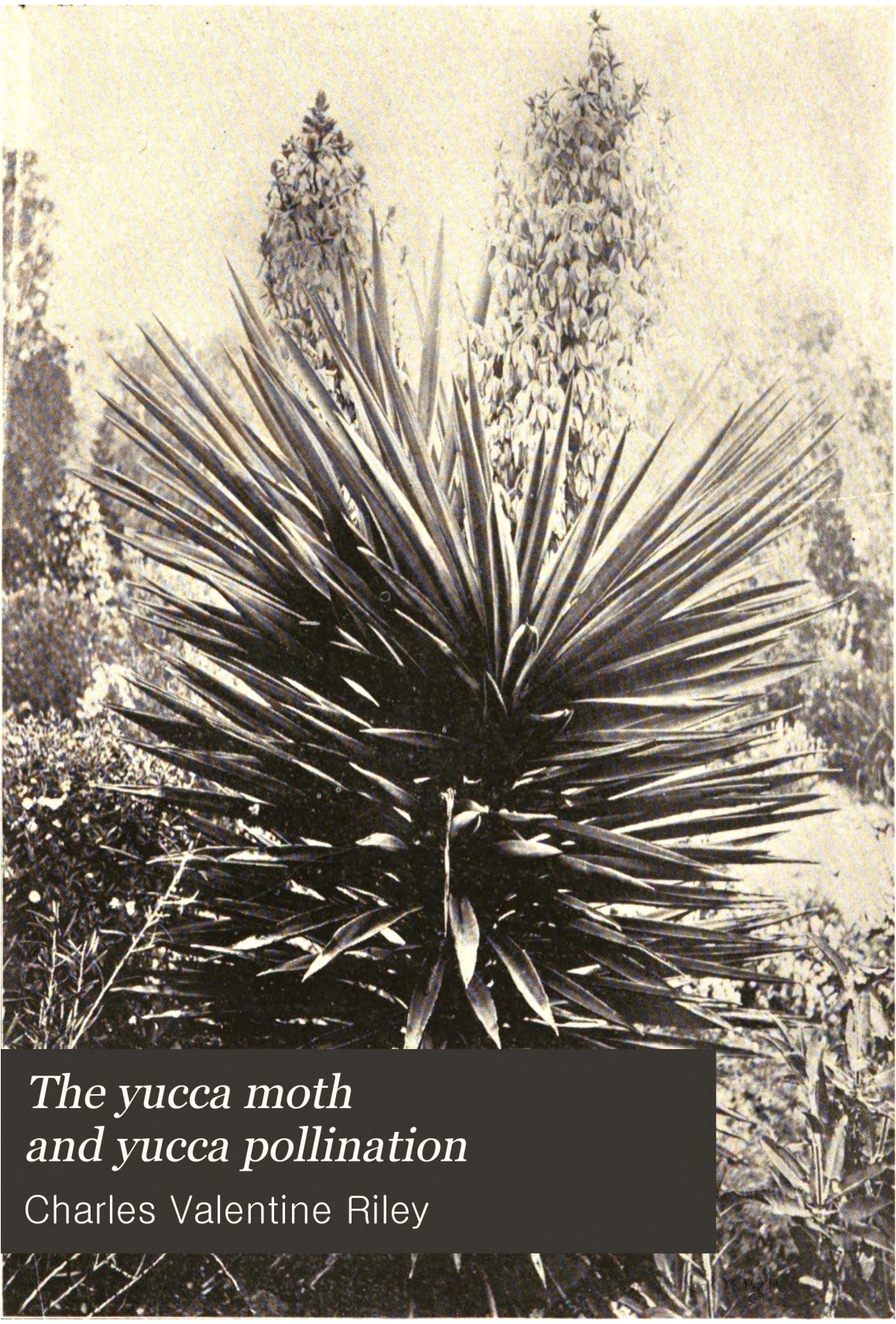

The yucca moth and yucca pollination

Charles Valentine Riley

MISSOURI

BOTANICAL GARDEN.

THIRD ANNUAL REPORT.

ST. LOUIS, MO.:
PUBLISHED BY THE BOARD OF TRUSTEES.
1892.

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PREFACE.

Under direction of the Board of Trustees of the Missouri Botanical Garden, its third annual report is presented to the public. As best calculated to promote the objects of publication, the diffusion of information concerning the institution and of the results of scientific work done in connection with it, it has been decided that an annual volume shall be issued in the early part of the year, containing the official report of the President of the Board and the Director of the Garden for the preceding year, together with such other matter as is considered pertinent. These volumes are primarily intended for distribution to botanical gardens, learned societies, and other scientific institutions, whose publications are desired in exchange; but when reason exists for it, they may also be sent to public libraries, or to individuals, although as a rule the latter cannot be carried on the regular mailing list for this purpose.

The pages of each report are electrotyped, and in order that scientific papers may be issued promptly on their completion, it has been decided that they may then be published, in advance of the volume, for which the electrotyped pages, bearing their original pagination at the bottom, will be held. In case of priority questions arising, therefore, when separates have been issued in advance, reference must be made to these for actual date of publication. Separate copies of all scientific papers are printed, so that botanists not in receipt of the complete reports may be supplied with those papers which are useful in their work.

For the accommodation of persons who may wish the publications of the Garden, but feel that they are not entitled to receive them by way of exchange or as aids to

scientific work, a few copies are offered for sale at about the cost of publication ($1.00 each, for the reports already issued, including the present, and 50 cts. for the revision of Epilobium reprinted from the second report) at the gate of the Garden, and by Dr. A. E. Foote, of Philadelphia, W. Wesley & Son, of London, and R. Friedländer & Sohn, of Berlin. Applications for the purchase or exchange of either reports or separate papers may be made also to the Director of the Garden.

WILLIAM TRELEASE.

ST. LOUIS, Jan. 14, 1892.

THE YUCCA MOTH AND YUCCA POLLINATION.

BY C. V. RILEY, PH. D.

PART I.

INTRODUCTORY.

Twenty years have nearly passed since the first announcement of the method of pollination of our Yuccas by the little white Lepidopteron which I christened *Pronuba yuccasella*. The curious facts connected with its structure and life habits and its intimate relation with the Yuccas; the ease with which it is confounded with the Bogus Yucca Moth, found in the same flowers, but possessing no power of pollination; the confusion which the facts have caused in the minds of other observers; the criticism and discussion which have followed the observations; and the opinions of others, often based on erroneous observations and conclusions — have resulted in a number of articles, scattered through a number of publications. My friend, Professor Trelease, has repeatedly urged me to put together a consecutive statement of the facts in the case, feeling that such a statement would prove useful to botanists and entomologists alike. It would seem, indeed, eminently appropriate to publish such a recapitulation in the Annual Report of the Missouri Botanical Garden, in which, while its founder was still living, many of the original observations, both by Engelmann and myself, were made.

The present article will fall, naturally, into two parts, the first a more popular recapitulation of the facts in reference to *Pronuba yuccasella* and Yucca pollination, in which will be repeated, almost verbatim, the earlier accounts as given in the third volume of the Transactions of the St. Louis Academy of Sciences and in my Fifth and Sixth Reports on the insects of Missouri, and elsewhere. In the

second portion will be transcribed from my notes some unpublished details not only in reference to this particular species but to other species of the family Prodoxidæ to which it belongs.

FERTILIZATION OF PLANTS GENERALLY.

The common belief, based upon the theological assumption that all things upon this terrestrial sphere are for man's especial benefit, was, and perhaps yet is, that flowers were endowed with beauty and fragrance for our particular pleasure. Let us look somewhat more closely into this matter, and see what modern science has to say about it. Ever since Linnaeus used the sexual characteristics of flowers in classification, and Erasmus Darwin sang of the loves of the plants, the philosophy of fertilization in the plant kingdom has been fairly apprehended. It has long been recognized that plants are divisible into homomorphic or self-fertilisable, and heteromorphic or cross-fertilisable species. All diclinous plants, or those having separate male and female flowers, belong to the latter category, which is further classifiable according to the means by which cross-fertilization is effected. One class (termed anemophilæ) depend almost entirely on the wind, and in these, of which our pines and other conifers, our poplars, willows, grasses, etc., are examples, the pollen or male element obtains in enormous quantities, is easily detached, and is generally produced early in spring, when winds prevail, and frequently before the development of the leaves, which would tend to impede its dispersion. The flower is inconspicuous and the stigma or female organ generally branched or hairy, so as to increase the chance of catching the wind-borne pollen. Water is an agency in the fertilization of a few plants, of which the singular Vallisneria is a striking illustration; while a few are aided by birds and higher animals; but by far the greater number are fertilized, or more strictly speaking, pollinized, by insects.

The most casual observer of nature must have appreciated, years ago, the fact that flowers are very important to insects, furnishing the essentials of life to those of several orders and especially to the Hymenoptera (Bees, Wasps, etc.) and Lepidoptera (Butterflies and Moths) in the form either of pollen or nectar. But that insects could be of any especial benefit to plants has only come to be acknowledged and fully appreciated of late years. Toward the close of the last century Christian Konrad Sprengel published an important work — Das Entdeckte Geheimniss der Natur — in which he maintained that the color, form, odor, secretions, and the general structure of flowers had reference to insects which are essential as pollinizers. The importance of insects as agents in cross-fertilization was scarcely appreciated, however, until the late Charles Darwin published the results of his researches on Primula, Linum, Lythrum, etc., and his elaborate work on the fertilization of orchids. The publication of these works gave to flowers a new significance and to their study almost as great an impulse as did his immortal "Origin of Species" to the general study of biology. Hooker, Bennett, Axell, Delpino, Hildebrand, Hermann Müller, and others abroad, and Dr. Gray and Mr. William Trelease in this country, have followed up this subject; and no one can familiarize himself with the results of their studies without a keen sense — if not a conviction — that in the vast number of cases Sprengel's early statement holds strictly true. By these deeper insights into the significances of the floral world, and their harmonies with the insect world, we learn to understand why night-blooming flowers are usually white, even where their day-blooming allies are brightly colored, as in the case of *Lychnis vespertina* and *L. diurna;* or why the calyx, which is usually hidden and green, becomes bright when exposed, as in the Berberry and Larkspur. Many flowers are known to close or "sleep," and while most of them follow the animal world in taking this rest at night, yet there are marked excep-

tions. The dandelion goes to rest at 5 p. m., and wakes at 7 a. m., while the popular names of "4 o'clock" and "John-go-to-bed-at-noon" sufficiently indicate the sleeping hours of Mirabilis and Tragopogon. Sir John Lubbock tritely asks "What is the meaning of sleep in flowers, if it is not in reference to insects?" The closing during those hours when the particular insects needed for pollination are at rest, would protect the flower from spoliation by useless raiders. This belief is also strengthened by the fact that anemophilous flowers of those fertilized by the wind, never sleep, and that flowers which attract insects by smell, emit their odor at particular hours.

But the most interesting fact not commonly understood, that has now been very fully established by the most thorough researches, is, that a very large number of plants, even where the sexes are united in the same flower, absolutely depend on insect aid for pollination, and that the contrivances to induce cross-fertilization are infinite in diversity, while the modifications in structure which these insects have undergone the better to fit them to perform this service, are equally remarkable.

In Dr. Asa Gray's little work, "How Plants Behave," etc., instances enough are given, in an admirably plain and lucid style, to show the manner in which many flowers are curiously and elaborately constructed so as *just not to do* of themselves what must necessarily be done for them in order to prevent degeneracy or extinction of the species. Some plants, as Fritz Müller proved, are so self-impotent that they never produce a single seed by aid of their own pollen, but must be fertilized by that of a supposed distinct species, or even of a supposed distinct genus; while in some cases the pollen and stigma mutually act on each other in a deleterious manner. In most of these entomophilous plants fructification may be brought about by the aid of more than one species of insects, and few plants offer a more striking instance of dependence or more curious floral mechanism to allure, than do the orchids. In

the genus Habenaria, for instance, we find flowers which in some cases strongly resemble butterflies; a separate pocket for the nectar; the pollen bound together in masses by elastic threads, so as to lessen the chance of loss; the base of the stamens forming flattened sticky discs placed in the best possible position for adhering to the head-parts of a moth endeavoring to reach the nectar. In all these features and others that might be mentioned, there is remarkable adaptation; and the flowers of many orchids, as they unfold, seem not only to invite but to court and crave the intervention of some scaly-winged marriage-priest "of glorious color and glistening eye," who shall at once procure a suitor and perform the nuptials. Yet here we have the adaptation of the plant only, and except in a few instances, as, for instance, in that Madagascar orchid, *Angraecum sesquipedale*, where the nectary is so deep that its nectar can be reached only by a moth (like *Macrosila cluentius*) with a very long tongue, our orchids are not dependent for pollination on any one Lepidopterous species, but may be aided by many which have tongues of sufficient length.

CONNECTION OF YUCCA AND PRONUBA.

There are, in fact, few plants which are dependent on a single species for pollination. So far as I know, the Yuccas furnish the only instance of this kind, for they actually depend on some particular species of little white moths belonging to the Tineina and to the genus Pronuba. The Yuccas are a very interesting genus of lily-like plants, so familiar to everyone in our public and private gardens that I need not say very much about them. There are numerous species and even sub-genera, but they are all characterized by anthers not reaching anywhere near the stigma, so that fertilization unaided can take place only by the merest accident. In other words, the stigmatic tube is nowhere within reach of the stamens, and the pollen either remains attached to the open and withered anthers or falls and

remains in different sized lumps on the inside of the perianth, and cannot be introduced into the stigmatic tube without artificial aid.

Our commoner garden Yuccas, forms of *filamentosa*, depend on the commoner Yucca moth, *Pronuba yuccasella* (Pl. 34, Fig. 1, *b. c.*) and so do all the different species found east of the Rocky Mountains, so far as we yet know. During the day-time we may, by knowing what and where to seek, often find this moth either singly or in pairs, resting with folded wings within the half-closed flowers. It is then not only hidden from ordinary view, but well protected by the imitative color of the front wings with that of the flower, so that close scrutiny is necessary for its detection. If we visit the plant after

> " * * * the garish day
> Has sped on his wheels of light away "

and when, with full-blown perianth, the Yucca stands in all her queenly beauty, and sends forth her perfume more strongly upon the night air, we shall, with a little patience, meet with this same moth, flitting swiftly from flower to flower and from plant to plant — the dusky nature of the hind wings and of the undersurface of the front wings almost completely offsetting and neutralizing, when in motion, the upper silvery whiteness of the latter, and thus still rendering the insect a little difficult of detection. It is principally the male which we thus see flying and, by the aid of a " bull's eye," we shall find the female for the most part busily at work in the flowers. He, with relatively stronger wing-power, can afford to spend in the most pleasurable way the few brief days allotted to him; but *she* is charged with a double duty and loses little time in its performance. As a part of the maternal task of continuing her race, she must act as foster-mother to the plant in order to ensure a proper supply of food to her larvæ, which, as we shall presently see, feed on its seeds.

STRUCTURAL CHARACTERISTICS OF PRONUBA.

As preliminary to a better understanding of the habits of the female, it will be well to draw attention to those structural peculiarities which distinguish her from all other species of her order and which so admirably fit her for the work she has to do. Pl. 34, Fig. 3 gives some details of the head (*a*) and an important structure which more particularly characterizes her and interests us, is the maxillary tentacle shown with its palpus at *b*. She has a pair of these organs, which are prehensile and spinous, and it is chiefly by means of these that she is able to collect and hold a relatively large load of pollen for the purpose of pollination. Another organ which is characteristic is the ovipositor. When this is entirely withdrawn, the tip of the abdomen presents a truncate appearance, the terminal joint being bluntly rounded at the tip with a slight projection both above and below and with a corrugated ridge dorsally a little in advance of the tip. This terminal joint is very much compressed from the sides, with a few stiff hairs around the terminal border. The ovipositor issues from the middle of the truncate end and when critically examined the basal part, when highly magnified, shows an imbricato-granulate surface, the granulations strongest basally and diminishing distally, while the terminal part is smooth, long, and peculiarly constructed at the tip, the extreme tip being notched or serrate and having a dorsal fin also finely and sharply serrate, running anteriorly from it—the whole recalling in form the caudal and second dorsal fins of the Lamprey (Petromyzon). It thus presents itself, as usually exserted when the moth is quickly killed while in the act of oviposition; the imbricate basal and smooth terminal parts looking like two joints, while the protruded portion of the vagina looks like a third and short basal joint. The various details shown in Plate 37, Fig. 1 will help to elucidate the nature of this organ. Ventrally along the terminal part is seen a membranous duct which broadens just

in front of the tip and has an outlet from which a soft, extensile oviduct can be extruded. This is fine, silk-like, pale, membranous and very elastic. It is smooth basally but armed along its terminal third with retrorse hairs, increasing somewhat in number and strength toward the tip, around which they are almost spinous. At first sight these would seem to be out of place and to impede rather than aid the insertion of such a delicate filament; but as we shall presently see the act of oviposition is a most intricate and difficult one and these hairs are doubtless sensitive and tactile and serve the double purpose of enabling the moth to feel her way in the ovarian cell and of temporarily anchoring in the soft wall thereof, while the egg is being passed to its destination. The manner in which this remarkable ovipositor is worked by chitinous rods with muscle attachments will be considered in a fuller statement of the internal anatomy of the moth in the second part of this paper. My purpose here is to call attention simply to those features which will more fully explain her visible acts, and it will be seen that this ovipositor is admirably adapted for cleaving through the young fruit and then running the egg into the ovarian cavity, as will be presently described. The male has no very marked characteristics and is distinguished from allied species chiefly by the structure of the exposed horny parts of the genitalia at the tip of the body. (Pl. 37, *r. s.*).

THE ACTS OF POLLINATION AND OVIPOSITION.

Though all the acts of the female are nocturnal, it is not at all difficult to follow them with a lantern, for, albeit ordinarily shy, she may be closely approached when she is about to oviposit. Her activity begins soon after dark, but consists, at first, in assiduously collecting a load of pollen. She may be seen running up to the top of one of the stamens, and bending her head down over the anther, stretching the maxillary tentacles, so wonderfully modified for the purpose, to their fullest extent, the tongue uncoiled

and reaching to the opposite side of the stamen. In this manner she is able to obtain a firm hold of the stamen while the head is kept close to the anther and moved peculiarly back and forth, something as in the motion of the head of a caterpillar when feeding. (Pl. 38, Fig. 2.). The maxillary palpi are used in this act very much as the ordinary mandibles are used in other insects, removing or scraping the pollen from the anthers toward the tentacles. After thus gathering the pollen, she raises her head and commences to shape it into a little mass or pellet by using her front legs very much as a cat does when cleansing her mouth, sometimes using only one leg, at another time both, smoothing and pressing the gathered pollen, the tentacles meanwhile stretching and curving. After collecting all the pollen from one anther, she proceeds to another and repeats the operation, then to a third and fourth, after which, with her relatively large load — often thrice as large as the head — held firmly against the neck and front trochanters, she usually runs about or flies to another plant; for I have often noticed that oviposition, as a rule, is accomplished in some other flower than that from which the pollen was gathered, and that cross-fertilization is thus secured.

Once fully equipped with this important commodity, she may be seen either crawling over or resting within the flower, generally with the head toward the base. From time to time she makes a sudden dart and deftly runs around the stamens, and anon takes a position with the body between and the legs straddling two of them, her head being usually turned toward the stigma. As the terminal halves of the stamens are always more or less recurved, she generally has to retreat between two of them until the tip of her abdomen can reach the pistil. (Pl. 37, Fig. 2). As soon as a favorable point is reached, generally just below the middle, she rests motionless for a short time, when the abdomen is slightly raised and the lance-like ovipositor is thrust into the soft tissue, held there the best part of a

minute, while the egg is conducted to its destination, and then withdrawn by a series of up and down motions.

