has reached the level of the cotyledon and the tip of the third leaf is just visible. The short blunt holdfasts are undivided. The basal half of the plant is covered with the network of the seed-coat. In this condition the plant passes the winter (Fig. 50, upper series).

During the succeeding growing season the plant doubles its length and adds one or two more leaves. The holdfasts become attached to the substratum and the formation of the "ball" is initiated. At the close of the third growing period the "ball" is composed of from two to three individual plants (Fig. 50, lower series), possessing one or more common holdfasts. In many instances the cotyledon still persists at this time. The four-year-old "ball" is composed of from eight to twelve small plants varying in length from one to two and one-half inches (Fig. 51). Fruits may be produced at this time, although they are rather small. A mature plant frequently produces four or five leaves in a single season.

It is possible to determine the approximate age of a "ball" by taking into consideration the number of leaves of the individual plant, the length of the stem, and the number of plants in the bunch. It is quite probable that many of the older "balls" are from twenty to twenty-five years of age (Figs. 2 and 3), while the majority of the large balls are at least from ten to fifteen years of age.

A PARASITE AND A LICHEN

A new species of *Colletotrichum* has been found on a large number of plants in the vicinity of Austin. The large dark, somewhat irregular acervuli occur on the young seedlings, the flower pedicels and on the leaves and stems of the mature plants, especially on the concave surface of the leaf. It frequently attacks the young leaves and stem, thus causing the death of the plant.

The following measurements are given for this species of *Colletotrichum:*

Acervuli 150-160 *mikrons* in diameter; *conidia* 7-7.5x13-15 *mikrons,* oblong with rounded ends; *setae* 45-90x4.5 *mikrons,* smoky and from four to five septate, quite pointed at the tip.

A comparison of this species with a *Colletotrichum* previously described[5] as occurring on *Tillandsia sp.* indicates that the two are distinct. *Colletotrichum Bromeliacearum* is proposed as the name for this new species.

An interesting lichen was found growing on the surface of the young seedlings and on the scales of the leaves of the mature plants. It usually covers the entire leaf, giving it a very dark-green color. Much branched fungous filaments are closely associated with the colonies of the alga (*Pleurococcus sp.*) Owing to the fact that no fruits were found, it was impossible to assign the lichen to any definite species.

THE EFFECT OF THE "BALL MOSS" ON ITS HOSTS

It is the current belief of the people of the Southwest that the "ball moss" gradually "saps the life" of its hosts. They behold its approach with as much dread as that of the mistletoe. This opinion is largely due to the fact that they have seen many dying and dead trees densly covered with it. The anatomical as well as the morphological structure of the plant is such as to necessitate an epiphytic rather than a parasitic existence. In the first place the holdfasts do not penetrate beyond the dead cortex of the bark, and in the second place the lack of organs for the absorption and conduction of food make it impossible for the plant to get its nourishment through its roots, which merely attach it to its substratum. The "ball moss," then, absorbs its water and mineral salts from the air and from precipitated moisture by means of its accessory structures, the scales, located on stem and leaf, and being provided with a chlorophyll apparatus, manufactures its food by the typical photosynthetic process. Mez[4] shows that the leaves absorb enough water from the atmosphere in three hours to last the plant for thirty-eight hours.

An examination of the relation of *Tillandsia recurvata* to its substratum brought out the fact that it not only is not dependent upon food derived from trees upon which it is growing, but that it grows equally well upon surfaces from which it would be impossible to obtain elaborated food. Vigorous fruiting bunches fifteen years old or more were found growing upon board fences and oak posts. Several five-year-old bunches, with their holdfasts cemented to the wire, were discovered growing between the twists of a barbed-wire fence. It also grows on granite boulders and electric light wire insulations. A number of bunches were suspended from the ceiling of the University greenhouses and kept in a perfect condition for a year and a half. They produced an abundance of fruits.

The second general idea concerning the effect of the "ball moss" is that it shades the tree to death. There is much truth in this statement. No doubt many buds are smothered by the dense growth of the moss on the young branches, especially in those trees on which, because of the lack of suitable light conditions, the *Tillandsia* attacks the terminal rather than the lower portion of the crown. Many of the people in the vicinity of Austin have become so firmly convinced of the injury to their trees that they either have attempted to have the moss scraped off the limbs or they lop the branches off close to the trunk. Unfortunately, the majority of people usually wait until about the 1st of March before pruning the trees covered with *Tillandsia recurvata.* At this time the moss has already shed its seed and the tree is covered with hundreds of minute seedlings. If the moss is to be scraped off at all, it should be done sometime before the dispersal of the seed, which in this vicinity takes place about the last of January. The writer has observed with interest the effect of scraping the moss off the limbs of the trees which were densely covered with it, and in most instances it was found that such trees put out their leaves several days earlier than the infected trees and that their foliage was more abundant.

Experiments were tried with a view of finding some more practical means of exterminating the moss. Ten healthy bunches, five directly from the field and five which had been previously soaked for an hour in water, were sprayed with a ten per cent kerosene emulsion and placed with the control set on a window-shelf. The following results were obtained:

Dry — Sprayed with 10 per cent kerosene solution.	Soaked in water one hour, sprayed with 10 per cent kerosene solution.	Control.
Experiments in the Laboratory.		
Dead three weeks later.	Dead four weeks later.	Alive and healthy.
Experiments in the Field.		
All of the outer leaves and young seedlings dead in six weeks.		Alive and healthy.

The ten per cent solution is sufficiently strong to kill all of the younger plants and the outer plants and leaves of the older rosettes, but the inner leaves being protected by the overlapping of the leaf-sheaths are apparently more resistant. A slightly stronger emulsion should be used in spraying the trees in the open. The trees should be sprayed in the fall as soon as the leaves have been shed. The experiments indicate that the most effective methods of extermination is by first scraping off the large plants, and then spraying with kerosene emulsion to kill the small plants which would be left behind. In the case of valuable shade trees this method may be resorted to, and it will not prove unduly expensive since the slow growth of the moss will render the frequent repetition of the treatment unnecessary.

The writer wishes to take this opportunity of expressing her sincere thanks to Dr. F. D. Heald and Dr. I. M. Lewis for their helpful suggestions and criticisms in the preparation of this paper.