In non-technical language, the pistil or the young fruit, below the stigmatic tube, shows externally at this time six quite distinct longitudinal divisions each having a median ridge, there being six corresponding depressions or concavities in which the six stamens fit, especially at the base. Technically, the pistil is a three-celled ovary, the styles bifid at tip and united so as to form the stigmatic tube. A transverse section anywhere about the middle will show that each of the six longitudinal sections contains a row of ovules within the ovarian cell. More strictly, the ovules are in pairs, as there are but three primary sections or carpels, divided by three primary divisions or dissepiments. Pl. 36, Fig. 1, shows a transverse section of one of these primary divisions or carpels which well indicates the position of the ovule (*a*) the funiculus (*b*), the placenta (*c*), and the ovarian cell (*d*). As the fruit enlarges the three secondary dissepiments narrow and coalesce, while the other three widen, so that the pod becomes practically three-lobed and the seeds are more distinctly in pairs, the inner side straight and the external quite convex. In oviposition the young fruit is pierced just within the ridge in the depression occupied by the stamens, and almost always on the side of one of the primary or deeper divisions, where the walls are thinnest, so that the ovipositor enters the ovarian cell at the external or rounded side of an ovule, and does not ordinarily touch the ovule itself. (Pl. 36, Fig. 2, *aa*). Rarely, however, the ovipositor penetrates the ridge and passes between two of the ovules, or sometimes even penetrates one, this last case being, however, quite exceptional.

During the insertion of the egg, which, as stated, usually occupies about one minute, a nervous twisting and trembling of the body may be observed, and so intent is the moth upon this work that after the ovipositor once penetrates the pistil, the whole perigon may be detached, some of the encumbering stamens and petals removed, and the insect

brought within the range of a good lens, when all her movements may be observed to the greatest advantage without disturbing her. In this way I have been able to watch the consignment of hundreds of eggs, and to admire the delicacy and elasticity of the oviduct proper, which issues from the chitinous sheath in a silk-like thread, almost invisible to the naked eye. While being withdrawn it is seen to be as long as, or longer than, the terminal abdominal joint and stretches or bends as the body is raised or lowered, in freeing it from the pistil. Indeed this freeing is a laborious job, and occupies from forty seconds to two minutes. Oviposition rarely begins before dusk, and takes place only in the flowers which are newly opened, *i. e.*, during the first or second nights after opening, as it is chiefly during these nights that the ovary is susceptible to pollination, the stigmatic tube and the ovules, which are at first open for the reception of the pollen, thereafter closing. The moth seems instinctively aware of this and is never found ovipositing in the older flowers. Indeed, her actions indicate that she investigates closely not only the condition of the pistil as to development, but as to whether or not it has already been punctured.

It may be well here, in order to more fully understand the action and influence of the moth, to look a little more closely into the characteristics of the Yucca flower at this stage of its development. A longitudinal section of the upper portion of the pistil will show us the style with its stigmatic tube, which, at this time, communicates with the ovarian cells. Trelease (who will, I hope, accompany this article with some botanical details showing the pollen tubes and other microscopic structures) has shown that the stigmatic liquor is not nectarian, but that the slight amount of nectar which is associated with the flowers, is secreted in thin pockets formed by partitions that separate the three cells of the pistil and which open externally by a contracted pore from which the nectar is poured through a capillary tube (enclosed by the closely applied but not outwardly

united lobes of the ovary) to the base of the pistil, so that nectar-feeding insects seek it, not about the stigma, but at the base of the stigma or of the petals, whether within or without. I have fully verified Trelease's statements by dissection of the pistil and by study of the insects seeking this scant nectar and endorse his conclusions, that, while the observations serve to disprove any positive value of their nectar in the pollination of the Yucca flowers, they add to the importance of Pronuba by showing that the acts of collecting pollen and transferring it to the stigma do not result in any food compensation, as I was at first inclined to suppose. In other words, there is no nectar to allure other nectar-loving insects and cause them to go to the stigma; but on the contrary, those which are drawn to the plant by the slight amount of nectar are led in the very opposite direction, viz., to the base of the style or of the flower. It is also an interesting fact that I have never noticed Pronuba feeding, as contradistinguished from pollinizing, for the motions of the tongue of Lepidoptera when feeding are quite characteristic and easily recognized. Indeed the two pieces which form the tongue are so often separated at tip, and so weakly joined throughout, as to raise the question, in connection with a somewhat imperfect alimentary canal, as to whether the moth feeds at all, and to suggest that the rather strong tongue, otherwise, assists pollination.

No sooner is the ovipositor withdrawn into the abdomen than the moth runs up to the top of the pistil, thrusts the pollen into the stigmatic opening, and works her head rapidly — the motion being mostly up and down and lasting several seconds. She works with a vigor that would indicate combined pleasure and purpose and makes every effort to force the pollen into the tube, thrusting it ordinarily from the base of one of the three primary clefts of the style. In my earlier observations I had always supposed that the tongue was used, in this operation, for sipping the liquid from the stigma after, or in connection with, her more

arduous work; but it is probable that, seeing that this liquid is not nectarian, Professor Trelease is right in stating that the tongue is used to thrust the pollen further into the cavity than her tentacles can reach, though I can see no necessity for this action so far as pollination is concerned. After the more vigorous motions of thrusting the pollen into the tube, she frequently rests in comparative quiet, working her tongue in the tube sometimes for four or five minutes together, but ordinarily the act of pollination ceases with the few vigorous thrusts already described. The importance of this act will be better appreciated when I state that numerous experiments in artificial or brush pollination have shown that effective fertilization in *Yucca filamentosa* is by no means an easy matter, and that it rarely takes place as effectively as through the actions of Pronuba.

This carrying of the pollen to the stigma generally follows every act of oviposition, so that where ten or a dozen eggs are consigned to a single pistil, the stigma will be so many times be-pollened. The ends of the tentacles, which are most setose and spiny, and which are always curled into the pollen mass when not uncoiled, must necessarily carry a number of pollen grains into the stigmatic tube each time pollination takes place; and I have noticed a gradual diminution in the size of the collected mass, corresponding to the work performed, which is indicated by the rubbed and worn appearance of the individual, the freshest specimens always having the largest loads. I have also noticed that where oviposition occurs thrice in the same pistil (and this is most common), the three corresponding acts of pollination are consecutively in the three deeper notches of the style, thus insuring a supply for the ovules in each carpel. Pollen collecting is, however, sometimes continued after oviposition has begun, but is rarely witnessed during the active period of egg-laying. This is, however, invariably followed by pollination, though not always alternating therewith. Indeed it is not uncommon for a female

to consign two or three eggs to the same pistil, before running up to the stigma and inserting the pollen.

While oviposition generally takes place in the manner described, the moth head outward (Pl. 37, Fig. 2) and straddling two stamens, the opposite position is sometimes assumed, and larvæ and punctures are not infrequently found in the upper part of the fruit, especially where a single fruit is stocked with ten or more larvæ. As the fruit enlarges, the mouth of the puncture forms a slight discolored depression, more noticeable in some varieties than in others; but the passage-way becomes obliterated.

DEVELOPMENT OF THE EGG AND LARVA: TRANSFORMATIONS OF PRONUBA.

The egg is an extremely delicate, thread-like structure, averaging 1.5 mm. in length and less than 0.1 mm. (Pl. 37, fig. 1, *m*, *n*, *o*.) in diameter, tapering at the base and enlarging slightly toward the capitate end, which has also a slightly indurated point. * It is impossible to follow it with the unaided eye or in fact with an ordinary lens, even if the pistil be at once plucked and dissected; but by means of careful microscopic sections, we may trace its course. From the position assumed by the moth, the ovipositor punctures the pistil somewhat obliquely, but as the egg is much longer than the diameter of the ovarian cell, the delicate oviduct of the moth bends and then runs vertically along the inner part of the cell next the placenta, and leaves the egg extending in this longitudinal direction along some seven or eight ovules, as

* In the ovaries the less developed eggs are shorter and elliptical, as shown in my earlier figure (Proc. A. A. A. S. XXIX, Fig. 3, *h*.) and there is every gradation between this and the more mature ova which have the same filiform character as when seen in the Yucca pistil. It is interesting thus to note that the immature and undeveloped egg of Pronuba corresponds with the mature egg of Prodoxus.

shown in the illustrations (Pl. 35, Fig. 2, *c. c.*).* The apical end of the egg soon enlarges (Pl. 37, Fig. 1, *n*) and the embryo may be seen developing in it, very much as in the case of the similarly elongate eggs of gall-flies (Cynipidæ), though the pedicel does not shorten, as observed in these last. Segmentation is noticeable on the second day and the Yucca ovule at once begins to swell and enlarge, the irritation (doubtless mechanical) influencing the plant tissue much as in the case of the punctures of the gall-flies just mentioned. Sometimes two or more adjacent ovules are thus affected.

The larva hatches in about a week and will be found at a point from 8 to 10 ovules above or below the external puncture according as the egg was thrust above or below it. It is not more than 1 mm. long and seems to live for some time on the juices of the degenerate and swollen ovules, but finally enters one that is developing, at the funicular base. So far as I have observed, the larva undergoes some three different molts, as but four different sizes of the head have been noticed. The general color, which is at first translucent white, conforms for the most part to the color of the tissues in which it is feeding; but becomes in time more yellowish, and finally, when mature, ordinarily acquires a rosy hue. The larva has no pro-legs, but has well-developed thoracic legs. It matures with the ripening of the seeds, which differs in time in the different species of Yucca, and also in the same species, but occupies on an average about a month in the ordinary *Yucca filamentosa*. The number of seeds destroyed is rarely more than a dozen and more frequently less, and I have recorded the fact of

* The position and development of the egg were studied in 1874, by Engelmann and myself (Trans. Ac. Sc. St. Louis, III, pp. 208–211) and while the egg, from those observations, is sometimes curled around an ovule in the ovarian cell, the position above described is the normal position as subsequent study has shown. I also gave there the duration of the egg state as four or five days, but it more often extends beyond a week. I also there attributed the swelling of the ovules to the action of the larva, but it begins before this hatches.

having found as many as twenty-one larvæ in a single pod. Just about the time the pods are hardening and ready to dehisce and the seeds have already colored, the full-grown larva bores its way out of the pod, makes its way to the ground — in all probability by the aid of a silken thread — and there bores several inches below the surface and forms a tough silken cocoon intermixed with the soil. It makes its burrow to the extreme epidermis of the pod sometime before it leaves, and if there should happen to be a long spell of wet weather at this time, the burrow is very apt to become saturated with moisture and the larva to perish from mould. I have never seen one issuing during the day, or in the early part of the night, so that it probably leaves the pod late at night. It remains as a larva within its cocoon during the fall, winter and spring months and only transforms to the chrysalis state a few days before the blooming of the Yuccas. The chrysalis, (Pl. 34, Fig 4) as shown in the figure, is armed with an acute spine on the head and with singular spatulate spines on the back, which are well fitted to enable it to work its way to the surface from its underground retreat.

It thus works its way partly out of the ground and as this is generally under the shelter of the mass of Yucca leaves (in the case of our filamentose species) the issuing is rarely seen, except by the most careful watching. The newly-escaped moth, with wings crumpled and moist, runs up one of the leaves and hangs thus sheltered, while her wings expand, following the invariable rule of all the members of her Order, and throwing them first back together to facilitate inflation (Plate 34, fig. 2) and only closing them and folding them along the body after they have become sufficiently firm.

EFFECT OF PUNCTURE ON THE FRUIT.

The effect of the puncture of the female moth in oviposition is at once noticeable on the young fruit by a darker green discoloration externally. In time this becomes a

depression, and the irregularities of the pods (Pl. 34, Fig. 5, *b*. *c*.) which have been considered characteristic of the fruit of the genus are chiefly due to these punctures, which, ordinarily occurring just below the middle of the pod, produce a more or less marked constriction there. This I have often proved by artificially pollinizing the flowers and protecting them from Pronuba, when the pods will develop in a regular, parallel-sided manner (Pl. 34, Fig. 5, *a*.) Internally the effect of the puncture is no less marked. A few of the ovules in the region of the puncture are at once affected, as already described, while the development of a yet larger number is more or less arrested, this being the case even when not touched by the ovipositor or the egg, or even where the egg fails to hatch. Did the ovules develop immediately around the egg it is probable that they would crush it. At Pl. 35, Fig. 2 *d* is shown a section of a carpel 7 days old with egg, and of another, *e*, with the larva just hatched.

EFFECT OF FERTILIZATION ON THE STALK.

It is an interesting fact that, however pollinized, whether by Pronuba or artificially, each Yucca panicle will mature but a certain number of pods, so that a number of those which are fructified drop after a few days' development, while some wither even after they have reached nearly full development. This gives an element of uncertainty to experiments and makes it necessary to be very careful. It is interesting also to note how the mere fact of fructification influences the main stalk, at least in *Y. filamentosa*, for where a panicle is protected with gauze, so as to prevent the access of Pronuba, and cause the dropping of all the flowers, the stalk soon thereafter withers and dies.

DATES OF THE FLOWERING OF THE YUCCAS AND APPEARANCE OF THE MOTH.

There is some irregularity in the flowering of our Yuccas, even of those of the same species. The typical form of

Y. filamentosa at Washington and St. Louis begins blooming about the middle of June, and is usually through blooming about the middle of July. In Philadelphia, so near to Washington, it blooms nearly two weeks later. *Y. angustifolia* blooms from a fortnight to three weeks earlier, so that it has almost ceased to bloom before *filamentosa* begins. *Pronuba yuccasella* is restricted in its appearance in the imago state, and in the eastern portion of the country appears coetaneously with the flowering of *Yucca filamentosa*, the males almost always being seen first. Thus both at St. Louis and at Washington *Yucca angustifolia* does not ordinarily set fruit, because it flowers before the Yucca moth appears. Occasionally, however, this last is about when some of the latest or terminal flowers are open, and I have known a few pods on the tip of the panicle of this species to be fructified in St. Louis. So in the more northern States, where *Yucca aloifolia* is cultivated, it blooms too late to be pollinized, and I have never known it to set fruit.

In South Carolina, as Dr. J. H. Mellichamp informs me, there is even greater irregularity in the blooming of *Y. filamentosa*, though the genuine or more typical form blooms a month earlier than at Washington. This is pollinized by Pronuba; but some varieties bloom earlier or later — even in autumn. In these later bloomings Dr. Mellichamp has never known fruit to be produced. The variety *lævigata* usually blooms two weeks later, and the variety *bracteata* still later than the typical form.

Yucca aloifolia blooms in the south in June and July and the earlier blooming specimens are pollinized by Pronuba.

Yucca gloriosa flowers in the south still later (September and October) and rarely sets fruit. It is very irregular, however, and on one occasion Dr. Mellichamp found a plant blooming in June in an old sandy field. This was the only plant he ever saw blooming in summer, and it produced fruit. I have seen a form of it blooming in March, with no sign of fructification.

Further accurate and careful observations are very desirable as to the dates of appearance of Pronuba in the Gulf States region. The general result of my observations in the southern States as to the presence of the insect would indicate that its appearance is adapted there to the greater irregularity of the blooming of the Yuccas; but as a general thing, *Y. aloifolia* is seldom fructified except when blooming at the same time as *filamentosa*, and the same is true of *gloriosa*, which more rarely produces fruit.

No one can observe our Yuccas closely without noticing a certain irregularity in blooming. The same root-clump of *filamentosa* will some years throw up several flower-stalks and in other years none. This is particularly noticeable in the Rocky Mountain region, and the fact that the flowers of *Yucca brevifolia* are uniformly scarce over large stretches of country has been repeatedly observed and reported to me. I observed it on my first visit to these tree Yuccas in 1887 and I remember very well that of *Yucca angustifolia* — which is quite common on approaching Denver and was found all along the Denver & Rio Grande R. R. to Colorado Springs, growing even in the side-walks of that town — not a single flower-stalk was noticed when I first visited those parts in 1873. This irregularity in blooming would prove fatal to insects depending upon the flower and fruit, were there not some provision to meet it, and it is one of the noticeable characteristics of the Yucca moths that they are equally irregular in development; for, as we shall presently see, a very large percentage of the moths fail to issue the year following the development of the larva, but show a great tendency to retardation in development, some of them not issuing until the second, third or fourth year. This is equally true of both Pronuba and Prodoxus.

NEED OF PRONUBA.

We have already seen that all the pods do not contain Pronuba larvæ, though we rarely find any on the fila-

mentose species that do not show the marks of puncture, which indicates that a great many punctures are fruitless in result, owing either to the difficulty of the operation of oviposition, or to the fact that the eggs, having been once consigned to the pistil, have failed to hatch, for one reason or another; or again, that the larva has, for one reason or another, perished. A similar mortality is connected with the similarly difficult and complicated oviposition of the Cynipidæ, as Adler has shown. In dissecting the young fruits of the filamentose Yuccas, with a view to critical examination, I have found that about half of them, on the average, contain nothing; but the proportion varies greatly in different localities and according to circumstances, and I may say that, as a result of my numerous examinations, fully two-thirds of the mature pods are found to contain the larvæ of Pronuba. All the experiments which I have so far made, or have known to be made, prove conclusively that the capsular species never set fruit without her aid.

SELF-FERTILIZATION OF YUCCA.

While the capsular Yuccas are thus sterile wherever Pronuba does not occur, or is excluded from the flowers, there is good evidence that some of the soft-fruited species have exceptionally set fruit where there is every reason to suppose that Pronuba does not exist. I have already shown, in previous writings, how the structure of the flowers of *aloifolia* renders the chance of pollination greater than in the other cultivated forms. There is no style, the stigma is sessile, and the stigmatic liquor is abundant, filling, and even overflowing, the shallow opening or tube. The flowers are always more pendulous, even in full expansion, than in the filamentose species and the stamens relatively longer, (Pl. 35, Fig. 1), so that there is more likelihood of the pollen falling on the papillose apex of the stigma or being brought near it by conniving petals. In this connection I also introduce a figure to show certain variations and deformities which sometimes occur in the pistil of *Y. filamentosa*

(Pl. 38, Fig. 1) and which would suggest another possible method of self-pollination, namely, by the stamens reaching an exceptional length. So far as any proof is concerned, this has never happened with any of the filamentose species, and in any event must be of extremely rare occurrence.

The mere accidental introduction of any of the pollen grains into the stigmatic liquor would in all probability serve to fertilize some of the ovules, though I doubt whether complete fructification could thus ensue. The stigmatic cavity varies very much in the amount of its secretion, which is sometimes abundant and at other times, almost or quite absent, and both Professor Trelease and myself have noticed that it is more abundant on *Yucca angustifolia* in its native habitat than on eastern grown plants.

PRONUBA THE ONLY INSECT POLLINIZER.

In my earlier studies, while the mutually beneficial adaptations of Pronuba and Yucca were at once apparent, I was strongly inclined to believe that there must be, occasionally, accidental pollination of the flowers by other insects, more particularly because of the fact just mentioned that the fleshy-fruited species were reported to occasionally produce seed in regions in which, presumably, the Yucca moth did not exist. I became interested, therefore, in carefully studying the habits of all insects found associated with or found within the flowers of Yucca. I have particularly watched and observed the Pennsylvania Soldier-beetle (*Chauliognathus pennsylvanicus*, Pl. 38, Fig. 3), which is more commonly found within the flowers than any other, and which has a peculiar mouth structure which would lead one to suppose that it would have something to do in attempting to get at the stigmatic liquor. Without going into details, I may say that observations covering a period of nearly twenty years have only served to convince me of the incapacity in this respect of all other insects associated with the plant. The Chauliognathus above mentioned I have never found anywhere near the stigma. All

its movements show that it seeks what little nectar it can find at the base of the flower, which it uses however, chiefly as a place of shelter. It may and I think does feed somewhat on the fallen pollen, and in so far interferes with pollination by the moth. The beetle is almost always found in pairs, the female quite gravid, and while her eggs have not yet been described, and the place of oviposition is yet unknown, they are in all probability laid in the ground, and the larva is known to be predaceous and to be one of the enemies of the common Apple Worm. None of the other insects have ever been observed to go to the stigma and none of them have been observed to gather pollen. The few Hymenoptera, including the common Hive Bee, which are on rare occasions found about the flower, are accidental rather than habitual visitors, and get little satisfaction in the modicum of sweet they can find near the base of the flower. The slightly glutinous nature of the pollen, which is not easily dusted on to hairy insects, makes it extremely doubtful whether it is ever, even by accident, attached to the head of an insect that might by chance seek the stigmatic liquid, and the experiments I have made indicate that, with the long-styled Yuccas, a very thorough and effective insertion of the pollen grains is necessary for fertilization. These general conclusions have been confirmed by specific experiments made for the purpose; for over and over again I have excluded Pronuba by covering the whole panicle with gauze and have admitted all sorts of other insects in the hope of inducing fertilization; but in every case I have failed, whereas, whenever Pronuba has been admitted to the flowers, there has been evidence of her work and fructification.

Pronuba yuccasella is found in all parts of the country east of the Rocky Mountains where the filamentose Yuccas normally range; but has not extended to all sections where they are cultivated. The time of its appearance, as we have seen, is strikingly coetaneous, east of the Missis-

sippi, with the blooming of *filamentosa*; while other cultivated species which bloom either earlier or later, and which, therefore, do not receive the visits of the moth, I have as already stated, never known to bear seed. On the western plains, where *Y. angustifolia* is native, the moth's season of appearance is adapted to the flowering of this particular Yucca. In California, *Yucca whipplei* is pollinized by *Pronuba maculata*, an invariably maculate species; while on the Mojave desert, *Yucca brevifolia* is pollinized by *Pronuba synthetica*, a species still more abnormal than *yuccasella* and modified to fit it to the peculiarities of that peculiar species of Yucca. In the Gulf States the typical *yuccasella* occurs, and fertilizes not only the filamentose Yuccas, but, as already shown, those individuals of the larger, fleshy-fruited species like *aloifolia* which happen to bloom about the same time of the year.

Thus we find that some species of Pronuba is connected with all the Yuccas, so far studied in this connection, and I have no doubt that this will be found to be generally true, so far as the indigenous species are concerned, and that in the native home of any of the species we shall find that pollination depends upon some species of Pronuba. This is rendered certain by the fact that wherever I have been able to examine the mature or partially mature fruit of other Yuccas in herbaria, I have in almost every instance observed the constriction and in most instances seen traces of the puncture and the work of the larva. A large and interesting form of Pronuba may be expected from the Giant Tree Yucca of northeastern Mexico (*Yucca filifera* Chabaud), the *palma* of the Mexicans, with its enormous pendulous panicles from four to six feet long. The fruit is described as often constricted, a result doubtless of the work of Pronuba, and the only pod in the herbarium of the Department of Agriculture, shows this constriction. This baccate fruit is from 2 to 3 inches long and the stigma of the young fruit is farther removed from the anthers than in any other species. The long, thin, smooth and more

flaccid leaves of this tree Yucca permit much more easy study (with the aid of a ladder) of its flowers than of *Yucca brevifolia*, with its stiff, sharp, serrate leaves, which form a veritable *chevaux-de-frise*. The small pod of *Yucca rupicola* from Texas, with its persistent beak-like style, also shows the work of Pronuba and is probably pollinized by a distinct species, as is also, doubtless, *Yucca treculeana*. I shall be delighted to receive any insects found in or connected with the flowers or fruit of any of the different species from Mexico and the south-west, or even ripe fruit, from any one into whose hands this paper may fall, and who has had an opportunity of studying the other species of Yucca which have not yet been studied in connection with pollination.

I have often been struck with the power which the moth has of detecting isolated plants blooming for the first time remote from other plants or in localities where she could not possibly have been previously developed, a fact which indicates that, where abundant, in addition to her ordinary more sedentary duties, she takes long reconnoitering flights.

GENERAL CONSIDERATIONS.

The facts here set forth can be observed by any one who will take the trouble to assiduously investigate them. It has been a source of frequent pleasure to me to introduce my friends to this little moth and its curious ways, and almost every one of my assistants, or those who have been associated with me, have been able to verify the facts repeatedly, while some of them have been of material aid in carrying on the observations; for these observations are more satisfactorily made by two persons than by one, as it is difficult for one person to hold the lantern and at the same time closely investigate. I would here express my particular indebtedness to Messrs. L. O. Howard, E. A. Schwarz, Otto Lugger, Albert Koebele, C. L. Marlatt, and Th. Pergande, who have aided in the different experiments, particularly the latter, who helped me in the earlier ones

in St. Louis and whose interest and enthusiasm have never failed to produce good results in any special work he has done for me.

In this connection I take pleasure in reproducing some experiences of Professor Trelease's, as communicated to me last July, not so much because they so fully confirm my own, as because they are in such refreshing contrast, in their accuracy and insight, to those of some others who have published on the subject. He writes: —

"In addition to my observations noted in Bulletin Torrey Club, 1886, 185, I have watched the moths at work in 1890 and 1891 — the only seasons when I have been at home during the blooming season — and have had my assistants, Duffey and Webber, make independent observations and demonstrate pollination to our garden pupils. The observations were made on *Y. filamentosa*, including its various forms cultivated in St. Louis under other names. Each act of oviposition is so promptly followed by pollination that the moth seems to have it on her mind to perform the latter as a sequel to the former, and I am disposed to think that my belief that either might occur first came from the first observation in a given case happening to begin between the two acts. I have not positively confirmed my observations on the use of the tongue in pollination, though Webber feels certain that he has this year seen it so used. I do not, therefore, look on it as normal — and this would lessen the probability of the habit of thrusting pollen into the stigmatic chamber having been acquired while the moth was feeding on the stigmatic fluid. The latter varies much in quantity, and as you have stated, frequently fills the chamber, especially in the early morning. The septal glands are quite as inactive as I at first stated; but this year we have several times in the early morning found abundant watery fluid both within and outside the perianth, as noted by Meehan, but without ascertaining its source. I am certain, however, from its position, that little if any comes from the glands. Before 9 a. m. we have several times this year seen a few hive bees gathering this fluid, both within the flower and from the outside, and I once saw a bee (Apis) probing, but apparently unsuccessfully and very hastily, the space between the bases of the filaments, and consequently the outlets of the nectar ducts. In addition to my assistants and pupils I have shown the acts of oviposition and pollination to the Vice-President of our Board, to Coulter, Evans and several other visitors to the Garden, as well as to my wife and her sister. Every one who has seen the work done shares your opinion and my own as to the intention shown by the moth. We notice that almost invariably the moth goes down to near the base of the stamens, then creeps up, gets settled between two stamens and backs down a considerable distance while testing the surface of the ovary with the ovipositor

before puncturing it. This year for the first time I have seen Pronuba at the anthers, once with Miss Johnson and Mr. Henry Hitchcock, once with Miss Johnson, and a third time with my wife. None of our observations on this point could be made under a lens, the moth being more shy than at the other work. In the first case a moth that had been seen to oviposit and pollinate once stopped and made a deliberate tour of the nearly empty anthers of the same flower, apparently scraping them out with its tentacles as Boll describes it, and with much the motion seen when she is thrusting pollen into the stigma. Frightened from the first flower, she went to another on the same cluster and rather nervously and hastily explored two anthers, after which, owing to the movements of so many persons about the plant, she became thoroughly alarmed and after nervously running about in several flowers, flew away. In the second case a moth similarly scraped an anther (or coiled and uncoiled its tentacles in it) but was frightened by our motions and, the light being strong (7:15 p. m.), crept to the bottom of the flower, remaining there in the usual diurnal resting position. In the third case my wife saw a moth go through the acts of oviposition and pollination twice, after which she collected pollen from four or five stamens of the same flower; on being called I saw the operation repeated on another stamen. The collection of pollen was not actually seen in either of these cases, but only the perfectly deliberate and intentional act of going to the ends of the filaments and gouging the anthers out with the tentacles, and the observation was not close enough in any case to say that the moth did not meantime bring the pellet together by a lateral motion of the maxillæ and round it in the manner described by you. But the act could have had no other object than the collection of pollen; and the third moth, which was caught, had a fresh ball of pollen.

"Above Manitou, where it is abundant, I studied *Y. angustifolia* in the first ten days of July, this year; — in fact was there for that purpose when your first letter came to St. Louis. Females (weathered) were invariably with pollen. One of them (No. 31) was seen to oviposit and pollinate twice, behaving precisely as in *filamentosa*. I was not fortunate enough to see the collection of the pollen on this plant. The difficulty I have had in watching this part of the work no doubt comes from the fact that the moth can in a few minutes accumulate pollen enough for many pollinations, so that it is a relatively rare operation. My observation on *filamentosa* (assuming her to have had pollen when thrusting the tentacles into the stigma in the first and third cases noted above) shows that she renews this load as it becomes exhausted. Males with very fresh wings were abundant in *angustifolia* flowers, and at the end of the blooming period were much more quiescent than the females, for a male could be found head down after an interval of several hours at night when the flower was re-examined. One pair was seen *in coitu* in a flower. One was seen to be nervously exploring the base of a flower between the filaments, but certainly found little or no nectar, and I have not seen another possible attempt at feeding. In *angustifolia* the stigmatic secretion is more commonly abundant than in *filamentosa*, but there is no greater flow

from the septal glands. Small beetles and flies were very abundant in the flowers and seem to feed on the pollen, collecting on the anthers for that purpose. The former may also gnaw the papillæ of filaments, for the stamens become sodden and wilt within a day or two when these beetles are present — but I have not seen the latter gnawing at them. In their operations upon the anthers these little insects sometimes dislodge a ball of pollen which falls down. In one flower with horizontal pistil such a lump was seen on the green style near its apex; but the probability of any pollen falling in this manner where it could develop its tubes in the stigmatic chamber, is very slight except in case of a possible deformity of the pistil by the reflection of the upper stylar lobe — thus opening the chamber above — or the upbending of the style so that the opening was directed toward the uppermost stamen. Aphides and Coccinellids were of course very abundant, but play no part whatever in pollination. A fair number of capsules were set this year, and all I saw were found to contain larvæ of Pronuba or to show the characteristic scars or constrictions where the moth had pierced the ovary.

"*Prodoxus* was very abundant, and I send you a number of both sexes. Nos. 19, 32 and 33, [all of *Prodoxus decipiens*] were seen ovipositing in stem of *angustifolia*, head upward, the abdomen being worked much as with Pronuba. Numerous Prodoxus were seen flying from flower to flower very actively, and the sexes were seen *in coitu* in a flower, the abdomens working much as in ovipositing. The female in the cases watched by me when ovipositing in the stem, crept *up* a short distance before laying each new egg.

"Apropos of Meehan's idea that the Pronuba moth close-fertilizes the flower, I have seen females when undisturbed go from flower to flower here, and several times in the mountains a female was seen, without having been disturbed, to fly off horizontally from a plant on the steep mountain side, with every evidence of the necessity for a long flight before finding another Yucca."

We have in the structures and functions which are so characteristic of this Yucca Moth, admirable adaptations of means to an end, whether for pollinizing the plant or providing for a future generation. The Pronuba larva rarely destroys more than a dozen of the seeds, so that several may develop within a single pod and yet leave many perfect seeds, while, for the reasons already stated, we occasionally have pods without a trace of the insect.

There is between Pronuba and its food-plant a mutual interdependence which excites our wonder, and is fraught with interesting suggestions to those who are in the habit of reasoning from effect to cause. Whether we believe, as

I certainly do, that this perfect adaptation and adjustment have been brought about by slow degrees through the long course of ages, or whether we believe that they were always so from the beginning, they are equally suggestive. The peculiar structure of the flower which prevents self-fertilization, though on a superficial view it strikes one as a disadvantage, is, in reality, of benefit, as the value of cross-fertilization has been fully established; while the maxillary tentacles of the female moth are very plainly an advantage to her species in the "struggle for life;" and it is quite easy to conceive, on Darwinian grounds, how both these characteristics have been produced in the course of time from archetypal forms which possessed neither, and in reality we get a good insight into the process in studying the characteristics of other species of the family Prodoxidæ. These peculiarities are, moreover, mutually and reciprocally beneficial, so that the plant and the animal are each influenced and modified by the other, and the same laws which produced the beneficial specialization of parts will maintain them by the elimination of all tendencies to depart from them.

The pollen grains would not adhere by chance to the rolled-up tentacles,* and we have seen how full of purpose and deliberation Pronuba's actions are. It may be that all her actions are the result merely of "blind instinct," by which term proud man has been wont to designate the doings of inferior animals; but no one can watch her operations without feeling that there is in all of them as much of purpose as there is in those of the female Pelopæus who so assiduously collects, paralyzes and stores away in her mud-dabs the spiders which are to nourish her young; or in the many other curious provisions which insects make for their progeny, which, in the majority of instances, they are destined never to behold. Nor can I see any good

* I refer here to the filamentose Yuccas. Where they are more distinctly glutinous, as in *Y. whipplei*, the statement is, perhaps, less true.

reason for denying these lowly creatures a degree of consciousness of what they are about, or even of what will result from their labors. They have an object in view, and whether we attribute their performances to instinct or to reason depends altogether on the meaning we give to those words. Define instinct as "congenital habit" or "inherited association" or, as I prefer to characterize it, as *the inevitable outcome of organization*, and most of the doings of the lower animals may justly be called instinctive; but the instinctive and reasoning faculties are both present, in most animals, in varying proportion, the last being called into play more especially by unusual and exceptional circumstances, and the power which guides the female Pronuba in her actions, differs only in degree from that which directs a bird in the building of its nest, or which governs many of the actions of rational men.

THE BOGUS YUCCA MOTH.

The natural history of this species, *Prodoxus decipiens*, has been elsewhere recorded;* but it will be well to show here wherein it differs from the true Yucca moth, notwithstanding the close general appearance of the perfect insects, which resemblance has necessitated the most careful observations and has often neutralized those which were careless. The moths (Pl. 39, Fig. 2, *a*, *b*.), in both sexes, are on the average considerably smaller than Pronuba, and, if anything, more abundant in the earlier opened flowers of *Yucca filamentosa*. The trained observer, however, will have no difficulty in distinguishing them, especially the females, even without close examination of the structure; for he soon comes to recognize the bull-dog like appearance of the head of the female Pronuba, as also the difference in the terminal joints of the abdomen, that of Prodoxus being thicker and darker. The males are distinguished with more difficulty, and yet here the small size

* *Am. Entomologist*, III, p. 142; Proc. Am. Ass. Adv. Sc. XXIX, 1880.

of Prodoxus and the darker coloring of the under surface and tip of abdomen will permit the separation ordinarily, and render more careful examination necessary only in exceptional individuals of both species, *i. e.*, the smaller specimens of Pronuba and larger specimens of Prodoxus. Closely examined, the female Prodoxus is found to have no maxillary tentacles, (there being a mere protuberance instead at the base of each palpus, Pl. 39, Fig. 2, *c.*), and in fact never makes any effort either to gather pollen or work in the stigma. Her ovipositor (Pl. 39, Fig. 3, *b*) while having a similar construction homologically, is yet a very different instrument from that of Pronuba. The male is at once distinguished by his longer and darker, differently shaped genitalia (Pl. 39, Fig. 3, *f*, *g*). This species does not breed in the fruit of the dehiscent Yuccas, but may not infrequently be found in that of some of the non-dehiscent forms, like *aloifolia*. The egg is thrust into the flower stalk, while this is yet sufficiently tender, and oviposition takes place usually before any of the flowers of *Y. filamentosa* are open. The first specimens are found, as a consequence, sometime before the flowering of this species. They are most abundant, however, when this Yucca begins to flower, and then diminish in number, though a few may be found even after the last of the *filamentosa* blossoms have gone. Thus it is always found associated with Pronuba, but in appearance antedates this last and more nearly corresponds with the blooming of *Y. angustifolia*, the stems of which species it most affects, wherever the two are grown together. Prodoxus is, in fact, in large measure dependent upon Pronuba, since, as we have already seen, the flower stems, especially of *Y. filamentosa*, die rapidly when none of the flowers are fructified, and it is doubtful whether Prodoxus could permanently perpetuate itself, except as a dependent on the efforts and effects of Pronuba. This species of Prodoxus is common in the South on *Y. aloifolia*, *Y. rupicola*, *Y. gloriosa*, and *Y. filamentosa*, and in the west on *Y. angustifolia*, and I have rarely broken

open a dry flower-stalk of any species without finding its larva, or examined a green stalk without the evidence of oviposition by the female.

I have often watched the act of oviposition which, though simpler, involves much the same motions as in Pronuba. The female has more difficulty in making an incision, and this is manifest by the many abortive and tentative attempts which she makes in her movements from one part of the stem to another. When she has once succeeded in inserting the ovipositor, and is fairly at work, she becomes as indifferent to examination and interruption as Pronuba, under like circumstances, and has often given me time to make the accompanying sketch (Pl. 39, Fig. 4) in the strong glare of the light. The incision always leaves a slight discoloration in the stem which becomes still more noticeable subsequently and forms a sort of cicatrice. (Pl. 38 Fig. 4, *a a*). The ovipositor—working much as one would work the tip of a hand-saw in making an incision — cuts a channel at a right angle from the surface and about 2mm. deep. The oviduct is short — not long and thread-like as in Pronuba — and the egg (Pl. 39, Fig. 3, *h*) is found at the base of this channel. The plant-tissues surrounding the egg seem to be disorganized by the irritation somewhat as in the case of Pronuba, and it requires nice manipulation to trace the egg which is extremely delicate and easily ruptured and in color and appearance closely resembles the surrounding tissues. It is compressed, elongate and without pedicel. It is, however, plastic and variable in form according to position. The apodal larva is hatched and begins to burrow about the ninth day after the egg is laid and in its curved position and general appearance, looks much more like some Hymenopterous or some Rhynchophorous than a Lepidopterous larva. It is pellucid white in color with black ocelli and brownish mandibles. It molts three times, so far as I have have been able to trace, acquires full growth in about a month and is then more often of a pale emerald-green color. It (Pl. 39, Fig.

1, *a*) possesses no legs whatever, and eats but a small part of the stem (Pl.39, Fig. 1, *f*) preparing in the autumn, for hibernation, a cocoon of white silk which is covered on the outside with its castings and which remains protected within the stem. Before making this cocoon, however, it generally eats a passage-way to the outer covering of the stem and lines this with silk, leaving but a very thin cap (*g*). The chrysalis is formed in the spring, and when about to give forth the moth, pushes its way out through this cap. This happens almost always toward evening and the moth escapes just as the shades of night help to shield it during its more helpless hours, from detection.

Various species of the genus Prodoxus are found associated with the different species of Yucca, breeding either in the flower stems, the main stalk, or sometimes in the fruit, and they will be considered more in detail, in the second part of this article. It suffices here to state that *Prodoxus decipiens* is the only species thus far found east of the Rocky Mountains; that while it is quite constant in coloration east of the Mississippi, it is often more or less spotted with black in Colorado and South Texas, and that it shows the same tendency to retardation in development already noticed in Pronuba, some larvæ remaining in the stems two, three or four years.

Where the stems are allowed to remain on the plant this Prodoxus becomes exceedingly abundant, and the stems are, when one year old, often seen to be riddled with the perforations which the chrysalis made in issuing, and this is especially true of *Y. angustifolia*.

Where the stems are cut, as they ordinarily are, in our gardens, soon after flowering, the larvæ are apt to be destroyed, so that the species becomes scarce.

To recapitulate, the figures on Plate 39, will sufficiently indicate the structural details of *Prodoxus decipiens* and give emphasis to the differences which I have already pointed out between it and *Pronuba yuccasella*, in the larva (Fig. 1 *a*) being apodal (lacking even the thoracic legs

which belong to Pronuba); in the pupa (*e*) among other differences, lacking the series of dorsal spade-like projections; in the form of the claspers in the male moth (Fig. 3, *f*, *g*); in the much stouter and differently shaped ovipositor of the female (Fig. 3, *b*, *d*); and especially in her lacking the maxillary tentacles.