Literature Cited

1. Billings, F. H., "A Study of Tillandsia usneoides." *Bot. Gaz.*, 38: 99-101. 1904.
2. Harshberger, J. W., "Vivipary in *Tillandsia tenuifolia* L." *Bot. Gaz.*, 49: 59. 1910.
3. Heald, F. D., and Wolf, F. A., "The Whitening of the Mountain Cedar." *Mycologia*, 2: 205-212. 1910.
4. Mez, Carl, "Physiologische Bromeliaceen-Studien. VII. Wasser-bilanzen von zwei lebend untersuchten Arten." *Jahrb. Wiss. Bot.*, 40: 226-229. 1904.
5. Patterson, F. W., "New Species of Fungi." *Bull. Torr. Bot. Club*, 27: 283. 1900.
6. Schimper, A. F. W., Plant Geography, 325-328. 1903.
7. Schimper, A. F. W., Die Epiphytische Vegetation Amerikas. 1888.
8. Small, J. K., Flora of the Southeastern United States, 245. 1903.

Explanation of Plates—I-X

Fig. 1a.—*Tillandsia recurvata* on *Quercus minor.*

Fig. 1b.—*Tillandsia recurvata* on *Sabina sabinoides.*

Fig. 2.—Branch covered with *Tillandsia recurvata.* In the center is a group of seedlings attached by their comae to the leaves.

Fig. 3.—Rosette with plants separated so as to show the attachment of the holdfasts to the stem.

Fig. 4.—Map showing the distribution of *Tillandsia recurvata* in Texas.

Fig. 5.—Cross section of the vascular axis of the stem.

Fig. 6.—Transverse section of the fibrovascular cylinder of the stem.

Fig. 7.—A *parenchyma* cell from a leaf showing the *megachloroplasts* and the *microchloroplasts.*

Fig. 8.—Transverse section of the leaf showing the arrangement of the vascular bundles, and the general structure of the leaf.

Fig. 9.—Transverse section of a fibrovascular bundle from the leaf.

Figs. 10 and 11.—Surface views of mature scale.

Fig. 12.—Transverse section showing an early stage in the development of a scale.

Fig. 13.—Longitudinal section showing a later stage in the development of the scale.

Fig. 14.—Section showing a mature scale.

Fig. 15.—Longitudinal section showing a stoma. The parenchyma cells which function as active guard-cells in closing the stoma are shown just below the true guard-cells.

Fig. 16.—Two-year-old seedlings growing on the leaf of Quercus minor. The seedlings were attached by their comae until the holdfasts became functional.

Fig. 17.—A year-old seedling with two young holdfasts.

Fig. 18.—Section of a young ovule showing the single archesporial cell, and the primordia of the inner integuments.

Fig. 19.—Longitudinal section of the nucellus. The archesporial cell has given rise to a primary parietal cell and a primary sporagenous cell.

Fig 20.—Longitudinal section of the ovule at a period previous to the first division of the megaspore mother-cell.

Figs. 21-23.—Stages in the formation of the row of four megaspores.

Fig. 24.—Section showing the degeneration of the three facultative megaspores and the enlarged megaspore nearest the chalazal end.

Figs. 25, 26, 27.—Stages in the formation of the embryo-sac.

Fig. 28.—Nearly mature embryo-sac showing the three antipodals, the primary endosperm nucleus, and the egg-apparatus.

Fig. 29.—Embryo-sac soon after the discharge of the male nuclei; (a) male nucleus; (b) tube nucleus. The fusion of the polar nuclei has been delayed.

Fig. 30.—Fusion of the micropylar and the antipodal polar nuclei before the rupture of the pollen tube to form the primary endosperm nucleus.

Fig. 31.—Fusion of the second male nucleus with the primary endosperm nucleus.

Fig. 32.—Lower end of the embryo-sac showing the first and second divisions of the endosperm nuceli.

Fig. 33.—Aggregation of young endorsperm nuclei.

Fig. 34.—Ovule at the time the embryo-sac has reached maturity.

Fig. 35.—Longitudinal section of an embryo about one-fourth grown, showing cotyledon, plumule, sheath, and beginning of differentiation of the holdfast.

Figs. 36 and 37.—Surface views of germinating seedlings showing the cotyledon, the sheath, the young leaf, and the root constriction.

Fig. 38.—Median longitudinal section of a young seedling showing the plumule and the folded edge of the sheath.

Fig. 39.—Fertilized egg-cell; synergids still intact.

Figs. 40, 41, 42.—Sections from the end of the embryo-sac showing the proembryos of two to three cells.

Fig. 43.—Section showing a young embryo in which the terminal cell has given rise to four cells.

Figs. 44 and 45.—Sections showing further development of the cells derived from the middle cell.

Fig. 46.—Longitudinal section of the embryo showing the differentiation of the dermatogen in the terminal portion and the first division of the basal suspensor cell.

Figs. 47 and 48.—Sections of more advanced embryos showing the first indications of the change in the external form in the embryo.

Fig. 49.—An outline drawing of a section showing a more advanced stage of the embryo.

Fig. 50.—Photograph of a series of plants showing their yearly growth. The seedlings of the upper, middle and lower rows are one, two and three years old respectively.

Fig. 51.—Plants on the first row are four years old. The first one on the second row is five years old. The last two are six-year-old "balls" composed of eight individual plants.

Fig. 52.—Vivipary in *Tillandsia recurvata*. The plants which have germinated in the capsule are two years old. Some seeds are attached by their comae to the leaves in the center. A young seedling clinging to the leaf may be noted in the upper left hand side of the photograph.

Fig. 1a.