Who, studying these two species in all their characters and bearing, can fail to conclude that, notwithstanding the essential differences that distinguish them not only specifically but generically, they have had a common ancestral origin? Pronuba, depending for existence on the pollination of the flower, is profoundly modified in the female sex in adaptation to the peculiar function of pollination. Prodoxus, dwelling in the flesh of the fruit or in the flower-stem, and only indirectly depending upon the fructification of the plant, is not so modified, but has the ordinary characters of the family in both sexes. In the former, the larva quits the capsules and burrows in the ground; it has legs to aid it in its work, while the chrysalis is likewise beautifully modified to adapt it to prying through the ground and mounting to the surface. The latter, on the contrary — never quitting the stem — has no legs in the larva state, and in the chrysalis state is more particularly adapted, by the prominence of the capital projection, to piercing the slight covering of the stem left ungnawed by the larva. The former is very regular in its appearance as a moth at the time of the flowering of the Yuccas in their native range. The latter appears earlier, as the food of its larva is earlier ready, and the female could not oviposit in the riper stem.

PART II.

This part may be looked upon as supplementary to Part I., and is intended to bring together some descriptive details, as well as some other details upon which the generalizations in Part I. are based. In connection with the new species that will be characterized, it will be convenient, and of some advantage to those interested in the subject, to bring together the previous descriptions.

INTERNAL STRUCTURE OF PRONUBA YUCCASELLA WITH REFERENCE TO THE REPRODUCTIVE ORGANS.

We have already considered the chief external characteristics of the female. If we examine the internal anatomy, we find that the ovaries are large and pyriform, composed of four multilocular tubes gradually enlarging to the point of insertion in the oviducts and with the opposite extremity prolonged into a binding cord attached to the thorax. The oviducts are rather short. There are two large sebaceous glands and two smaller accessory glands, and a large copulatory pouch connected with the oviduct by a short tube or canal which opens close to the entrance of the ductus seminalis, this leading to the receptaculum seminis. This receptaculum is nearly as large as the bursa, pyriform, flattened dorso-ventrally when empty, but more rounded when filled with semen. Its chief characteristic, however, is a pair of curious brown radiate bodies the rays or spicules springing from a central hub, which looks like the disk of a composite flower. These bodies are attached at opposite sides of the pyriform sac and are so large and conspicuous as to be readily seen through the walls of the abdomen when this is mounted in balsam. The hub is concave from the outside and convex from the interior, the disc presenting a granulated structure and the spicules radiating from its margin obliquely into the interior of the sac. Each spicule, when closely examined, is seen to have along its inner border, a hollow groove run-

ning from the base to the extreme tip (Plate 40, Fig. 2, *d*). There are some seventy or more of the longer spicules and other shorter ones; but they vary less in length than in other species. In the impregnated female there is found within this receptaculum and almost filling it, what appears to be an inner sac with a narrow neck entering and following the neck of the receptaculum. This is doubtless but a combined mass of spermatic particles or fasciculi forming what has been called by Lepidopterists the large spermatophore. The albumen-like wall or envelope of this mass is somewhat thickened as it approaches the hubs of the receptaculum but then suddenly becomes thin and is somewhat insecurely fastened to the hubs so that when the spermatophore is detached, there is practically an opening in each side at the point where it was attached to the receptaculum. There are three membranes to this receptaculum, an external or muscular, a middle or serous, and an internal or mucous. The strong fibers of the muscular coat radiate from the border of the hub of one of the chitinous bodies, and are inserted in a similar position upon that of the opposite side. They thus include the whole of the sac until toward the neck, where they change to circular constricting fibers, and thus continue through the duct. Plate 40, Fig. 1, *a* gives an enlarged view of this receptaculum, with a longitudinal section through the hubs at *b*, showing the large spermatophore or inner sac *c*, and the space between it and the walls of the receptaculum, showing the manner in which the hub and the radiate spicules are placed at *d*. In *Pronuba yuccasella* this receptaculum averages about 1.7 mm. in length, by 1. mm. in diameter, the crusher or radiate body measuring 1. mm., the rays averaging 0.43 mm. in length and the hub or axis 0.14 mm. in diameter. By way of exhibiting how very much more strongly developed this receptaculum and its crushers are in *yuccasella* than those in any of the other species, I have introduced (Plate 40, Fig. 2) drawings of the similar organs of

Pronuba synthetica (*a*); *P. maculata* (*b*); and *Prodoxus decipiens* (*c*), drawn to the same scale. In *P. synthetica* the receptaculum averages about 1. mm. in length and 0.66 in width; the crusher has a diameter of 0.43 mm., the longer rays about 0.17 mm. in length and the axis or hub about 0.10 mm. in diameter. The crusher in this species looks much more like a burr, there being 16 of the longer, 24 of a shorter size, 32 yet shorter and a number of the shortest which graduate into the tubercular inner surface of the hub. In *P. maculata* the receptaculum has a length of 0.66 mm., and a diameter of 0.5 mm.; the crusher has a diameter of 0.4 mm., the longest rays a length of about 0.17 mm., and the axis a diameter of 0.06 mm. In *Prodoxus decipiens* the receptaculum has a length of 0.65 mm. and a diameter of 0.3 mm. The crusher measures 0.09 mm. with the longest rays 0.05 in length and axis 0.02 in diameter. The axis is relatively longer than in the other species, and the spicules are much reduced in number.

The object of these chitinous bodies has been somewhat of a puzzle, all the more difficult to solve that they seem to be quite exceptional, and, in the remarkable development which they here present, absolutely unique, so far as I have been able to ascertain. They attracted my attention in my earlier studies of Pronuba and I was glad to find, on visiting Dr. H. A. Hagen in 1880, that he had been very much interested, in his studies of Prodoxus, in the similar but smaller organs of that insect. His explanation of their function, as elaborated in the Zoologischer Anzeiger (Jan. 1882), is doubtless correct, viz., that they serve to liberate the spermatozoa from the spermatophores, but he was in error in locating them in the bursa instead of the receptaculum. The muscular arrangement which I have described is well suited to such a purpose. In the somewhat flattened receptaculum the spicular arms actually intermingle and the radiating muscular coat possesses the only arrangement of fibers which would enable a simple contraction to bring at once the whole contents of the sac into

the nest of pointed blades. At the same time an egress is afforded the liberated spermatozoa through the mouth of the duct — the only point not constricted by the radiating fibers — and once within its walls a successive contraction of its muscular fibers, like the vermicular action in the small intestines of mammals, would cause their ready descent to the oviduct. Thus the spicules not only serve to liberate the spermatozoa, but also to facilitate their egress through the attached base, where the spermatophore wall is thinnest.

THE OVIPOSITOR.

We have already seen, in the characterization of what may be called the external parts of the ovipositor, that it consists apparently of two principal joints, the basal part, when highly magnified, showing an imbricato-granulated surface, the granulations strongest basally, and diminishing distally, and each having a more or less distinctly marked, retrorse point, while the terminal part is smooth and ends in a delicate dorsal, chitinous saw and a strong serrate tip.

It is the working of the ovipositor, however, by the rods connected with it to which I wish to draw more particular attention here. On carefully dissecting the abdomen, there are seen along the dorsal integument four large, distinct, tough, longitudinal muscular bands. Viewing them ventrally each is seen to be inserted upon the widened free end of a slender, brown, horny rod, strongly attached, by an accumulation of muscular tissue, to the base of the vagina. The two inner rods (Pl. 37, Fig. C, *i*, *i*) are nearly parallel, the outer two slightly divergent (*k*, *k*). When the ovipositor is withdrawn the two inner rods extend back beyond the others and reach to the base of the third abdominal joint or even somewhat beyond. These two inner rods converge to form the lateral walls of the ovipositor proper, extending as dark streaks to its extreme tip. The ovipositor is therefore a continuous piece, and in reality not jointed, though appearing so from the different sculpturing of the basal and terminal covering.

This basal and sculptured portion of the integument represents the part which is invaginated when the ovipositor is withdrawn. The outer rods enter on either side of the walls of the anal joint, extending and attached to the tip of the vagina. This arrangement for the exsertion of the ovipositor is at once simple and admirable, the contraction of the muscles forcing out the inner rods and carrying with them the ovipositor, and also extruding the tip of the vagina. The flexible and extensile oviduct is contained within the hollow center of the horny sheath and is doubtless extruded by the contraction of the body walls. In the other two species of Pronuba here dealt with the rods are rather stouter and relatively shorter than in *yuccasella*.

This general internal structure of the female here described is common to all the three species of Pronuba so far known, but the receptaculum seminis and the radiate bodies contained in it are, as already stated, in none of them so large and conspicuous as in *yuccasella*. In *P. synthetica* they are about half as large, with the spicules stouter and straighter and reminding one of some stiff-spined Echinid. In *P. maculata* they are yet smaller. The same general structures also obtain in Proxodus, with much modification of the ovipositor, however, and the radiate bodies of the receptaculum are smaller and seem in some species even to be obsolete. In *P. decipiens* they are smaller in proportion to the size of the sac, which is itself much smaller and more elongate than in *Pronuba yuccasella*. The spicules, however, are relatively larger, though few in number.

THE SPECIES OF PRONUBA.

Generic Characters of Pronuba.

Imago.—*Primaries* (Pl. 34, Fig. 3, *h*) elliptical, the apex subacuminate; disc closed, though somewhat indistinctly between marginal veins 5–8; 12-veined, exclusive of sub-median (1, *a*); costal vein stout, connected with sub-costal near base, and not extending beyond middle of wing; the sub-costal vein sends, from about one-fourth its length from base, a branch which reaches costa where the latter commences to round off; it also sends, from about the middle of the wing, a branch through the discal space, forming an accessory discal cell, and sometimes considerably passing the disc, and forking outside, so as to form marginal veins 7 and 8, though more often forking just at the transverse discal vein; a feeble, disco-longitudinal veinlet starts independently near the base, forks near the middle, and forms a second accessory discal cell; sub-median vein distinct only near the margin, and indicated by an opaque line along the basal half of the fold; internal vein feeble and bifid at basal third. *Secondaries* (Pl. 34, Fig. 3, *i*) broad, subacuminate at tip; shoulder slightly produced and armed in the ♂ with a long spine, and in both sexes with a tuft of long scales; 8-veined, exclusive of sub-median (1, *a*), which is distinct; disc entire; costal vein extending three-fourths of the length of wing; an independent, feeble, disco-longitudinal veinlet, forking about the middle of the wing, the upper branch sometimes considerably passing the disc, and then forking into marginal veins 5 and 6, but more often forking at transverse vein; internal vein feeble and simple. *Head* (Pl. 34, Fig. 3, *a*, ♀), free, sparsely haired; epicranium flattened or depressed; ocelli obsolete; clypeus large; eyes round and salient; antennæ filiform and simple in both sexes, nearly one-half as long as front wing, the basal joint long, bulbous, and twice as stout as the others; maxillary palpi (Fig. 3, *b*) very long, 5-jointed, *the basal joint in the ♀ produced into a long, stout, cylindrical, prehensile tentacle, armed with spines springing from flattened tubercles (c); this joint in the ♂ a mere blunt-pointed tubercle (d)*, the other joints almost smooth; 2d, short, stout, and directed backward; 3rd, more slender, and as long again as 2nd; 4th, thrice as long as 3rd; 5th, as long as 2nd, slender and subfusiform; the tip generally notched; labial palpi (*g*) moderately covered with hair-like scales, reaching nearly to base of antennæ; 3-jointed; basal joint curved and stout; 2nd, half as long and straight; 3rd, short and fusiform; tongue long and smooth. *Legs* with the front femora and tibiæ short, the hind femora and tibiæ long and stout; the usual single spur on the front, a pair on the middle, and two pairs on the hind tibiæ. *Abdomen* ♀ with the anal joint long, horny, nearly bare; the ovipositor long, extensile, formed of two rods, the membranous covering of which is imbricato-granulate at base, the tip horny, serrate, and with a serrulate dorsal wing; ♂ shorter, blunt, and slightly swollen at tip; the genital hooks large, sub-spatulate, symmetrical; the upper edge entire and

thickened, the lower edge excavated about the middle, with a tooth or tubercle in middle of excavation.

EGG. — Soft, filiform and clavate.

LARVA. — With thoracic legs but without prolegs.

CHRYSALIS. — With a capital projection and very strong dorsal abdominal spines.

PRONUBA YUCCASELLA Riley.

[Pl. 34, Figs. 1, 2, 3, 4.]

EGG. — Thread-like, averaging 2 mm. in length, with a long pedicel and gradual enlargement toward apex which has a minute indurated tip.

LARVA (Pl. 34, Fig. 1, *a*). — Average length 14 mm. Broadest on thoracic joints, thence gradually decreasing to extremity, which is quite small. Color, carneous, with a paler greenish tint below. No piliferous spots, but a very few minute and short stiff hairs springing from the ordinary positions of such spots. A transverse dorsal wrinkle, on each of the principal joints, more or less distinctly divided in two by a medial-dorsal depression, which is sometimes slightly bluish. Joints deeply incised and with a lateral, sub-stigmatal, longitudinal wrinkle (Fig. 1, *d*). Thoracic legs stout but short, with three joints and a claw. *No prolegs.* Stigmata (9 pair) forming a small rufous circle on anterior portion of joints 1 and 4–11. *Head* (Fig. 1, *e*, *f*, *h*, *i*, *j*, *k*) partially retractile, copal-colored; epistoma sharply defined; labrum slightly pilose; mandibles stout, rounded, and with four acute teeth, each diminishing in size from without; maxillæ with the inner lobe rounded and furnished with (usually two) short fleshy hairs, the palpi four-jointed, the terminal joint with bristles; labium prominent, with the spinneret conspicuous and the palpi two-jointed — the first long, with a fleshy hair at tip, the second small, spherical, and also terminating in a fleshy hair; antennæ two-jointed, the terminal joint with a bristle; ocelli pale, around a dark crescent. Cervical shield flattened and not well-defined.

White when young; more or less green and rosaceous when mature. Mostly curved in the fruit, like the larvæ of the Rhyncophora.

CHRYSALIS ♀, (Pl. 34, Fig. 4, *m*, lateral view). — Average length 8 mm.; greatest diameter about ⅓ the length. Thick and stout, with the dorsum greatly arched. Head with a prominent, conical projection on top and two smaller ones between the eyes. Most characteristic feature a series of six dorsal, arcuated, horny plates — one on the anterior half of each of joints 5-10. These plates have anteriorly 10–12 blunt, flattened, recurved projections, the largest in the middle from which the others are successively lessened. The ends of some of the larger ones are shaped like the share of the more common shovel-plow. In the first row the arcuation is greatest, and the projections largest and directed most forward; all which features are gradually lessened with each succeeding joint. Joint 11 has no plate, and but 4 posteriorly directed spines, while joint 12 has two broad and flattened dorsal processes. Tip of abdomen rounded and reaching beyond the processes. Each joint has a transverse series of stiff yellow hairs, and four such are quite conspicuous on mesothorax, and others on top of the head and on face. Color, when fresh, pale green, with the wing-sheaths darker. When mature, and just before giving forth the moth, the head, thorax, breast between the antennæ, and tip of abdomen, are light brown; the eyes, dorsal plates and projections, darker brown; the wing-sheaths and inter-spaces between dorsal plates, whitish; and the sides greenish.

♂, (Pl. 34, Fig. 4, *l*, dorsal view). — Distinguished generally by the somewhat smaller size; by the dorsal projections not diminishing

on joints 8–11, but rather increasing in size; by the greater shortness of joint 11, and the greater length of joint 12; and by the apex not being so rounded, and not extending beyond the two broad anal processes. At maturity the maxillary pieces are somewhat flatter, owing, doubtless, to the fact that in ♀ the spiny cylindrical tentacles lie stretched nearly their whole length, and cause them to bulge more.

IMAGO (Pl. 34, Fig. 1, *b*, *c*).—Average expanse, ♀ 25 mm.; ♂ 23 mm. *Primaries*, above, uniformly silvery white, the scales loosely set; fringes concolorous; beneath, pale fuscous, with a brassy reflection; paler internally; fringes either concolorous or paler; costa with a brush of dark hairs. *Secondaries* semi-transparent, pale fuscous both above and below; paler internally, the fringes white and the brush on shoulder dark. *Head* white; antennæ and tongue dingy yellow; maxillary palpi of same color, with the exception of tentacle, which is darker; labial palpi with scales on second joint dark brown above; eyes black. *Thorax* white. *Legs* dingy yellow, more or less covered with pale scales. *Abdomen* with the terminal joint in ♀ always bare, with the exception of a few short, stiff hairs near tip, and the scales on the other joints very loosely attached.

Described from many specimens of both sexes. Remarkably uniform in characteristics, no other variation noticeable than in size.

PRONUBA MACULATA Riley.

[Pl. 42, Fig. 2.]

The species was described (Proc. Am. Ass'n. Adv. Sci., Vol. XXIX., August, 1880), from two females and five males, taken by Mr. H. K. Morrison at Caliente, Kern Co., California, upon the flowers of a species of Yucca, undetermined at that time. Since then I have taken it in the flowers of *Yucca whipplei* near San Diego, Cal., and Mr. A. Koebele has reared it from larvæ in the seed-pods of this same Yucca taken at Newhall, Los Angeles Co., California.

In June, 1876, I received from the late Dr. C. C. Parry pods and flowers of this Yucca collected at San Bernardino, which showed evidence of Pronuba work. The pollen is abundant and quite glutinous, and the tentacles of the moth would seem to be fitted for dipping into and coiling around the same; while the modification of the tongue plainly indicates that it is an accessory organ in this collecting and pollinating, and adds strength to the suggestions already made (p. 110) that the tongue in this genus is not a sucking organ. The stamens in this Yucca are long and straight, the style short and constricted, and the stigma expanded and peltate. Of all the Yuccas it would seem to be most easily self-fer-

tilizable. Yet a Pronuba is needed and it will prove most interesting to observe her manner of working.

Neither pollination nor oviposition has been observed in this species, nor is the chrysalis so far known, and I shall be very glad to get further facts upon the subject from those having opportunity to observe them.

The habits of the larva are very similar to those of *yuccasella*. It leaves the pod as soon as mature, buries in the ground and spins a similar cocoon. I have known a few to remain in gathered pods, however, after having made the perforation which was partly closed with web, and though this would indicate that transformation may exceptionally take place within the pod, the fact has not yet been experimentally proved.

LARVA.—Average length 16 mm. Absolutely identical with that of *yuccasella* both in coloration and structure, the only difference noticeable being that, if anything, it is slightly more slender and with the thoracic segments less swollen.

IMAGO (Pl. 42, Fig. 2).—Expanse, ♀, 19–21.5 mm.; ♂, 17–17.8 mm. *Head* white eyes black, mouth parts yellowish but very sparsely clothed with white scales; antennæ yellowish, the tips fuscous, sparsely clothed with scales on the basal half only; maxillary tentacle (*mt*) yellowish, the base green, large, more swollen, much longer than the tongue, tapering toward tip which is often coiled spirally; hirsute rather than spinose, covered densely with fine hair, intermixed with scales, and a few spines on ventral side; maxillary palpi (*mp*) but half as long as tentacle with the basal or elbowed joint very prominent, the second joint not bulbous and the third joint relatively much shorter than in *yuccasella;* tongue (*t*) short, stout, swollen basally and, together with the maxillary palpi, hirsute (they are smooth in *yuccasella*) the hairs strong and spinous beneath. *Thorax* white; primaries (*pr*) with the upper surface opaque white, bordered with from 10–12 black spots (when all are present) of varying size and running from just beyond the middle of the wing to about the inner angle; the disc with 5 spots, 4 of them in a line from base to apex, the 2nd and 3rd rather farthest apart, the 5th or middle one below and nearest the 3rd from the base; under surface deep fuscous, intensified around the borders and with the spots of upper surface barely indicated; fringes white; secondaries transparent, being very slightly covered with elongate fuscous scales, thickening on the borders, especially toward apex; fringes faintly fuscous; legs white, tarsi very sparsely clothed and yellowish except at extreme tips, which are more fuscous. *Abdomen* white beneath, fuscous above. Integument of head yellowish; of thorax and coxæ black or blackish. Terminal abdominal joint in ♀ short and thick, obliquely truncate from beneath (*a*) usually bare, honey-yellow with its base black; ovipositor stout, decurved, the terminal, horny joint (*tjo*) broad and rounded at the tip and at its edge finely denticulate. Claspers of ♂ short, abruptly curved upward, the base broad and rounded, the tip expanded, leaf-like, twisted, preceded by a deep excavation, but without tooth or tubercle (*gs*, side view; *gp*, posterior view)

Described from 12 ♀♀, 9 ♂♂ from Southern California. In the specimens from Los Angeles Co., California, the spots along the anterior margin are, as a rule, considerably smaller, those at posterior border more or less confluent and often united with the terminal of the discal spots; while two or three of the remaining discal spots are wanting. The apical fringe and a shade of the apex are distinctly dusky or blackish. The secondaries are somewhat darker, especially toward the apex of the anterior margin, with a narrow blackish border all around and more or less distinctly dusky fringe. In specimens not rubbed, the anal joint of the female abdomen, and the male genitalia are freely covered with pale hair.