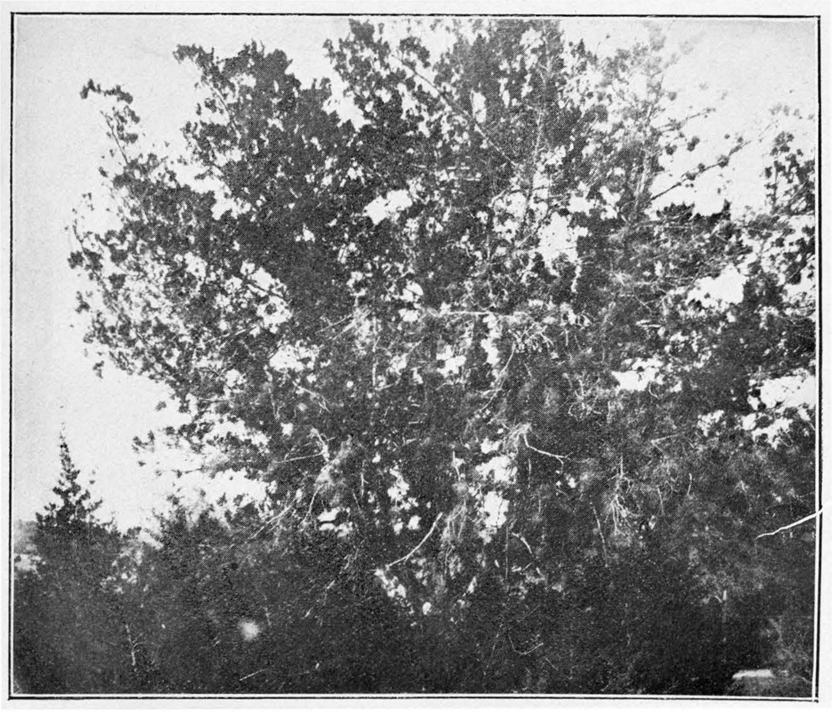


Fig. 1b.

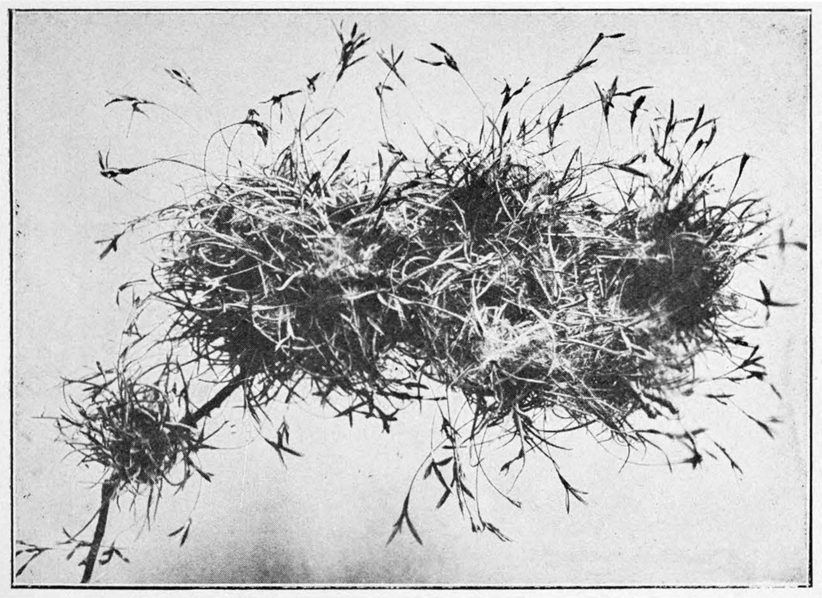


Fig. 2.

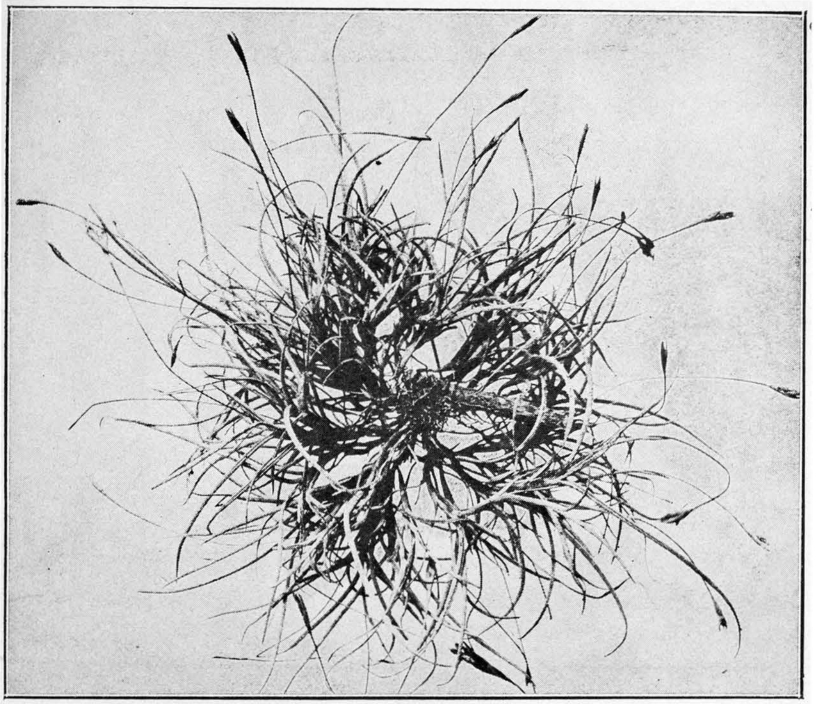


Fig. 3.

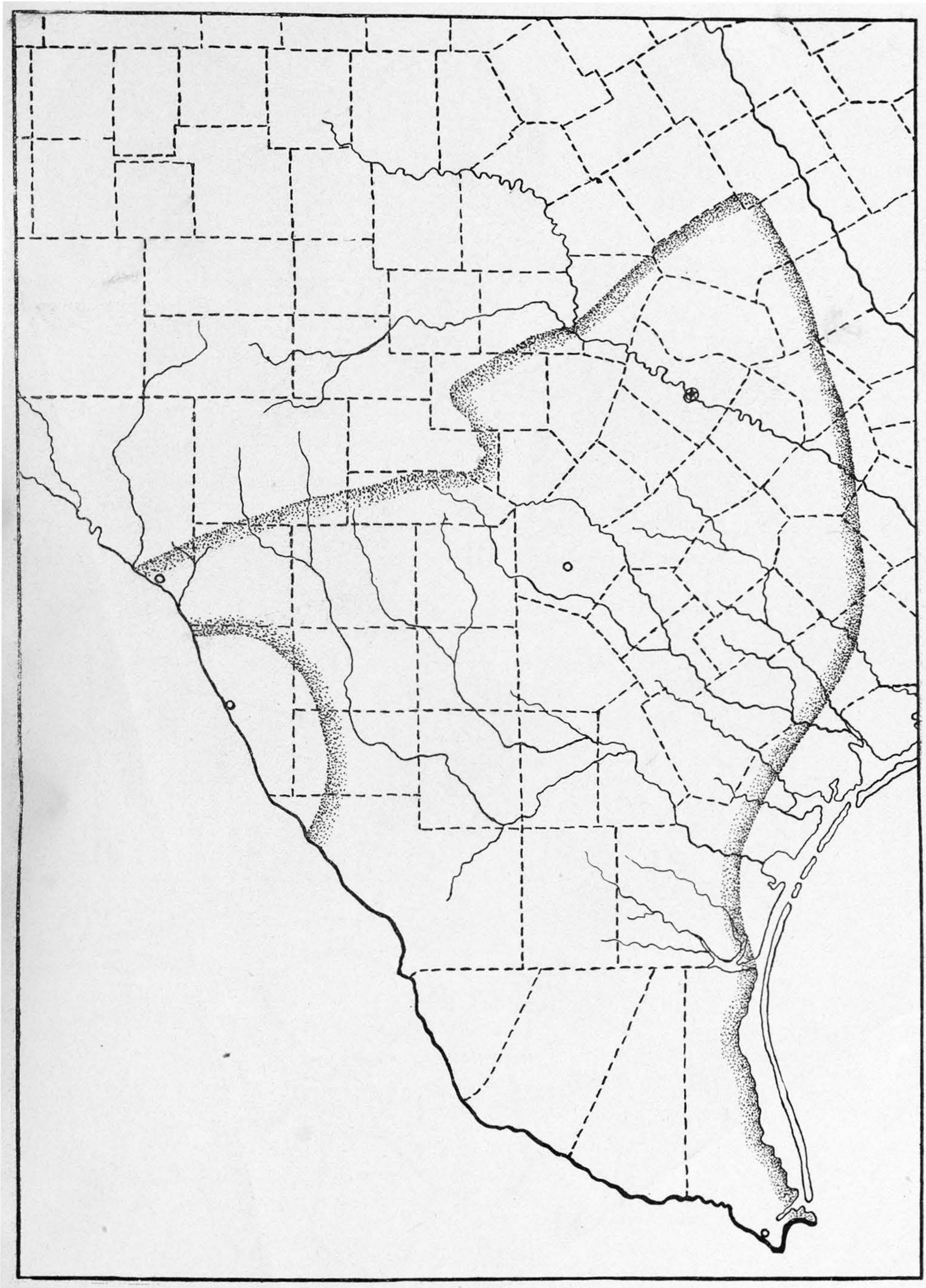
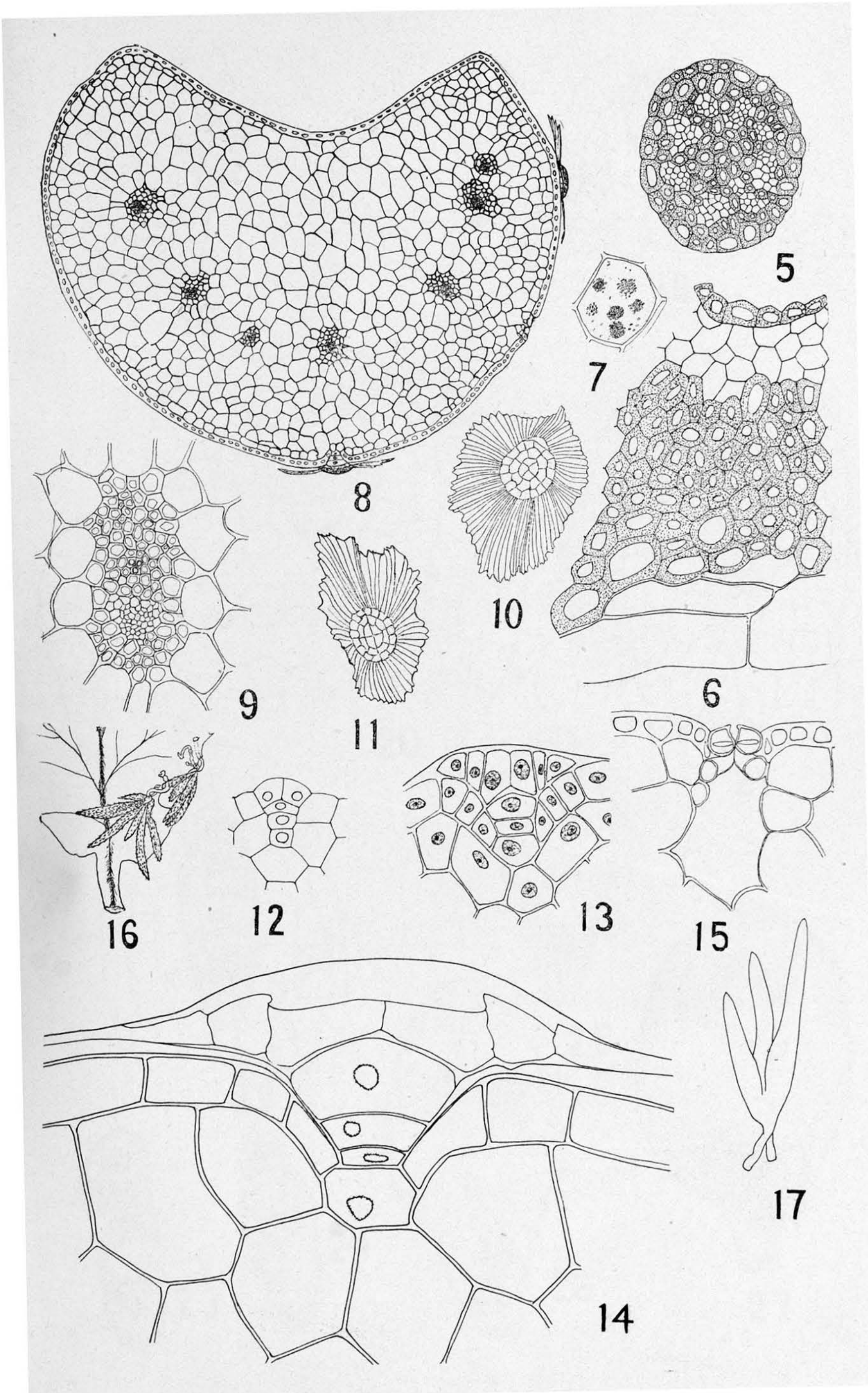