Examination of the venation in one male shows that marginal veins 7 and 8 arise from the transverse vein independently of the discal branch of the subcostal vein and that the upper fork of the independent discal veinlet is wanting.

In one of the male specimens only four of the spots on the border of the primaries are present, and in this specimen, as well as in one other male and one female, the second discal spot is absent.

PRONUBA SYNTHETICA, n. sp.

[Pl. 41, Figs. 1, 2; Pl. 42, Fig. 1.]

This is the most remarkable of the three known species of the genus and bears a striking general resemblance to certain Saw-flies (genus Dolerus), both in color, habitus, and form. It also strongly recalls, especially in nature and with wings closed, certain Neuropterous species of the family Sialidæ, as *Sialis infumata*.

This general resemblance is due to certain characteristics which are quite abnormal in Lepidoptera, *e. g.*, the naked and fuliginous wings, and the dark, polished and flattened body, with its broadened, horny and angulate tip. But it extends to other details. Thus the two metathoracic pale spots, exactly in the position of the cenori of the Tenthre-

dinidæ, are more noticeable than in any other Lepidopteron, and while careful study shows them to be superficial and hardly homologous with the cenci they would seem to have some similar *raison d'etre.** The broad and deep insertion between thorax and abdomen, with its contrasting coloring, also serves to increase the general likeness.

Though I had briefly visited the tree Yuccas (*Y. brevifolia*) of the Mojave desert, in March, 1887, it was not until April 14th, of the same year, that I was able to spend a whole day among them, mostly in the Antelope Valley. There were but few specimens in bloom, but a number showed the old fruit, and it was with no little satisfaction that in almost every case I found that this indicated the presence of some Pronuba of a relatively large species, as evidenced by the holes of exit of the larva. The flower has the perianth very dense, the petals thick, fleshy, almost leathery, curved in at the tips, the bracts large and tough. Mr. Koebele was with me at the time, also Mr. Frank Godey and Mr. J. G. Wickersham. On account of the scarcity of the flowers, and the difficulty of reaching them without disturbing the moths, but two specimens of this Pronuba were obtained; but the small white *Prodoxus sordidus* was abundant in the flowers and its work everywhere noticeable in the flower-stems. From the fact that I could not be among those curious Yuccas at night, I was unable to witness the acts either of pollination or of oviposition of its particular Pronuba. The structure and characteris-

* The structure and function of these cenci spots in Hymenoptera seem to be little understood. They vary in structure in different families, but for the most part consist of a membrane or lid which covers a cavity and suggests that they are sound-producing organs. In Lepidoptera the similarly placed, but superficial spots, are not specialized, but mere inflations or modifications of the chitine wall. They are wanting in the Rhopalocera and higher groups of Heterocera, while in the Tortricina and Tineina, in which they are usually well developed, they have remained unnoticed because usually hidden by the vestiture, or not conspicuous, through lack of contrasting coloring.

tics of the species are, however, well adapted to the work it has to perform in the densely packed and but partially opened flowers of this Yucca with their denser petals and firmer pistils; for all the parts which are representative of the other species of Pronuba are here more stout, and the denuded and flattened body is well suited to creeping between the flowers. There is no question but that the tree Yuccas represent an ancient type of our flora, and *Pronuba synthetica* may also be looked upon as an ancient type of our Lepidopterous fauna. That it should have so many striking peculiarities that recall insects of other orders, is, therefore, very suggestive. I was very anxious to obtain the larva and chrysalis of this species, and the following year Mr. Koebele, at my request, revisited the tree Yuccas and succeeded in May, 1888, in obtaining infested fruit. As soon as this was received, the larvæ left the pods and entered the ground, some of them forming cocoons almost identical in appearance with that of *yuccasella*. Others remained in the larva state, without forming cocoons. Indeed, one peculiarity noticeable was the great length of the larval life, as a few had not yet formed their cocoons by the end of 1889, or more than a year from the time they were received, while one was living and unchanged, in its cocoon, in August, 1891, or nearly two years and a half from the time it left the fruit. However, most of those that were reared to the imago state, whether by Mr. Koebele in California or at Washington, issued the following March or April. These facts would indicate that while normally the moth is produced the ensuing year, yet belated individuals may not issue from the ground until the second or even the third year, and I have been informed that it is not an uncommon thing for *Yucca brevifolia* to produce no flowers over large districts during some years. The tendency to retardation in development is, under these circumstances, advantageous to the species.

LARVA (Pl. 41, Fig. 2, *a*). — Length when full-grown, 14 mm. Somewhat more cylindrical than that of *yuccasella*, the general color being bluish-green tinted with a rosaceous hue; otherwise undistinguishable from those of the other two species.

CHRYSALIS (Pl. 41, Fig. 2, *b*, *c*). — In size, general shape and arrangement of the spines similar to that of *yuccasella*, but readily distinguished by the wing-sheaths in both sexes reaching only to the sixth abdominal joint and the posterior legs to the seventh, whereas in *yuccasella* the former reach to the eighth and the latter to about the middle of the ninth. The medio-dorsal spines are also longer, more prong-like and less spatulate, while the capitate spine is perhaps less prominent. The difference is more particularly noticeable in the greater length and prominence of the two spines on the second abdominal joint. The anal joint in the male is narrower and comparatively longer, and the two terminal teeth much shorter than in the female, also not so well defined as in *yuccasella*. The anal segment in the female is broader and stouter than in *yuccasella*, with the teeth shorter, stouter and further apart. (*c*, *d*, *e*, *f*, *g*, *h*.)

IMAGO (Pl. 41, Fig. 1, *a*). — Expanse ♀, 15-20 mm.; ♂ 16-18 mm. Body flattened, piceous. Wings smoky-gray; the scales sparse and as easily lost on the upper surface, especially of primaries, as in the Sesiidae, so that none but those carefully killed soon after issuing from the chrysalis show the wings well covered. In such specimens the general color is cinereous, the primaries but slightly darker than secondaries, the scales being narrow and elongate, mostly gray, but with an admixture of black ones. The exposed membrane of the wing is fuliginous except a narrow discal space and more or less of the costal region which remain sordid white. Fringes paler but sparse and easily lost except at anal angle of hind wings, where they persist. Veins black and strong. Body but sparsely clothed in freshest specimens and soon becoming bare except at neck; highly polished and minutely punctate, and in some specimens with metallic tendency. *Head* (Fig. 1, *b*) with the hair pale ferruginous; eyes brown, naked; labial palpi bownish-black with sparse white scales; maxillary tentacles stout and brown, shorter than tongue; max. palpi nearly as long as tentacle, basal joint stout, rounded, joints 2 and 3 short, sub-equal in length, joint 4 very long, terminal joint with two spines at tip; tongue very stout, long and ferruginous; antennae black. *Thorax* with two singular transverse-ovoid translucent and somewhat opalescent spots recalling the so-called cenchri of Tenthredinids; legs stout and dark, the hind tibiae and tarsi pale ferruginous. *Abdomen* separated from thorax dorsally by a broad and deep suture which is pale rufous by contrast with the general piceous color; anal joint (Pl. 42, Fig. 1, *c*, *d*) in ♀ rufous, with darker shade at base, the sides compressed from above and expanded into a broad and angulate wing, the borders of which are thickened and stiffened and converge to a rather sharp tip which is, however, obliquely truncate from the side; ovipositor issuing generally at right angles and with the same parts as in *yuccasella* but all stouter and shorter (*e*, *f*). In the ♂ the dorsal fulvous suture or pit between thorax and abdomen is more profound and concave, the abdomen is less flattened and the claspers are brown, very stout, one-half as long as the abdomen, the basal part broad and leaf-like, the terminal part abruptly curved upward, dilated into a decurved triangular tip, and the prong quite long, slightly curved and denticulate at tip (*a*, *b*).

Described from 28 ♀♀, 10 ♂♂, from the fruit of *Yucca brevifolia*.

THE SPECIES OF PRODOXUS.

It is my design to give here descriptions of all the species so far as known. The early stages of these different species are remarkably similar and it is extremely difficult — at times quite impossible — to point out characters by which to separate them. It will be well, therefore, first of all to reproduce the original description of *Prodoxus decipiens*, somewhat amplified, and merely describe the others by comparison. The ovipositor varies in appearance according as it is extruded or not.

Generic Characters of Prodoxus.

Imago.—Agreeing with Pronuba, except in the following important particulars: The basal joint of the maxillary palpi in the female is not produced into a spinous tentacle, but is formed just as in the male, being a mere blunt-pointed tubercle.

Larva. — Apodous.

Chrysalis. — Without prominent dorsal spines.

PRODOXUS DECIPIENS Riley,

[Pl. 39, Figs. 1, 2, 3, 4.]

Egg.—Soft, white, easily yielding to pressure, and hence variable in shape, but usually elongate, rounded at both ends about 0.4 mm. in length, and less than 0.1 mm. wide.

Larva (Pl. 39, Fig. 1, *a*). — Length 5 to 7 mm. Apodous, plump, broadest on joints 2 and 3, tapering thence posteriorly, with the dorsum strongly arched and the head and prothoracic joint more or less fully bent down on the breast. The body is glabrous and not conspicuously wrinkled and the general aspect strongly recalls some Hymenopterous or Rhyncophorous larvæ. Head small, retractile. Stigmata placed as in Pronuba, *i. e.*, the first pair on the hind portion of the prothorax and rather lower down than the succeeding 8 pairs, which are on the anterior portion of joints 4 to 11, the prothoracic spiracles somewhat larger than the rest. Color of body either pale yellowish-white, or emerald-green, this last being the more usual color of the mature and especially of the hibernating specimens. The head is honey-yellow with a dusky spot on each side, a dash on each suture of the epistoma, the mouth dark brown, the mandibles black, labium and maxillæ white; the mandibles have four teeth, much blunter than in Pronuba, though the labial palpi are smaller and more plump and the labium and maxillae do not surpass the mandibles. The cervical shield is not defined as in Pronuba, but consists of 4 chitinous patches of the same color as the head.

Chrysalis (Pl. 39, Fig. 1, *e*). — Average length about 6 mm. Of the same color as in Pronuba but much more slender, with the dorsum less arched and lacking the characteristic dorsal, arcuated plates with their peculiar recurved, flattened spines, there being in place of them the barest indication of a transverse row of minute points or teeth not re-

curved but pointing posteriorly, near the anterior border of joints 6-11; joint 5, which is so strongly armed in Pronuba, being here perfectly smooth. Joint 12 in both sexes is unarmed as in ♂ but not in the ♀ Pronuba, while the terminal subjoint is much swollen and curved upward, with two minute spines taking the place of the broader, compressed processes in Pronuba. The capitate point is much stouter and beak-like, flattened and somewhat excavated laterally, so that the upper edges form each a sharp carina. The sexes are only distinguishable by the somewhat less swoolen sub-joint in the ♀ and her longer leg-sheaths, which reach a little beyond the tip of the body, whereas in the ♂ they fall short of the tip.

IMAGO ♀, (Fig. 2). Average expanse 16 mm. In general appearance closely resembling *Pronuba yuccasella*, but the upper surface is ordinarily more silvery and less creamy in appearance, and the dark shades, as of the eyes and the dark hairs of the palpi, front legs and tarsi and at the base of the costa on primaries, are more pronounced and blackish. The under surface is somewhat darker, and the tip of the abdomen not truncate but pointed, and slightly beveled off superiorly. The terminal joint is swollen and darker than in Pronuba. The ovipositor is stout, dark brown, laterally flattened, between three and four times as broad as in Pronuba, shorter, the sculpture of basal portion closer, finer and ribbed, the tip obliquely cut off below and having a series of minute teeth, the ventral one being more conspicuously produced, and a series of eight or nine more prominent teeth along dorsal edge, while two distinct grooves run along the whole length and several smaller ones are noticeable near the tip. (Fig. 3, *a*, *d*.)

♂, Somewhat smaller than ♀, the genitalia being more elongate and prominent than in Pronuba, the claspers extending fully twice as far, less recurved, and having on the lower border 4 small black points or tubercles, equidistant from each other. (Fig. 3, *f*, *g*.)

Described from numerous specimens of both sexes, either found in the flowers or reared from the stems of different species of Yucca throughout the eastern States.

All the specimens obtained or reared east of the Mississippi have been immaculate, with the faintest tendency to a few minute spots; but western forms, especially those from Texas and Colorado, show a greater tendency to maculation, the number of spots ranging from 1 to 5 or more, usually arranged along the middle in the form of a broad W, a dot representing each angle and each outer tip. When the basal spot alone is absent the four remaining present the figure of a rhomboid. When it is absent and there is another spot posteriorly we have the W inverted. When a single spot is present there is no regularity in its position, and it may be differently placed on the two opposite wings of the same specimen. There may also be more spots on one wing than on the opposite one, while I have seen specimens with the thorax spotted with two metathoracic mesial

spots, one above the other. When there are more than five spots, the additional spots are ranged around the posterior border. These spots are sometimes so small as to be confined to a single scale.

PRODOXUS MARGINATUS Riley.

[Pl. 43, Fig. 2.]

This species was described in 1880 (Proc. A. A. A. S. Vol. XXIX.) from specimens collected by Mr. H. K. Morrison in Kern Co., Calif. I have since been able, through Mr. Koebele's collecting in 1886, to rear it from the petioles and basal portions of the pods of *Yucca whipplei* obtained in Los Angeles Co., Calif., in the flowers of which it is also frequently met with from the end of April to the end of June. Its habits, so far as they have been observed, are quite similar to those of *decipiens*, the larvæ remaining within the petioles nearly a year, transforming and issuing during the ensuing month of April. No especial observations have been made on the method of oviposition and the egg has not yet been obtained.

LARVA. — Average length 3–4 mm. General color pale bluish-green. Head honey-yellow, marked each side of the clypeus with some more or less distinct but irregular dusky patches. The cervical plate concolorous with the body, but marked in front and behind with two faintly dusky patches, otherwise agreeing precisely with *P. decipiens*.

CHRYSALIS. — Except in the smaller size and less prominent spines and sculpturing, agreeing exactly with that of *decipiens*. This is especially true of the male chrysalis. The frontal tubercle in the female, besides being smaller, lacks the sharp lateral carinæ and has on the sides a shallow longitudinal channel or depression. The dorsal tubercles on the eighth abdominal joint are also transversely ovoid instead of being perfectly cylindrical at the base.

IMAGO (Pl. 43, Fig. 2).—Expanse 8-10 mm. Color white, the clothing of body very sparse, especially on the abdomen, and showing more or less distinctly the integument which is dark brown often with an æneous tinge. Antennæ bare towards tip and yellowish. Primaries (Fig. 2, *pr*) satiny-white with a terminal black band of varying width; under surface fuscous, almost black on costal and posterior borders; fringes white. Secondaries white with a broad costal and apical fuscous shade; under surface concolorous; fringes white. Apical abdominal joint of ♀ blackish, slender, very obliquely truncate above, the tip blunt-pointed (Fig. 2, *a*). Ovipositor short and stout; the horny terminal joint gradually narrowed to the pointed tip, the upper edge very finely and acutely serrulate (Fig. 2, *tjo*). Claspers of ♂ (Fig. 2, *c*) not dentate, their form much concealed by scales, the large arms broad and of nearly uniform width; large upper basal piece obtusely angulated in the middle.

Described from 21 ♀ ♀ and 22 ♂ ♂ collected and reared in Southern California.

The males are as a rule smaller than the females with the marginal band often much narrower, sometimes reduced to a small dot or even entirely wanting.

PRODOXUS INTERMEDIUS Riley.

[Pl. 43, Fig. 1.]

This species was described in the same paper as the preceding from two female specimens taken by Mr. J. Boll in Texas and one taken by myself July 18th, 1887, at Ute Pass, Colo. No others have been taken since, and the early states and the male remain unknown. This species is very interesting as showing how closely, except in lacking the characteristic maxillary tentacle, the species of Prodoxus may come to the typical Pronuba. The character of the ovipositor in this Prodoxus would indicate that the species breeds perhaps normally in the fruit, notwithstanding it can have nothing to do with pollination. It would thus be entirely dependent for its existence on the efforts of Pronuba.

IMAGO (Pl. 43, Fig. 1), ♀.— Expanse 28.5 mm. Coloration as in *Pronuba yuccasella*. Basal joint of the maxillary palpi not provided with a tentacle, but having a slight tubercle at the tip. Apical joint of the abdomen (Fig. 1, *a*) shaped as in *Pronuba yuccasella*, but slightly deeper and possibly a little thicker. Ovipositor, shaped as in *Pronuba yuccasella*, but slightly stouter, more acuminate at tip and with the serrations of membrane finer and more numerous (*tjo*). The sculpture of basal joint shows like very fine punctations in angular rows (*bjo*).

Described from 2 ♀ ♀ from Texas and 1 ♀ from Ute Pass, Col., July 18, 1887.

PRODOXUS CINEREUS Riley.

[Pl. 43, Fig. 4.]

Originally described in the same paper as the preceding from seven males collected in Kern Co., California, by Mr. Morrison. Since that time I have obtained numerous specimens either from the flowers of *Yucca whipplei*, in Los Angeles Co., California, collected by Mr. Koebele, or reared from the flower stems of the same species of Yucca.

The species prefers the main stem of the plant for purposes of oviposition. Stems, received in May, 1887, gave forth the moth during the latter part of that month, but others issued from the same stems during the same month of May in the consecutive years of 1888, 1889 and 1890, thus indicating great variation in the development of the species and a remarkable tendency to retarded development. The eggs and the early states have not been observed, nor the earlier states preserved and described.

IMAGO ♂. — Expanse 12 mm. Head, thorax, legs and apical ventral joints whitish. Primaries ashy; secondaries and under surface of all the wings brown with a cinereous reflection. Tip of maxillary palpi and apical third of antennæ black; the integument of body black. Claspers (Fig. 4, *a*, *b*) dark testaceous, similar in form to those of *decipiens* but without teeth; large upper basal piece broadly rounded or subtruncate; the smaller piece beneath it of similar shape.

♀ showing no differences whether as to size or coloration of scales, the head being somewhat darker, on the average. Anal joint of same form as in *decipiens*, the ovipositor being more slender than in any of the other species of the genus and coarsely toothed along the entire upper edge.

Described from many specimens.

PRODOXUS ÆNESCENS Riley.

[Pl. 43, Fig. 3.]

This species was also described in the same paper as the preceding from 3 females and 8 males collected by Mr. Morrison, in Kern county, California, but I have since reared it from the main stems of *Yucca whipplei*, also collected by Mr. Koebele, at Newhall, Los Angeles Co., California. The egg and mode of oviposition have not yet been observed, but Mr. Koebele reports that the larger larvæ (doubtless those which produce females) work in the stem with the head upward, while the smaller larvæ work downward, and that they go through their transformations in the month of May. I have serious doubts whether there is any sexual difference in the position of the larvæ in the stem, as might be gathered from his observation.

LARVA. — Attaining a length of 9 mm. with a diameter of only about $\frac{1}{8}$ the length, and distinguished from the other species by this greater slenderness and relatively greater length. The body tapers but little posteriorly and the general aspect is more that of a Cerambycid larva

than of a Rhyncophorous larva. General color pale greenish. Head honey-yellow, darkest in front with a broad brownish anterior border, more or less distinct, and a narrow blackish lateral line and dusky markings each side of the clypeus, thus resembling that of *P. marginatus*. The cervical shield with two or three more or less confluent faintly dusky spots anteriorly and 2 rather well defined somewhat quadrate black spots posteriorly.