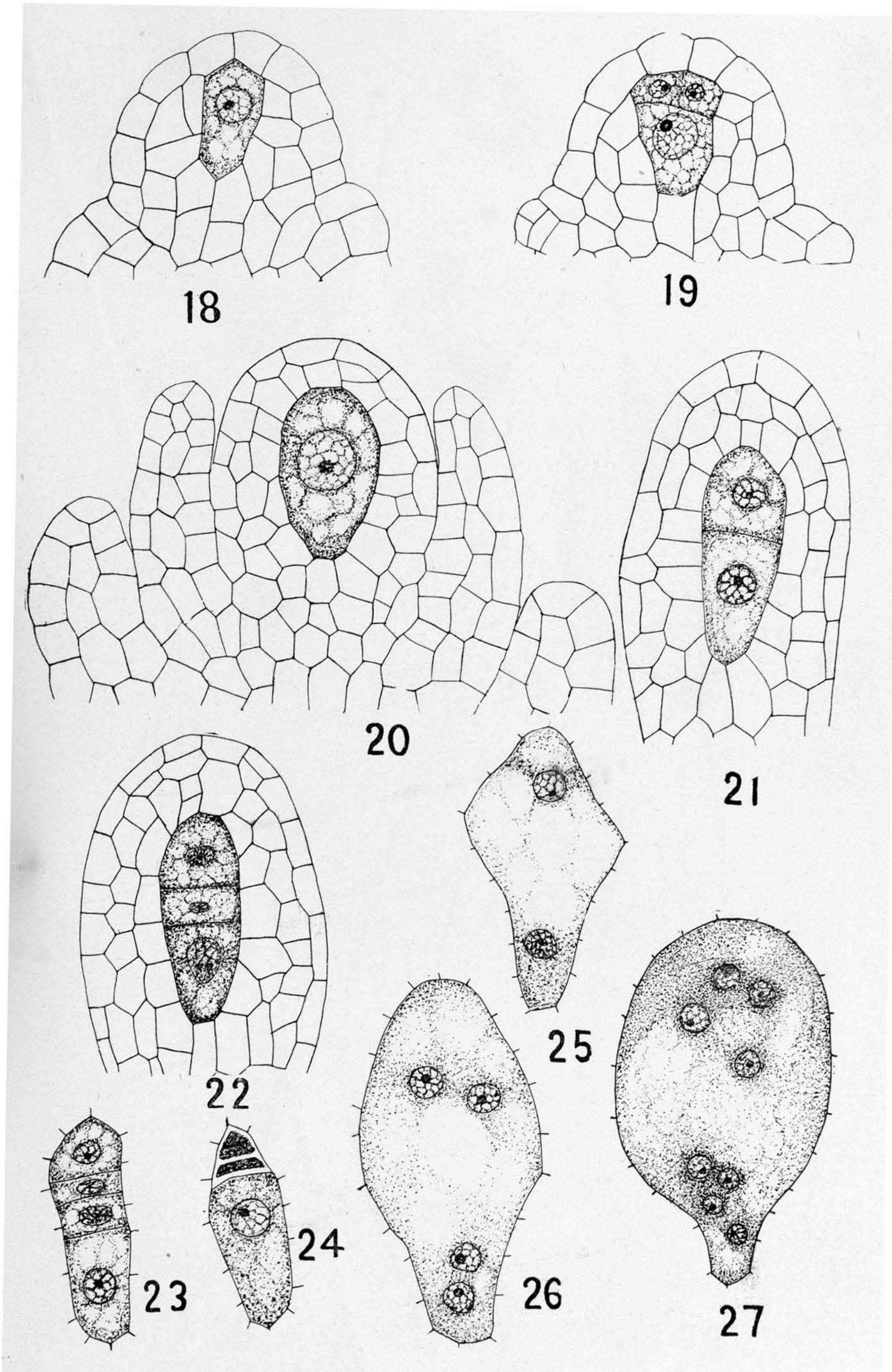