CHRYSALIS. — Scarcely distinguishable from that of *decipiens*, except by the smaller size, smaller spines, and finer sculpturing. The frontal tubercle is relatively shorter and stouter.

IMAGO. — Expanse, ♀ 14.7 mm.; ♂ 11.2—14 mm. General color, bronzy, the primaries with a distinct purple reflection. Under surface of thorax, the coxæ and the femora clothed with white scales. Head whitish, with scattered black hairs; labial palpi with black hairs; 4th and 5th joints of maxillary palpi and the antennæ, except at the base, black. Integument black. Apical abdominal joint (Fig. 3, *a*) swollen as in *P. decipiens* and obliquely truncate from above, but the tip is also truncate from beneath and the lower border is slightly excavated. Ovipositor short and stout, very broad; the upper border of the horny terminal joint (Fig. 3, *tjo*) thin, arched and finely serrate, the tip obliquely truncate beneath and at the base of the truncation forming a small, thin tooth, the base beneath forming a blunt tooth, the border between these teeth retuse. Claspers of ♂ (Fig. 3, *c*) with no teeth on the arms beneath; the arms more slender than in *cinereus* and narrowed more abruptly near the base; the broad basal part with a small tooth at the apex within. Large upper basal piece forming a stout process at the apex.

Described from 20 females and 38 males taken from Southern California, many of them reared from the main stem of *Yucca whipplei*.

PRODOXUS PULVERULENTUS, n. sp.

I have five specimens of this species, all females, two of them reared from the seed-pods of *Yucca whipplei* in May, 1886, by Mr. Koebele, the pods obtained at Santiago, California, while three specimens were given me by President H. W. Harkness, and Mary K. Curran, of the California Academy of Science, in April, 1887, and obtained from the flowers of the same Yucca. The adolescent states are still unknown.

IMAGO ♀. — Expanse 9–10 mm. General color, white; head with the antennæ white, the basal half fuscous; eyes brown; palpi pale yellowish, hairs white. *Thorax*, with the hair mixed with a few blackish scales; primaries white, more or less densely sprinkled with blackish scales at the posterior third and sparsely so on the remaining portion. These dark scales produce a powdery appearance of the wings, the amount varying in the specimens before me, there being in two of them but a faint trace of the darker scales; secondaries white, with a broad dusky anterior margin; under surfaces more densely flecked with blackish scales and hence somewhat darker. *Abdomen* fuscous above, with a few long whitish hairs on the terminal two joints; venter and legs white. Tip of the abdomen shaped as in *P. marginatus*.

PRODOXUS Y-INVERSUS, n. sp.

[Pl. 43, Fig. 5.]

Specimens of both sexes of this species were reared from parts of a pod of an unknown species of Yucca (but doubtless *Y. baccata*) received from Mr. D. C. Chapman, of Washington, D. C., who had obtained them in May, 1883, from New Mexico, the moths issuing during May of the following year. The larvæ infest the fleshy portions of the pod and produce hard, gall-like swellings. The cocoon, which, as with the other species, is constructed within the burrow, is pale brownish, and resembles an elongate, cylindrical bag, rounded at the base and cylindrical at the apex. When ready to transform, the larva retires to the lower third of the bag and separates it from the upper two-thirds by a dense, tough, delicate whitish layer of silk, thus dividing the cocoon into two unequal chambers. No larvæ were preserved, but those which were noticed in cutting open the swellings showed a remarkable resemblance to those of *decipiens*. The chrysalis also has not been studied.

IMAGO.— ♀. Average expanse 14 mm. ♂ 10–12 mm. General color white. Head, thorax, legs and abdomen white beneath, the hairs between the antennæ occasionally yellowish. Eyes black; palpi white; tip of labials yellowish; tongue pale yellowish. Primaries (Fig. 5, *a*) marked with black as follows — a costal streak along the basal half, widening posteriorly and more or less completely fused with a round spot near its end. An elliptical or roundish spot about the middle of the wing at the basal third; a more or less sharply defined inverted-Y-shaped band across the posterior third of the wing, with its exterior arm generally connected posteriorly with a black patch which extends along the posterior border but is more or less broken at the extreme border and also along its inner margin. This terminal dark patch usually broadens toward the apex and is sharply cut off on the costa at about the outer fourth of the wing. Secondaries pale yellowish, darkest at apex; fringes concolorous. Undersurfaces with the dark markings of the primaries less sharply defined. Abdomen, brownish above, the male claspers (Fig. 5, *b*, *c*), yellowish-brown, almost bare, quite slender, and gradually narrowing toward the tip, which is almost acute; each arm is provided with 5 or 6 very small, cylindrical, acute teeth at the posterior edge; basal lobes are almost circular and concave at the inner side; upper basal plate triangular. Anal segment of the female obliquely truncate from above, but slightly so beneath, the ovipositor stout, yellowish-brown, its terminal part slender, compressed laterally, the upper edge of the apex being finely and acutely serrate. (Fig. 5, *d*, *e*.)

Described from four males and seven females, no two of which are exactly alike in the marginal details of the inverse Y-shaped band, nor in those of the terminal patch.

PRODOXUS RETICULATUS, n. sp.

[Pl. 43, Fig. 7.]

I have but three females of this species, taken by Mr. Koebele in March at Los Angeles, California, but without any notes of habit.

IMAGO.— ♀. Expanse 10–11 mm. General color, white. Body with whitish hairs, those of the head inclining to yellowish, intermixed with a few darker hairs, especially around the antennæ; the terminal joint of the palpi pale fuscous; vestiture of the legs superiorly dusky, with a slight cupreous reflection. Primaries with transverse blackish bands as follows: An oblique basal band much constricted at middle so that costal half is usually triangular; a narrow band along the posterior border and the intervening space between these two bands occupied by a broad W-shaped band, the outer arms of the letter running parallel with the basal and terminal bands. Fringes white. Secondaries gray; fringes somewhat darker. Undersurfaces gray, with a brassy reflection, the darker markings of the primaries being but faintly indicated. *Abdomen* with the anal joint perpendicularly truncate, the flexible basal part of the ovipositor rather broad at base and pale, while the terminal part is stout, sharp and brownish in color.

PRODOXUS COLORADENSIS, n. sp.

[Pl. 43, Fig. 6.]

Of this species I have seen but a single male, taken in 1884, by Mr. Morrison, in Colorado. In general appearance, as well as in the genital characters, it seems to be quite closely related to *P. y-inversus*.

IMAGO.— ♂. Expanse 11 mm. General color white and somewhat glossy, the hair of the head being faintly yellowish between the antennæ. Eyes black; antennæ white at basal third, the rest fuscous; palpi and tongue pale yellow. A few hairs on the maxillary palpi and the extreme tip blackish. Primaries (Fig. 6, *a*) with a well defined band starting at right angles from costa to basal third and then obliquing suddenly though slightly toward base; a somewhat similar band across the middle of the wing obliquing first in the opposite direction, *i. e.* posteriorly, and then almost parallel with the first band; and a forked or somewhat Y-shaped band across the posterior third of wing; a terminal black border connects with this Y-mark at anal angle but not at apex, and there is more or less black at base of wing. Secondaries whitish above; fringes white. Undersurfaces faintly dusky with a slight æneous reflection and the markings of the primaries less defined than above, and the secondaries somewhat dusky toward the apex. Abdomen brownish with the scales also brownish, especially along the sides, but white beneath. Claspers pale brown, covered with long yellowish hairs and almost identical in form with those of *y-inversus* (Fig. 6, *b*, *c*).

PRODOXUS SORDIDUS, n. sp.

I first found this species in the flowers of *Yucca brevifolia* on the occasion of the discovery of *Pronuba synthetica*, while other specimens were subsequently obtained by Mr. Koebele. In general appearance the species seems nearest related to *P. cinereus*, being, however, much paler, with the greater portion of the hind wings white.

IMAGO. — ♂. Expanse 8–10 mm.; ♀ 11–13 mm. General color creamy-yellow, the females showing the most white. A more or less distinct dusky or blackish posterior margin to the secondaries, the dark color broadening toward the apex. The undersurfaces have a tendency to metallic reflection and the darker color of the hind border of the secondaries is repeated. Abdomen grayish-brown dorsally, with iridescent reflection. Anal segment of ♀ reddish-brown, obliquely truncate from above, the tip rounded. Ovipositor yellowish-brown, slender and finely denticulate along the upper edge. Male claspers similar in shape to those of *decipiens* but more slender, the base comparatively broader and the apex more abruptly rounded; the basal side-piece narrower and pointed at tip; the posterior edge with from 3 to 5 small slender teeth.

Described from 5 males and 5 females.

EXPLANATION OF PLATES ILLUSTRATING YUCCA MOTH AND YUCCA POLLINATION.*

PLATE 34.

Fig. 1.— *Pronuba yuccasella:* *a*, larva; *b*, ♀ moth with closed wings; *c*, do. with wings expanded — nat. size; *d*, side view of one of the middle joints of larva; *e*, head of larva, beneath; *f*, do., above; *g*, thoracic leg of same; *h*, maxilla; *i*, mandible; *j*, spinneret and labial palpi; *k*, antenna — enlarged.

Fig. 2.— *Pronuba yuccasella:* moth soon after issuing from chrysalis, showing position of wings when expanding and before fully dried. ×3.

Fig. 3.— *Pronuba yuccasella:* generic characters — *a*, side view of head and neck of female denuded, showing how the collected load of pollen (1) is held by the tentacles (2); (3, 4, 5, tongue, antenna and maxillary palpi;) *b*, maxillary tentacle and palpus; *c*, an enlarged spine; *d*, maxillary palpus of ♂; *e*, scale from front wing; *f*, front leg; *g*, labial palpus; *h*, *i*, front and hind wings denuded; *j*, anal joint of female with ovipositor partly extruded showing silk-like oviduct — all enlarged.

Fig. 4.— *Pronuba yuccasella:* *l*, male chrysalis; *m*, female do.

Fig. 5.— Mature pods of *Yucca angustifolia:* *a*, artificially pollinized and protected from Pronuba; *b*, normal pod, showing constrictions resulting from Pronuba puncture and exit holes of larva; *c*, one of the lobes cut open showing larva within.

PLATE 35.

Fig. 1.— Flower of *Yucca aloifolia* showing stouter pistil and shorter style as compared with *filamentosa*.

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* The author is under obligations to Prof. Edwin Willets, Assistant Secretary of Agriculture, for the use of the illustrations Pl. 36, Figs. 1, 2; Pl. 37, Fig. 2; Pl. 38, Fig. 2, and Pl. 41, Figs. 1, 2. The others are either from his drawings and previously used, or made from his studies especially for this article, by Miss Lillie Sullivan.

Fig. 2.—*a*, longitudinal section of pistil of *Yucca filamentosa* showing (*b*, *b*) punctures of Pronuba, and (*c*, *c*) the normal position of her eggs in the ovarian cell —×11; *d*, section of a punctured carpel 7 days after oviposition showing the egg yet unhatched and the manner in which the ovules in the neighborhood of puncture have been arrested in development so as to cause the constriction —×2; *e*, section of an older carpel showing the larva above the original puncture —×2; *f*, a seed 13 days from oviposition showing young larva at funicular base —×8.

PLATE 36.

Fig. 1.— Transverse section of one of the carpels of pistil, after the flower has opened: *a*, ovule; *b*, funiculus; *c*, placenta; *d*, ovarian cell; *e*, fibro-vascular bundles; *f*, fibro-vascular tissue; *g*, primary dissepiment.

Fig. 2.— Transverse section of pistil about middle, one day after oviposition, showing (*a*, *a*) puncture of ovipositor, and (*b*, *b*) position of egg —×17.

PLATE 37.

Fig. 1.— A, tip of anal joint and vaginal projection of ♀ *Pronuba yuccasella* from side showing ovipositor with parts extended: *b*, basal part; *c*, its file-like surface; *d*, terminal part with its dorsal serrate wing (*f*), its dentate tip (*e*), its ventral membranous outlet (*g*) and the extended oviduct (*h*); B, the same parts further enlarged; C, ventral view of tip of abdomen showing the two pair of rods *i*, *i* and *k*, *k* with their muscular attachments, the parts of ovipositor similarly lettered as in A; *m*, *m*, eggs taken from Yucca pistil; *n*, egg showing development of embryo; *o*, mature egg from ovary of ♀; *r*, *s*, genital claspers of ♂, lateral and dorsal views — all enlarged, the pedicels of eggs not sufficiently slender.

Fig. 2. — Flower of Yucca with near petals removed to show normal position of Pronuba in ovipositing.

PLATE 38.

Fig. 1. — Pistils of *Yucca filamentosa*, showing (*a*) a deformed specimen and (*b*, *c*, *d*) varying lengths of the stamens.

Fig. 2. — *Pronuba yuccasella*, female, in the act of gathering pollen from the anthers — ×5.

Fig. 3. — *Chauliognathus pennsylvanicus: a*, larva; *b*, its head and prothorax; *c*, *d*, *f*, *g*, *h*, its mouth parts; *e*, its leg; *i*, beetle — all enlarged but *a* and *i*.

Fig. 4. — Flower-stem of Yucca showing scars resulting from oviposition of female *Prodoxus decipiens* (*a*, *a*) and pupal exuvia of same protruding (*b*, *b*, *b*).

PLATE 39.

Fig. 1. — *Prodoxus decipiens: a*, larva; *b*, head from above; *c*, *d*, left jaw and antenna; *e*, pupa; *f*, infested stem cut to show the burrows, castings, cocoons (*i*), exit hole (*g*) and pupa shell (*h*) — all enlarged but *f*, the hair line between *a* and *e* showing natural length.

Fig. 2. — *Prodoxus decipiens: a*, imago, wings closed; *b*, female do. wings expanded — nat. size; *c*, maxillary palpus with its basal tubercle enlarged.

Fig. 3. — Genital characters of *Prodoxus decipiens*: *a*, tip of ♀ abdomen rendered somewhat transparent; *b*, basal part of ovipositor; *c*, its sculpture; *d*, terminal part of same; *e*, its tip more enlarged; *f*, genitalia of ♂ from side; *g*, do. from above; *h*, egg — all enlarged.

Fig. 4. — *Prodoxus decipiens:* Female in the act of ovipositing — ×3.

PLATE 40.

Fig. 1. — *a*, receptaculum seminis of *Pronuba yuccasella*, showing radiate bodies or crushers and muscular structure; *b*, same, longitudinal section through axle of hub, showing the main sac and the inner sac at *c* and the radiate bodies in the intervening space at *d* — ×40.

Fig. 2. — *a*, outline of receptaculum seminis of *Pronuba synthetica*; *b*, do. of *Pronuba maculata*; *c*, do. of *Prodoxus decipiens*, all drawn to same scale as figure 1; *d*, enlarged spicule showing ventral groove and a transverse section of same.

PLATE 41.

Fig. 1. — *Pronuba synthetica: a*, ♀ with wings expanded, hair-line showing natural size; *b*, lateral view of the head and neck, more enlarged, showing a purely lateral view of the trophi, not in pairs to avoid confusion. The maxillary palpus (*mp*) with its tentacle (*mt*); tongue (*t*); labial palpus (*lp*); base of antenna (*at*); eye (*e*); front trochanter (*ft*).

Fig. 2. — *Pronuba synthetica*: *a*, larva, from side; *b*, ♀ chrysalis, ventral view; *c*, do., lateral view — nat. size in hair-line; *d*, lateral; *e*, dorsal view of anal joints of ♂; *f*, *g*, do. of ♀; *h*, dorsal view of 2nd and 3rd joints of abdomen — all more enlarged.

PLATE 42.

Fig. 1. — *Pronuba synthetica: a*, enlarged view genitalia of ♂ from side; *b*, do., from behind; *c*, anal joint of female with ovipositor exserted, dorsal view; *d*, do., lateral view; *e*, ovipositor, dorsal view, still more enlarged; *f*, do., from side.

Fig. 2. — *Pronuba maculata: a*, tip of female abdomen; *bjo*, basal joint of ovipositor; *tjo*, terminal joint do.; *ov*, oviduct; *mp*, max. palpus; *mt*, maxillary tentacle; *t*, tongue; *gs*, claspers of male from side; *gp*, do. from behind; *pr*, front wings showing arrangement of spots in two of the more common forms — hair-line showing nat. size.

PLATE 43.

Fig. 1. — *Prodoxus intermedius: a*, anal abd. joint of female — ×10; *bjo*, basal jt. ovipositor — ×40; *s*, its sculpture; *tjo*, terminal jt. do.; *ov*, oviduct.

Fig. 2. *Prodoxus marginatus: a*, anal abd. jt. of female —×26; *bjo*, basal jt. ovipositor; *tjo*, terminal jt. do.; *ov*, oviduct; *c*, claspers of male from above —×18; *pr*, front wing — hair-line showing nat. size.

Fig. 3. — *Prodoxus œnescens: a*, anal abd. jt. of female with ovipositor retracted —×15; *bjo*, basal jt. ovipositor; *tjo*, terminal jt. do.—×28; *ov*, oviduct; *c*, clasper of male from above —×18.

Fig. 4. — *Prodoxus cinereus:* male claspers (*a*) from above —×8; and (*b*) from side —×15.

Fig. 5. — *Prodoxus y-inversus: a*, left front wing — hair-line underneath showing natural size; *b*, genitalia of male, dorsal view —×14; *c*, do., lateral view —×18; *d*, anal joint of female with ovipositor exserted, lateral view —×20; *e*, tip of ovipositor still further enlarged.

Fig. 6. — *Prodoxus coloradensis: a*, left front wing — hair-line underneath showing natural size; *b*, male genitalia, dorsal view —×15; *c*, do., lateral view —×18.

Fig. 7. — *Prodoxus reticulatus:* female with wings expanded — hair-line showing natural size.

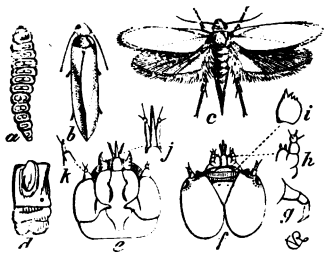
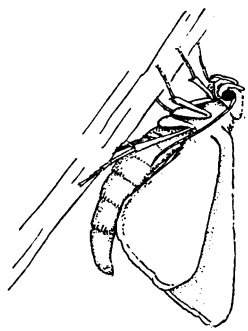


Fig. 1.



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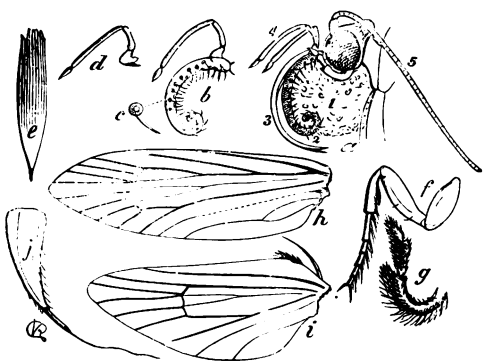


Fig. 3.

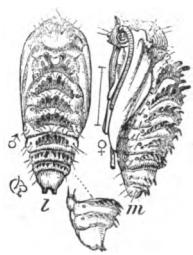


Fig. 4.

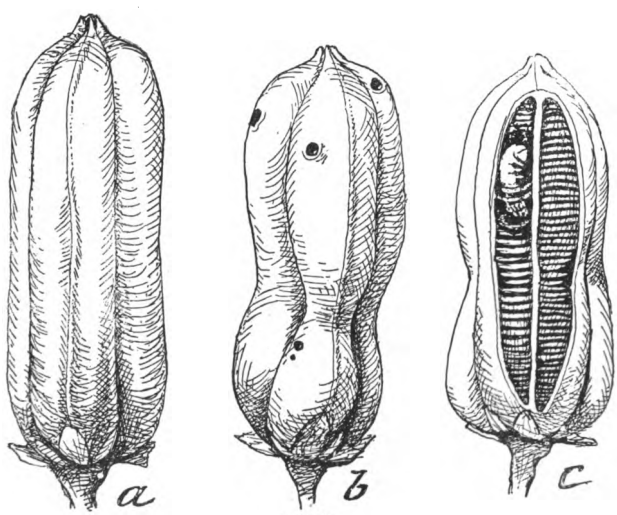


Fig. 5.

CHARACTERS OF PRONUBA YUCCASELLA.

Fig. 1.

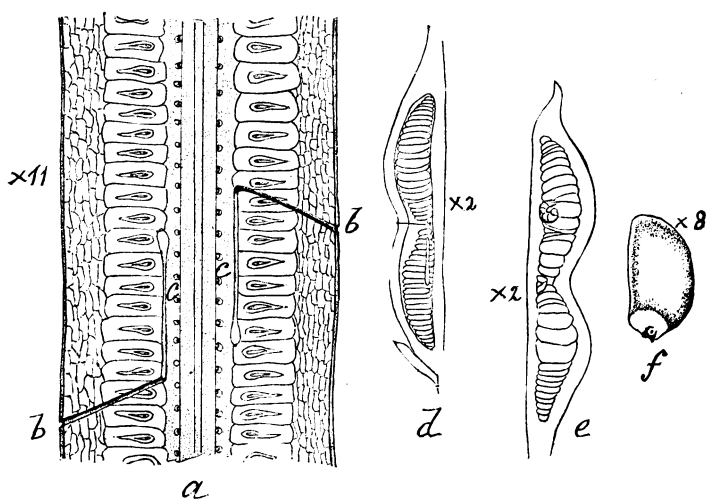


Fig. 2.

OVIPOSITION OF PRONUBA.

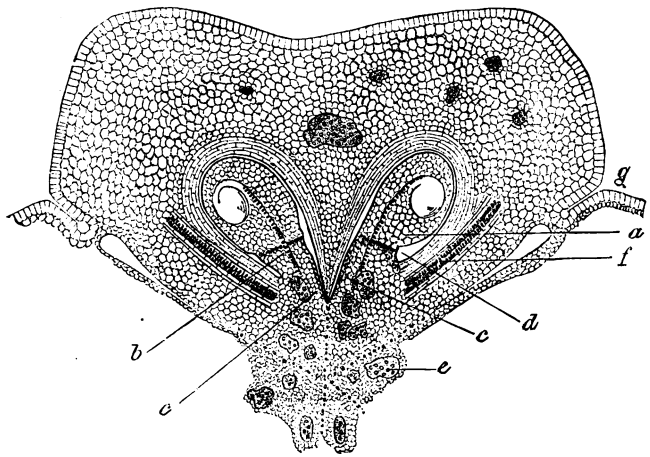


Fig. 1.

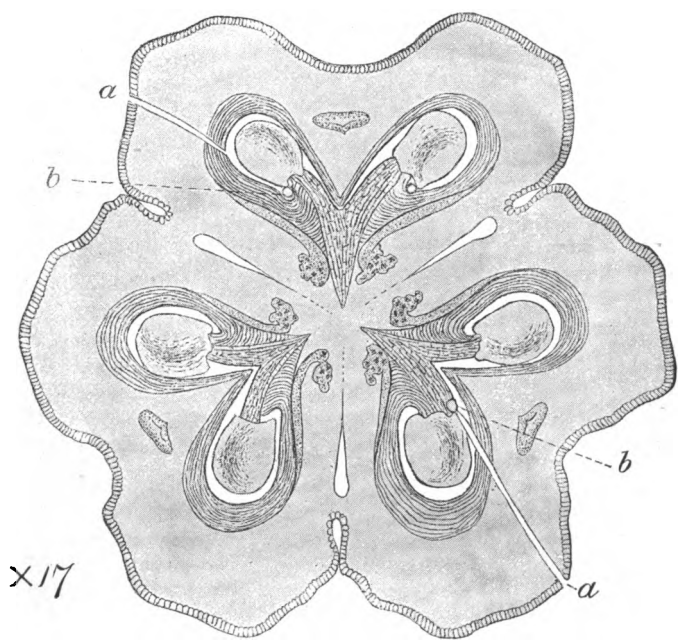


Fig. 2.

OVIPOSITION OF PRONUBA.

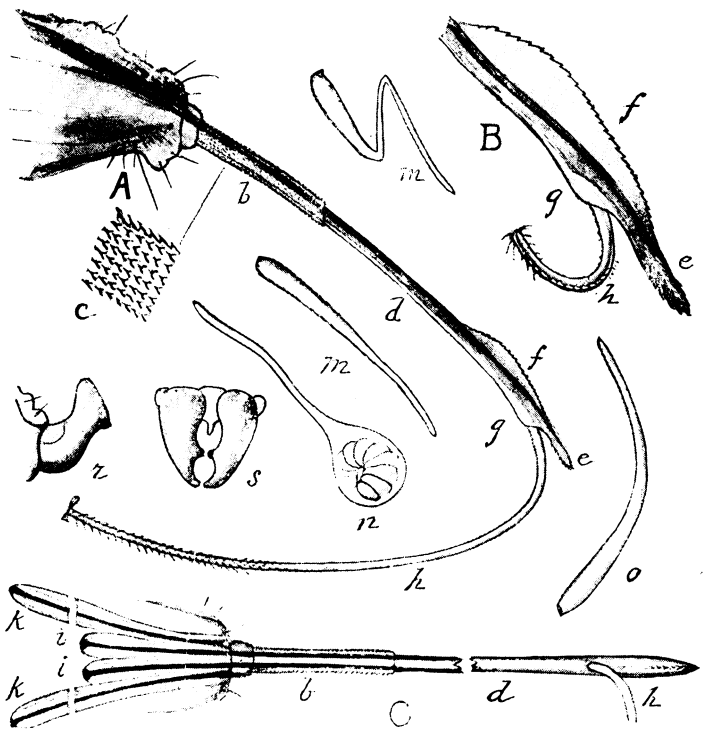


Fig. 1.

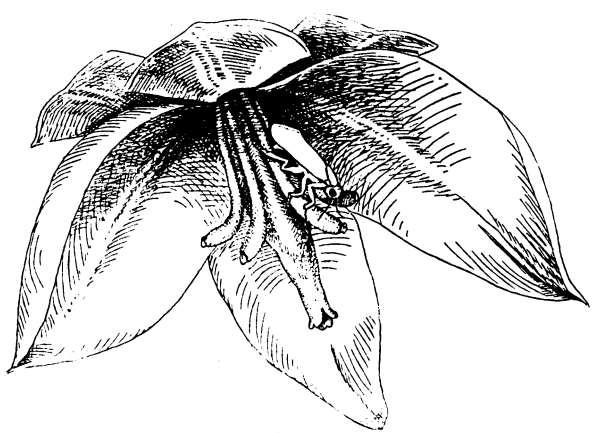


Fig. 2.

OVIPOSITION OF PRONUBA.

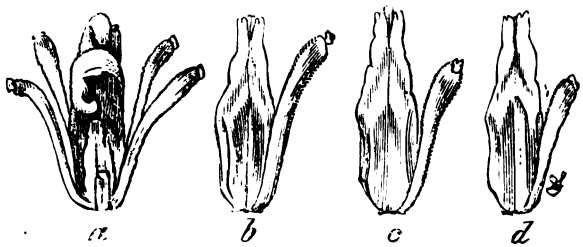


Fig. 1.

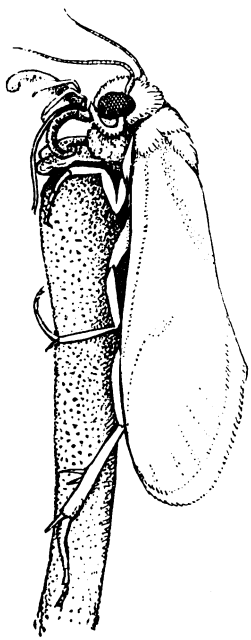


Fig. 2.

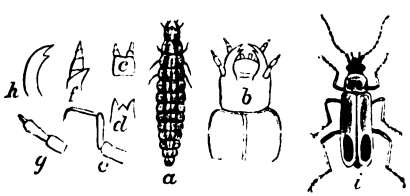


Fig. 3.

Fig. 4.

PRONUBA AND YUCCA POLLINATION.

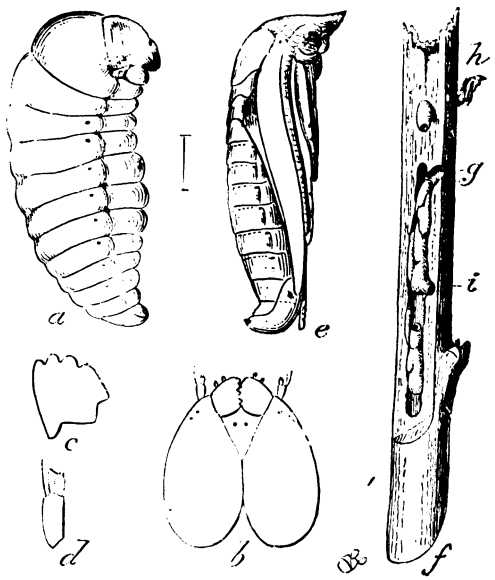


Fig. 1.

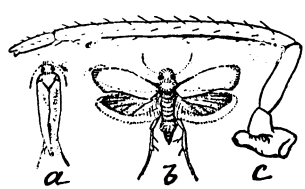


Fig. 2.

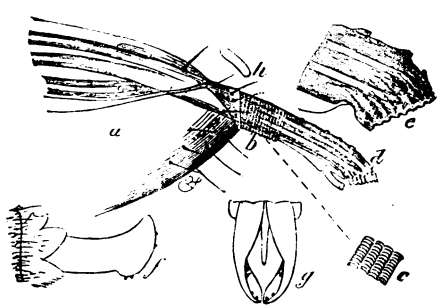


Fig. 3.

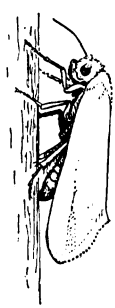


Fig. 4.

PRODOXUS DECIPIENS.

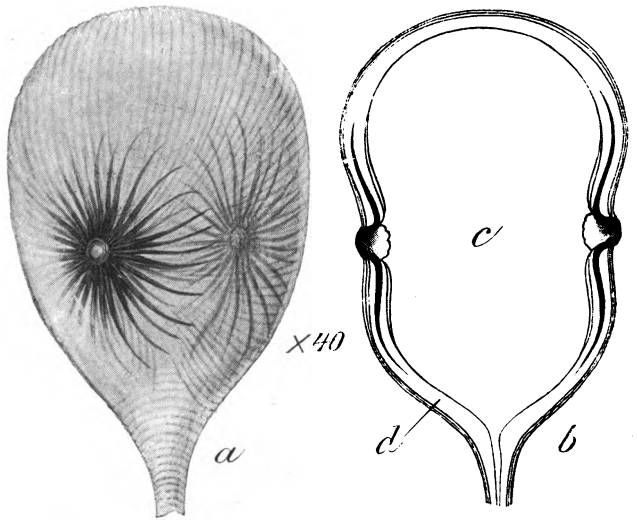


Fig. 1.

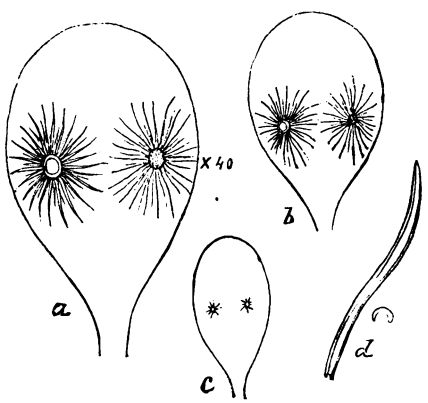


Fig. 2.

RADIATE ORGANS OF PRODOXIDÆ.

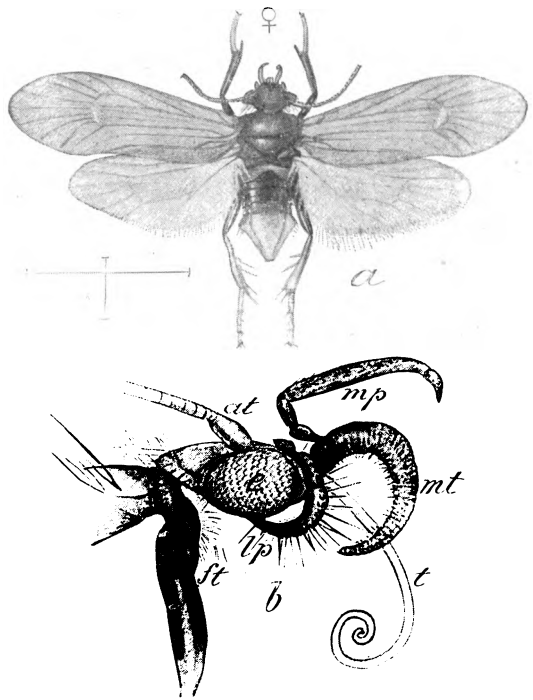


Fig. 1.

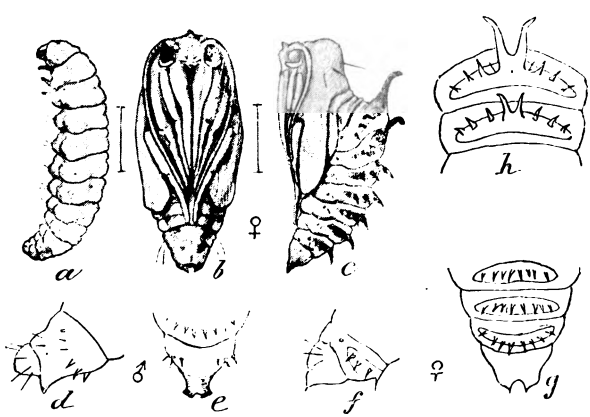


Fig. 2.

PRONUBA SYNTHETICA.

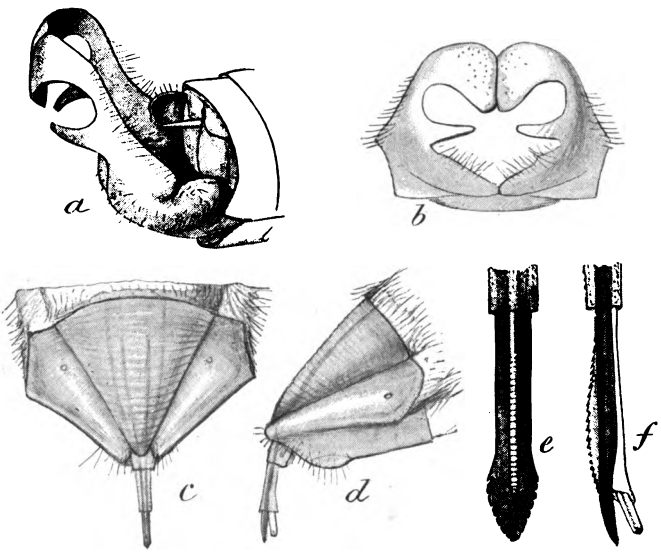


Fig. 1.

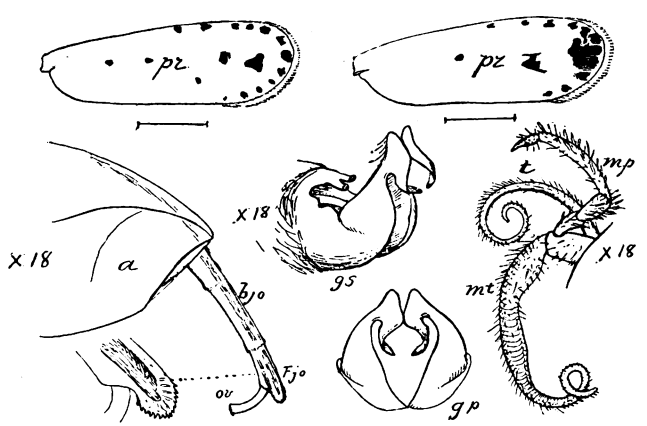


Fig. 2.

PRONUBA SYNTHETICA AND P. MACULATA.

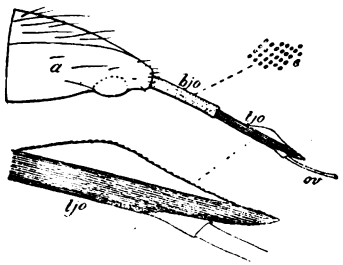


Fig. 1.

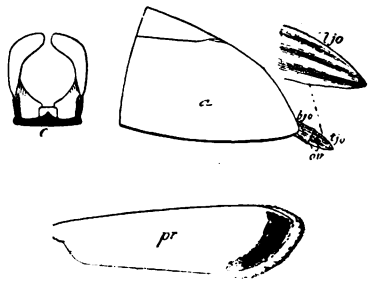


Fig. 2.

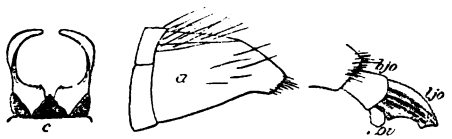


Fig. 3.

Fig. 4.

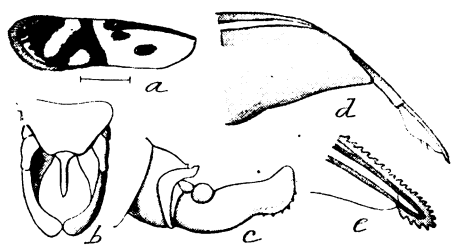


Fig. 5.

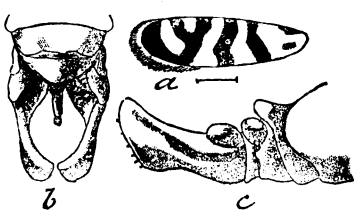


Fig. 6.

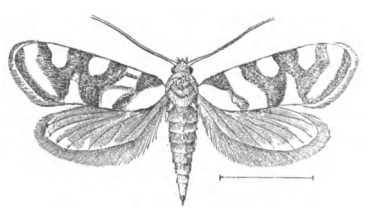


Fig. 7.

SPECIES OF PRODOXUS.

NOTES AND OBSERVATIONS.

1. DETAIL ILLUSTRATIONS OF YUCCA.

During the time that I have resided in St. Louis, I have many times had occasion to observe the principal facts connected with the pollination of *Yucca filamentosa* and the forms referred to that species by Dr. Engelmann, and to demonstrate them to visitors to the Garden. The Chairman of the Garden Committee of the institution, who viewed them in my company last spring, was so impressed with their interest that I made a short visit to the Rocky Mountains early in July last, for the purpose of making similar observations on *Y. angustifolia*, with the intention of summarizing for the present volume all that was known on the subject. On my return I found on my table a letter from Professor Riley, to whom, and Dr. Engelmann, the discovery and elaboration of the curious facts is due, offering to prepare for this report a paper such as I had in mind. As an account from his pen promised far greater completeness and interest than I could have hoped to attain, his offer was very gratefully accepted, and the article appears in the preceding pages.

While reviewing the material at the Garden bearing upon Yucca, I found a large number of drawings by Dr. Engelmann, which I had intended utilizing in connection with my paper; and as these sketches depict the floral and capsular structure of some species that have as yet been inadequately figured, I have had them redrawn in ink by Miss Grace E. Johnson for photo-engraving, and publish them herewith. I have included with them reproductions of photographs showing the habit of growth of several species, and also some figures illustrative of our observations on *Y. filamentosa*, which had been prepared before the receipt of Professor Riley's paper, and may prove of interest in connection with it.

Yucca is a small genus of evergreen leaved plants of the lily family, belonging to the Central American flora and that of the Southern United States, one species reaching well up into the Rocky Mountains. Engelmann recognized fourteen species, while Baker, who has also made the Yuccas the subject of much study, admits half as many more, several of the additional species having been called varieties by Engelmann, though several others are known only from plants in cultivation (few of which have flowered or fruited), and are regarded by some botanists as probable forms or derivatives of other species known in a state of nature.

While the more eastern of our species are short-stemmed, several of those native in the southwest become trees, often of considerable size and with thick rough bark. The fruit of the section with pulpy carpels is more or less eaten, and the fibers of the leaves are used for cordage by the Mexicans who also make a good deal of domestic use of the root-stocks as a substitute for soap. Some years since the proprietors of an English newspaper established a mill in the home of one of the tree Yuccas, intending to make paper pulp from its wood, but the enterprise was shortly abandoned.