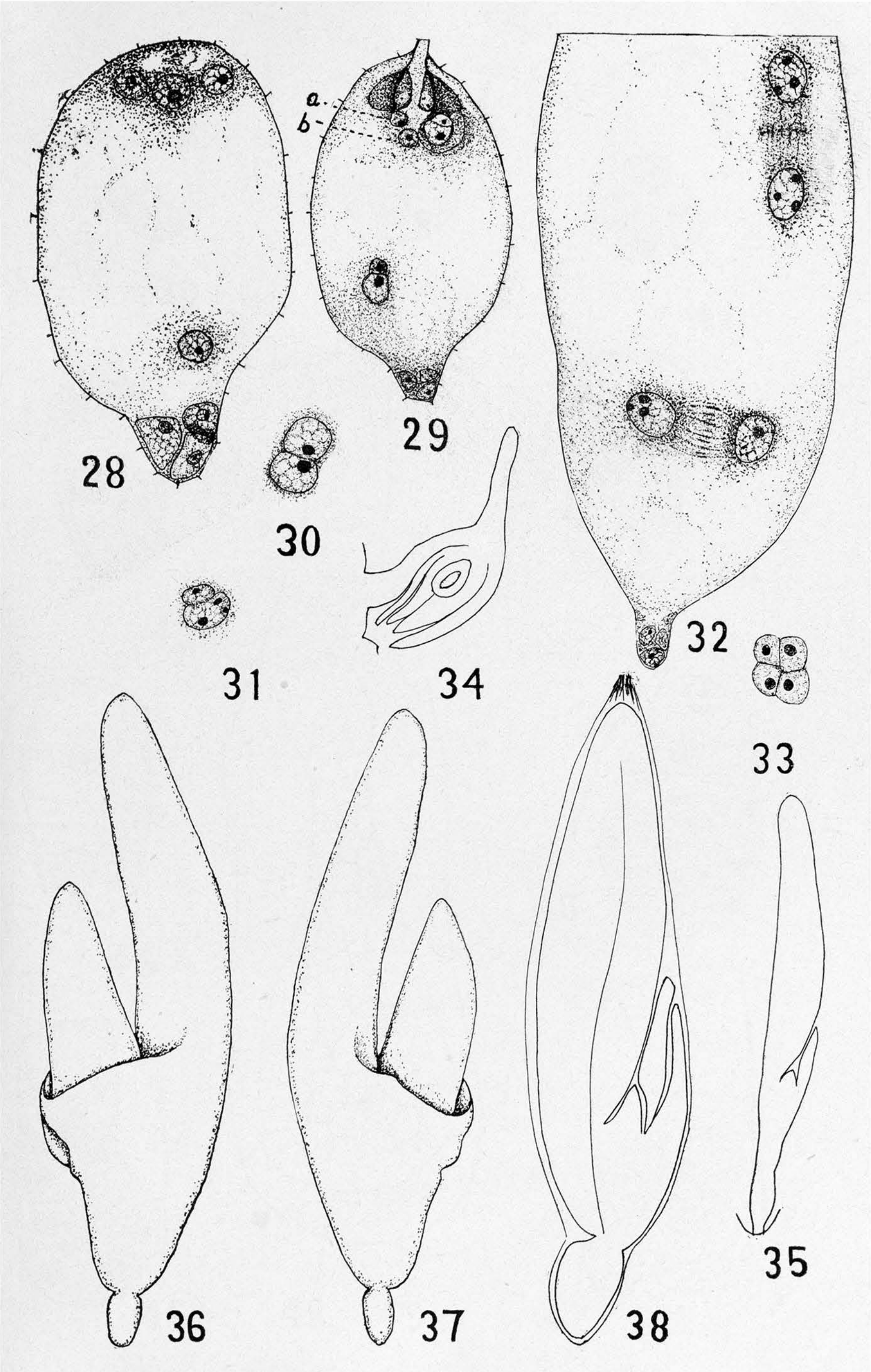
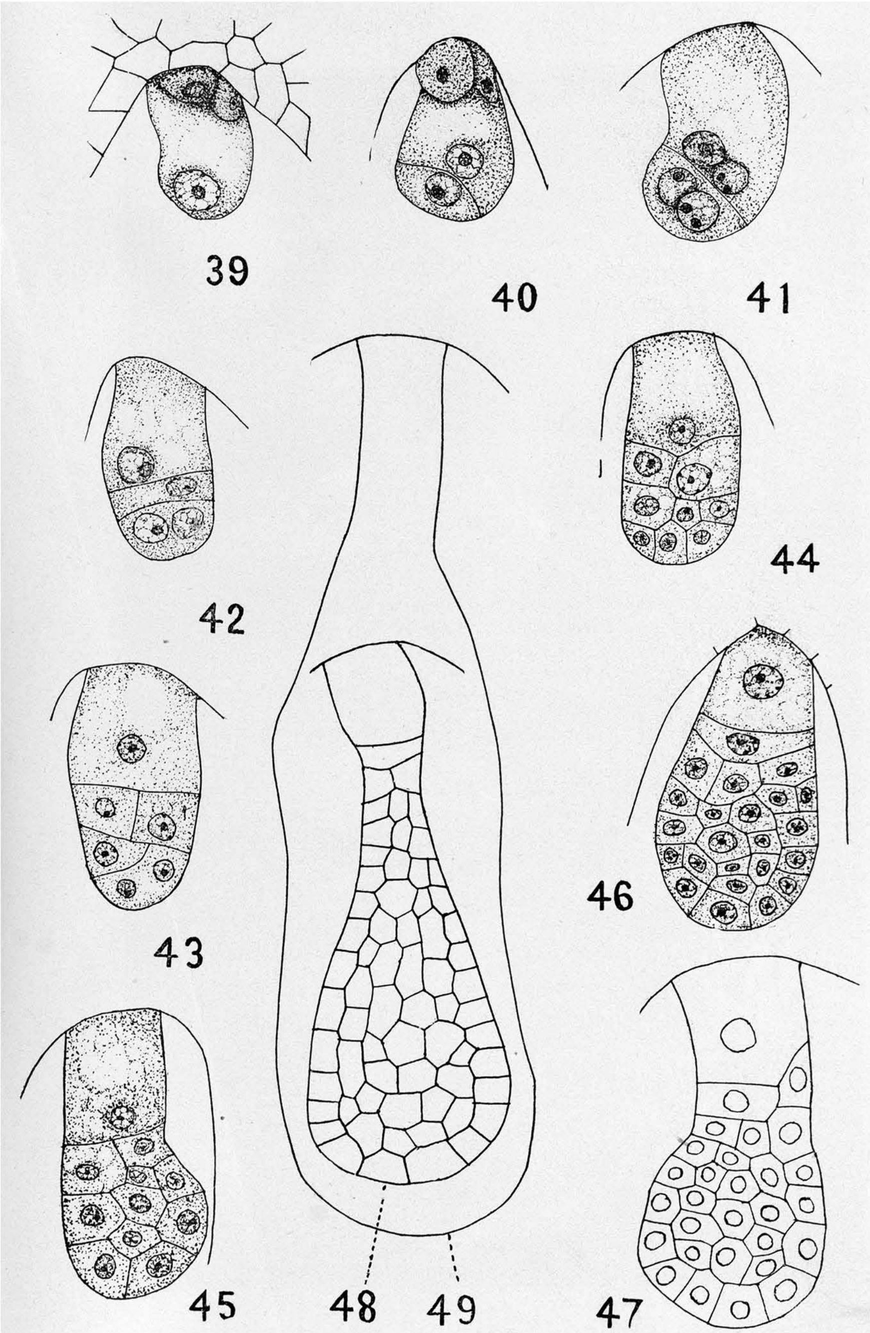


Fig. 4.


5
7
6
8
9
10
11
16
12
13
15
17
14


18
19
20
21
22
23
24
25
26
27


a
b
28
29
30
31
32
33
34
35
36
37
38


39
40
41
42
44
43
46
45
48
49
47

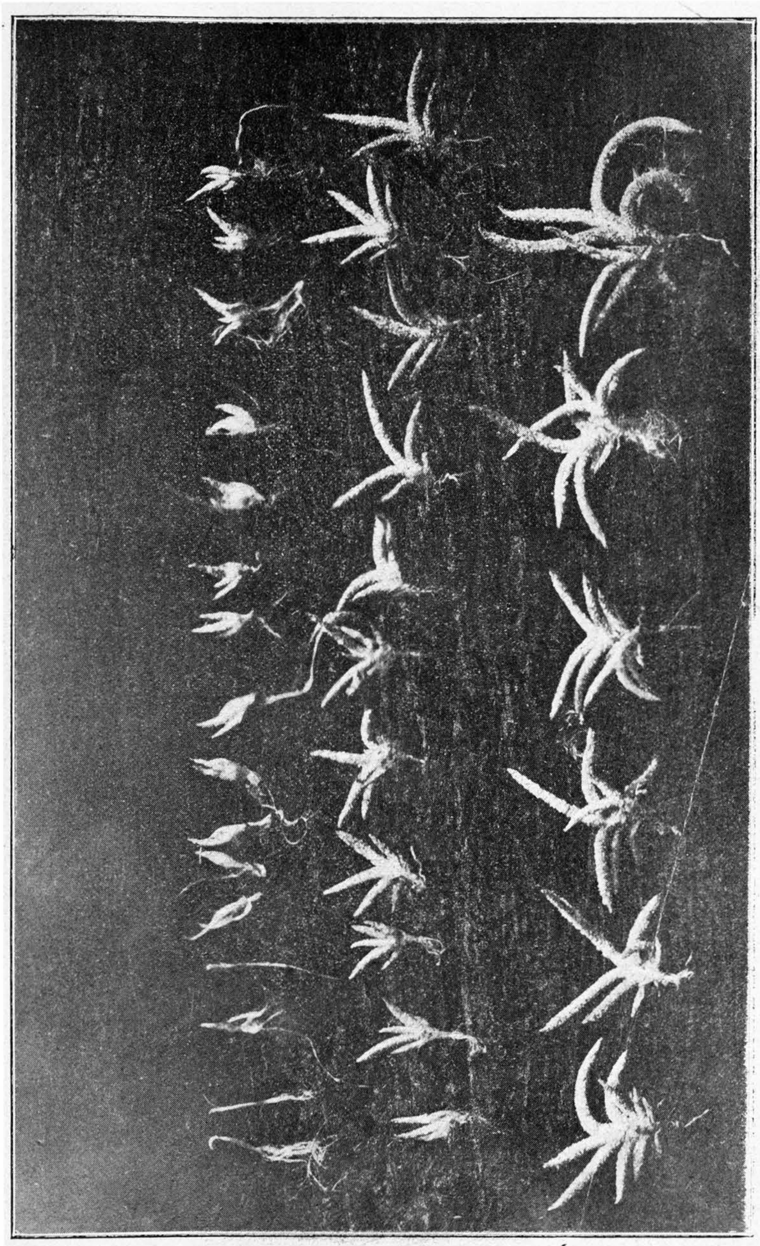


Fig. 50.

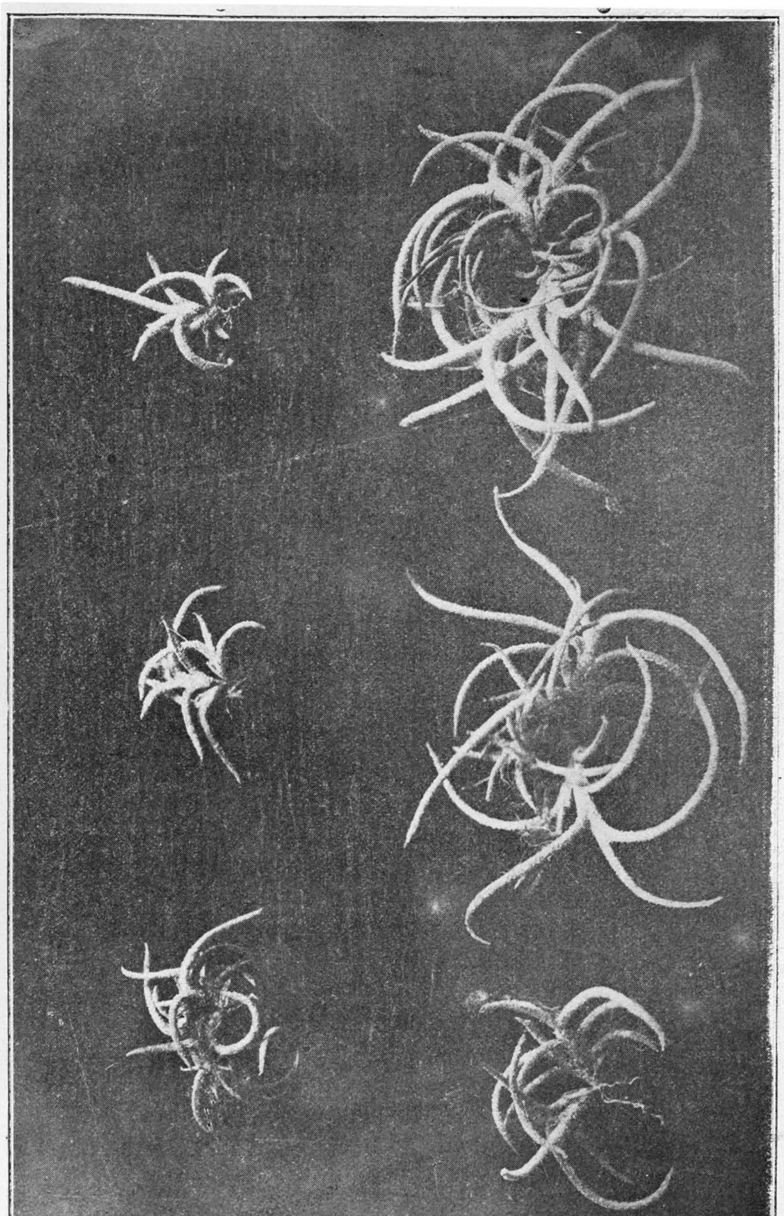


Fig. 51.

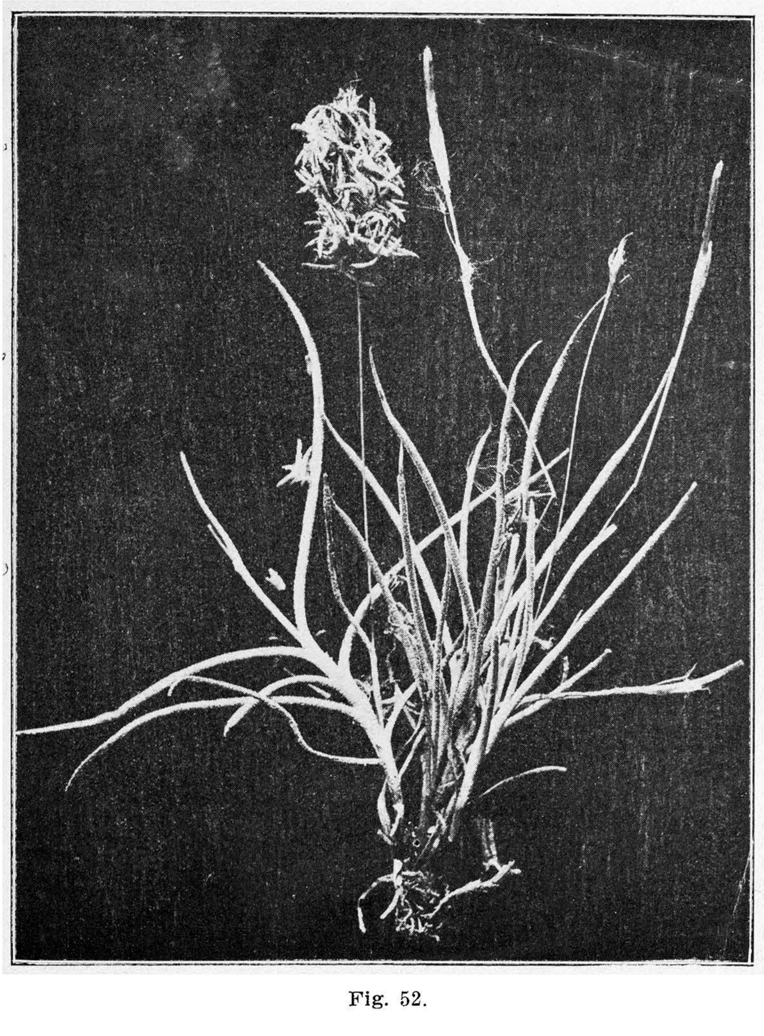


Fig. 52.

THE UNIVERSITY OF TEXAS BULLETIN.

(*Continued from inside front cover*)

7. *Railroad Transportation in Texas*, by C. S. Potts. 214 p., 6 maps, charts. March, 1909. $1.50.
8. *Crime and the Treatment of the Criminal*, by C. S. Potts. 86 p. May 1, 1910. 25 cents.
10. *Problems of Prison Reform*, by C. S. Potts. 40 p. December 8, 1910. 20 cents.
11. *Recognition of the Republic of Texas by the United States*, by Ethel Zivley Rather. 101 p. January 1, 1911. 75 cents.
12. *English Elements in Jonson's Early Comedy*, by Charles Read Baskervill, 328 p. April 8, 1911. $2.50.

MEDICAL SERIES

1. *Yellow Fever: a Popular Lecture*, by James Carroll. 32 p. June, 1905. 15 cents.
2. *The Care of the Insane*, by Dr. M. L. Graves. 16 p. 1905. 15 cents.
3. *The* 1903 *Epidemic of Yellow Fever in Texas and the Lessons to Be Learned from It*, by Dr. G. R. Tabor. 22 p. June, 1905. 15 cents.
4. *Further Experiments in the Use of Drugs as Stimulants in Accidents Occurring During Anaesthesia*, by O. H. Plant, 31 p. February 8, 1911. 25 cents.

SCIENTIFIC SERIES

6. *Vegetation of the Sotol Country in Texas*, by W. L. Bray. 24 p., pl. June, 1905. 25 cents.
7. *Observations on the Habits of Some Solitary Wasps of Texas*, by Carl Hartman. 72 p., pl. July, 1905. 25 cents.
10. *Distribution and Adaptation of the Vegetation of Texas*, by W. L. Bray, 108 p., pl. map. November, 1906. 35 cents.
11. *A Sketch of the Geology of the Chisos Country*, by J. A. Udden. 101 p. April, 1907. 50 cents.
12. *The Clays of Texas*, by Heinrich Ries, 316 p., illus. pl. 1908. $2.00.
13. *The American Mistletoe*, by H. H. York. 31 p., pl. 1909. 50 cents.
14. *Symptoms of Disease in Plants*, by F. D. Heald. Illus. November, 1909. $1.00.
15. *Field Studies of the Behavior of the Lizard Sceloporus Floridanus*, by H. H. Newman and J. Thomas Patterson. 23 p., illus. December, 1909. 25 cents.
16. *The Austin Dam*, by T. U. Taylor, 85 p., illus. December 22, 1911. 75 cents.
17. *On the Electrostatic Effect of a Changing Magnetic Field*, by J. M. Kuehne. 15 p. January 15, 1911. 25 cents.
18. *Fauna of the Buda Limestone*, by Francis Luther Whitney. 54 p., illus. May 22, 1911. $1.00.

To those who desire it a complete list of the publications of the University of Texas will be furnished. Requests for this or for Bulletins should be addressed to the University of Texas Bulletin, Austin, Texas. Exchanges should be addressed to the University of Texas Library.

Austin Printing Co., Austin, Texas.