Like most of the monocotyledons, aside from the palms, Yucca has left few if any fossil remains complete enough for certain determination, and Professor Lester F. Ward informs me that only one fossil species has ever been referred to the genus Yucca, — namely *Y. Roberti*, Bureau, found in the Paris basin, — and that even this is generally considered to belong to Yuccites, a form assemblage, some of the components of which are of very early origin, but none of them of necessity closely allied to the existing genus Yucca, nor representing its ancestral type.

The principal revisions of the genus are by Engelmann, in the Transactions of the St. Louis Academy, iii, pp. 17, 210 and 371 (brought together, with additional descriptions and notes printed elsewhere by him, in his Collected Writ-

ings, p. 276, — published under the auspices of the Garden in 1877); Baker, in the Journal of the Linnean Society, xviii, p. 219, and Kew Bulletin of Miscellaneous Information, Jan. 1892, p. 7; and Watson, in the Proceedings of the American Academy, xiv, p. 251. Reference should be made to these papers, and to Professor Sargent's Forest Trees of North America, p. 218, for the synonymy and bibliography of each species, since only the more recent figures are referred to here. The retention of varietal names for forms subsequently raised to specific rank would involve certain changes in the nomenclature, which are indicated under the species affected.

No better general classification of the Yuccas that are actually known has been found than the following, which represents Engelmann's views, except that by general consent *Y. filifera* has been raised to specific rank from a variety of *Y. baccata*, where Engelmann left it, while Mr. Brandegee has added *Y. valida*, from Mexico, and Baker has just added from the gardens of the Riviera *Y. Hanburii*, said to be from Rocky Mountain seed.

From an examination of this enumeration of species, in connection with the accompanying plates and the figures cited, it will be seen that we are still unpossessed of a knowledge of the floral and fruit details of several species, while some of the figures drawn from dried specimens may be inaccurate in some degree; so that persons who have it in their power to secure faithful photographs or drawings from growing plants may materially contribute to a correct knowledge of this difficult group by supplying the deficiencies, and they may further the same end by obtaining ripe seeds for cultivation in botanical gardens.

SYNOPTICAL LIST.

* EUYUCCA. — Styles stout, the connivent apexes forming a more or less developed central stigmatic cavity: filaments papillate.

A. *Sarcoyucca.* — Fruit pendent, fleshy and indehiscent: ovules and seeds thick, marginless: albumen ruminated.

Y. aloifolia, L. Sp. i. (1753), 319; Engelm. Coll. Writings, 287; Watson, *l. c.* 251; Baker, *l. c.* 221; Nicholson Gard. Dict. 228. — Plates 7 & 44.

Y. Yucatana, Engelm. Trans. St. L. Acad. iii. (1873), 37, and reprint 288; Watson, *l. c.* 251; Baker, *l. c.* 221. —Plate 45.

Y. Guatemalensis, Baker, Refugium Botanicum, v. (1872), pl. 313, and Journ. Linn. Soc. *l. c.* 222; Engelmann, *l. c.* 289; Watson, *l. c.* 251; Nicholson, *l. c.* 233.

Y. Schottii, Engelm. Trans. St. L. Acad. iii. (1873), 46, and *l. c.* 292, 300; Watson, *l. c.* 252; Baker, *l. c.* 228.

Y. macrocarpa, Engelm. Bot. Gaz. vi. (1881), 224, and *l.c.* 299 and 300; Nicholson, *l.c.* 234; Baker, Kew Bull. 1892, 8. —Plate 46. (Perhaps only the well developed form of the preceding).

Y. valida, Brandegee, Proc. Calif. Acad. (2), ii. (1889), 208, plate 11; abst. in Garden & Forest, iii. 106.

Y. Treculeana, Carr. Rev. Hort. vii. (1858), 280; Engelm. *l. c.* 290; Watson, *l.c.* 252; Baker, *l.c.* 226; Sargent, *l. c.* 218, and Garden & Forest, i. 54 (with figure of habit); Pringle, Garden & Forest, iii. 338; Nicholson, *l.c.* 234, f. 250. —Plates 1 & 47.

Y. baccata, Torr. Bot. Mex. Bound. (1858), 221; Engelm. *l.c.* 276, 291, 300; Watson, *l.c.* 252; Baker, *l.c.* 229; Parish, Garden & Forest, iv. 136; Nicholson, *l.c.* 229. —Plates 2 & 48.

Y. filifera, Chabaud, Rev. Hort. 1876, 432; Nicholson, *l. c.* 232, fig. 243, 244; Sargent, Gard. & Forest, i. 78 (with habit figures), and iv. 324 and 396; Baker, Bot. Mag. (3), xlvii. pl. 7197. — *Y. baccata*, var. *australis*, Engelm. Trans. St. L. Acad. iii. (1873), 44, and *l. c.* 291; Watson, *l. c.* 252; Baker, *l. c.* 229. — An adoption of the varietal name, which has priority, would cause the plant to be known as *Y. australis* (Engelm).—Plates 3 & 4.

(Y. Desmetiana, Baker, Gard. Chron. 1870, 1217, Journ. Linn. Soc. *l. c.* 222, and Kew Bull. 1892, 8, Engelmann, *l.c.* 290; and Y. Peacockii, Baker, *l. c.* 223, and Kew Bull.

l. c. 8, are species unknown in flower, but perhaps belonging to the group Sarcoyucca.)

B. *Clistoyucca.*—Fruit pendent (or erect in the first), dry and coriaceous but indehiscent: ovules and seeds thinner, marginless: albumen entire.

Y. brevifolia, Engelm. Bot. King (1871), 496; *l. c.* 276, 293, 297, 298; Watson, *l. c.* 252; Baker, *l. c.* 221; Sargent, *l. c.* 218; Parish, Gard. & Forest, iv. 135. — *Y. Draconis*, ? var. *arborescens*, Torr. Botany of Whipple in Rept. Pac. R. R. Surv. iv. (1857), 147. — If the varietal name were adopted, this would be *Y. arborescens* (Torr.) —Plates 5 & 49.

Y. gloriosa, L. Sp. i. (1753), 319; Engelm. *l. c.* 289, 297; Watson, *l. c.* 251; Baker, *l. c.* 225; Nicholson, *l. c.* 232, f. 247–249.—Plates 6, 7 & 50.

C. *Chænoyucca.*—Fruit erect, capsular with septicidal dehiscence: ovules and seeds thin, the latter broadly wing-margined: albumen entire.

Y. rupicola, Scheele, Linnæa, xxiii. (1850), 143; Engelm. *l. c.* 293; Watson, *l. c.* 253; Baker, *l. c.* 222, and Bot. Mag. (3), xlvii. pl. 7172; Nicholson, *l. c.* 234.— Plate 51.

Y. angustifolia, Pursh, Fl. (1814), 227; Engelm. *l. c.* 276, 294; Watson, *l. c.* 253; Baker *l. c.* 226; Sargent, Gard. & For. ii. 244, 247 (habit figures); Nicholson, *l. c.* 228, f. 238 & 239.—Plates 8 & 51.

Y. elata, Engelm. Bot. Gaz. vii. (1882), 17; *l. c.* 299; Sargent, *l. c.* 219, and Gard. & For. ii. 368 (with habit figures). — *Y. angustifolia*, var. *elata*, Engelm. Proc. St. L. Acad. iii. (1873), 50; *l. c.* 294. — *Y. angustifolia*, var. *radiosa*, Engelm. Bot. King (1871), 496. — The rule of priority, if applied to varietal names, would make this *Y. radiosa* (Engelm.)—Plate 9.

Y. filamentosa, L. Sp. i. (1753), 319; Engelm. *l. c.* 295; Watson, *l. c.* 254; Baker, *l. c.* 227; Nicholson, *l. c.* 231, f. 240–242.—Plates 10, 52 & 53.

(Y. Hanburii, Baker, Kew Bull. 1892, 8, from the de-

scription of foliage characters would appear to belong to the group Chænoyucca, but its flower and fruit are unknown.)

* * HESPEROYUCCA. — Style slender, with an expanded peltate or thimble shaped stigma: filaments glabrous.

Y. Whipplei, Torr. Bot. Mex. Bound. (1859), 222; Engelm. *l. c.* 277, 296, 297, 298; Watson, *l. c.* 254; Baker, *l. c.* 230; Revue Horticole, 1884, 324; Nicholson, *l. c.* 234. — Plates 11, 12 & 54. — Baker, in Kew Bulletin, January 1892, 8, proposes to separate this from Yucca, under the generic name Hesperoyucca.

EXPLANATION OF PLATES ILLUSTRATIVE OF YUCCA.

Plate 1. *Y. Treculeana.* — Plant blooming at the Villa Thuret, Antibes, France, in 1876.

Plate 2. *Y. baccata.* — From a photograph taken near San Diego, Cal., Mar. 16, 1876, by Parker, × $\frac{1}{30}$.

Plate 3. *Y. filifera.* — Young plants cultivated at the Villa Thuret, Antibes, France, in 1876.

Plate 4. *Y. filifera.* — Plants blooming at the Villa Thuret in 1891, from a photograph furnished by Professor Naudin.

Plate 5. *Y. brevifolia.* — Plant in the desert east of the Sierra Nevada, × $\frac{1}{60}$; from photograph presented by Dr. Parry in 1867.

notation on original states "taken 1867"; date of photo. given as June 23, 1870 Mo Bot Gard sheet no. 140140

Plate 6. *Y. gloriosa.* — Specimen blooming at the Villa Thuret, Antibes, France, in 1876. (The original of a cut published in the Gardeners' Chronicle, June 30, 1883.)

Plate 7. *a. Y. aloifolia; b. Y. gloriosa.* — From a photograph of fruiting plants taken in 1872, on the grounds of the Department of Agriculture, × $\frac{1}{17}$.

Plate 8. *Y. angustifolia.* — Fruiting plants on the mountains near Manitou, Col., July, 1891.

Plate 9. *Y. elata.* — Flowering specimen on the plains of Arizona, photographed by Pringle. Copied, by permission, from Garden & Forest, ii. 569.

Plate 10. *Y. filamentosa.* — Plants blooming in the Missouri Botanical Garden, June, 1891.

Plate 11. *Y. Whipplei.* — Plants beginning to bloom, × $\frac{1}{15}$, from a photograph by Parker, Apr. 13, 1876, near San Diego, Cal.

Plate 12. *Y. Whipplei.* — Plants in full bloom, × $\frac{1}{18}$, from a photograph taken near San Luis Obispo, Cal., in 1873, by Dr. W. W. Hays.

Plate 44. *Y. aloifolia.* — 1. Stamen and pistil, × 2; 2, ends, and 3, side view and section, of fruit, natural size; 4, sections of seed, × 2. — After Engelmann.

Plate 45. *Y. Yucatana.* — 1, Habit, after a sketch by Schott in 1865; 2 and 3, flowers, natural size; 4, stamens and pistil, × 2; 5, leaf margin, × 15. — After Engelmann.

Plate 46. *Y. macrocarpa.* — Two fruits, natural size. — After Engelmann.

Plate 47. *Y. Treculeana.* — 1, Flower, natural size; 2, stigma, × 2; 3, fruit, and 4, cross section of same, natural size; 5, sections of seed, × 2. — After Engelmann.

Plate 48. *Y. baccata.* — 1, Stamen and pistil, natural size, and cross section of ovary, × 2; 2, fruit, natural size; 3, sections of same, reduced one-half; 4, sections of seed, × 2. — After Engelmann.

Plate 49. *Y. brevifolia.* — 1, Margin of leaf, × 15; 2, pistil, natural size; 3, stamens, × 5; 4, fruit, and 5, end view of same, natural size; 6, sections of seed, × 2. — After Engelmann.

Plate 50. *Y. gloriosa.* — 1, Flower, natural size; 2, pistil and cross sections of same, × 2; 3, fruit, and section of same, natural size (from photographs of the Washington fruit of plate 7, *b*); 4, sections of seed, × 2. — After Engelmann.

Plate 51. 1–4, *Y. rupicola;* 5–7, *Y. angustifolia.* — 1, Symmetrical capsules, natural size; 2, section of seed, × 2; 3, margin of leaf of var. *rigida*, × 15, and 4, prominence of same, × 75. — 5, Stamens and pistil, natural size;

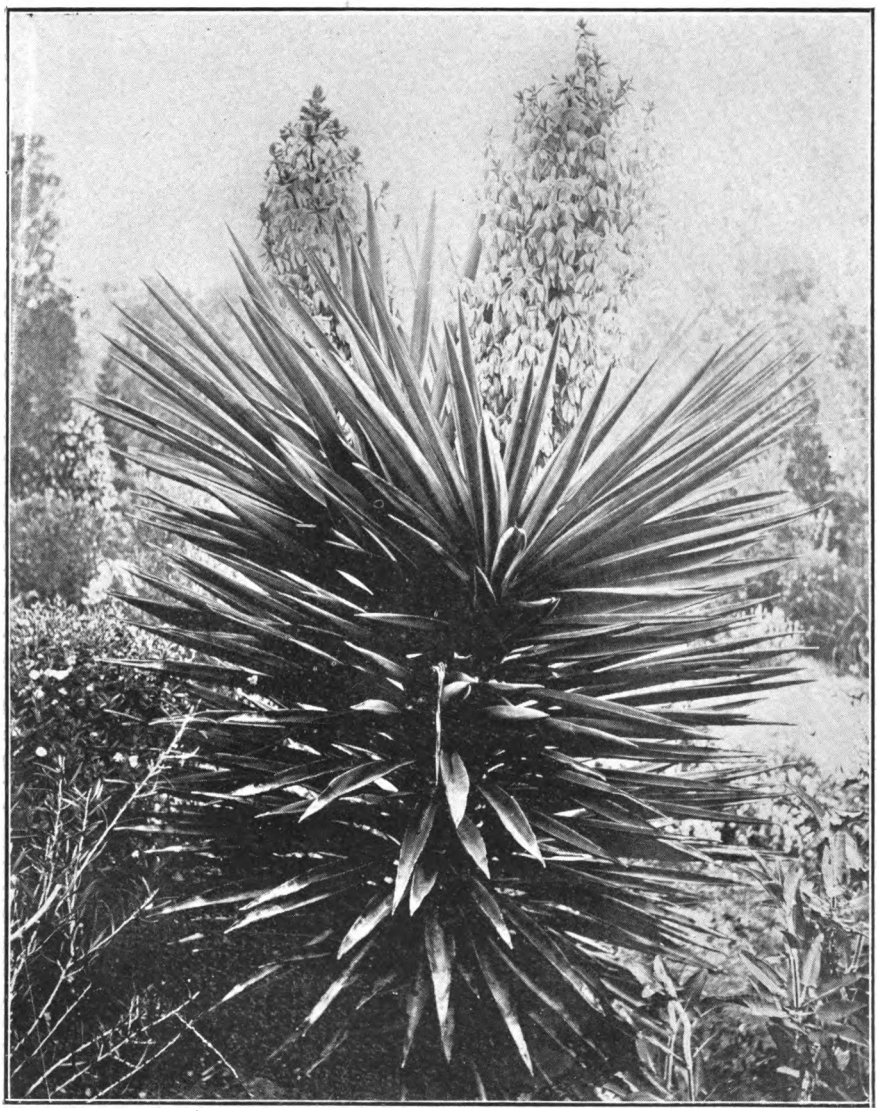
6, symmetrical capsule, natural size; 7, sections of seed, × 2. — After Engelmann.

Plate 52. *Y. filamentosa.* — 1, Sections of pistil at various heights, showing connection of stigmatic chamber with ovarian cells, × 2; 2, stigma, × 3; 3, stamen before and after dehiscence, enlarged; 4, Pronuba larva *in situ* in nearly mature capsule, natural size; 5, young ovules bored by larva, enlarged; 6, capsule (too symmetrical) after escape of larvæ, natural size; 7, seed and sections, × 2; 8, developing egg of Pronuba, × 30. — 1 and 5 to 8, after Engelmann; the remainder from nature by Miss Johnson.

Plate 53. *Y. filamentosa.* — 1, Pistil at time of fertilization, in longitudinal section, showing on the right development of pollen tubes through the stylar channel into ovary, and on the left the septal nectar gland A, with its duct, B, and outlet C, × 5; 2, part of cross section at A B, showing below, the outer portion of septal gland, and above, the duct B and its outward closure by the surface papillæ of ovary, × 75; 3, pollen tube, × 150; 4, emergence of same from extine of pollen grain, and 5, distal end of same, showing the not infrequent occlusion of cell cavity, both × 400; 6, apex of ovule in longitudinal section, showing egg apparatus and entering pollen tube, × 400. — 3 and 4 after Engelmann, the remainder from nature by Mr. Webber.

Plate 54. *Y. Whipplei.* — 1, Section of flower, and 2, side view of pistil, — from the Gardeners' Chronicle; 3, pistil, 4, section of stigma, 5, section of ovary, and 6, stamen, enlarged; 7, capsule, natural size; 8, sections of seed, × 2. — After Engelmann.

W. T.



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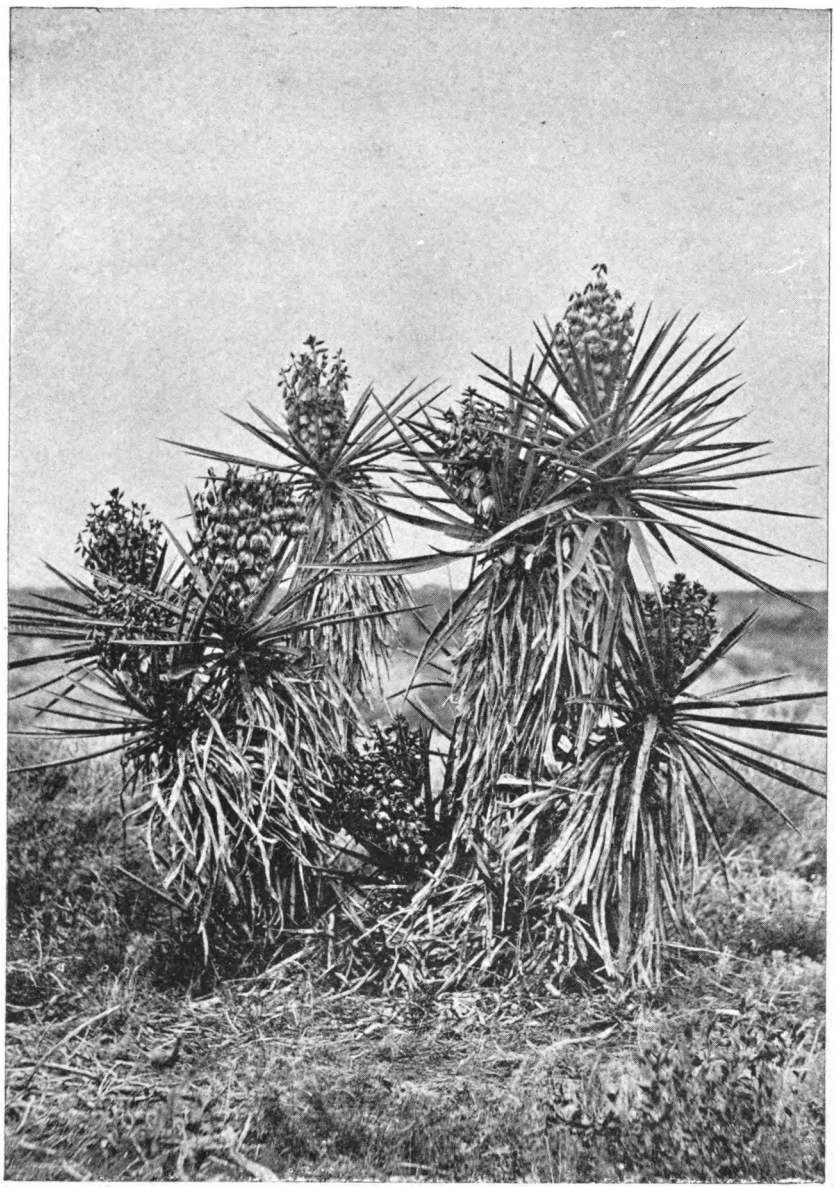

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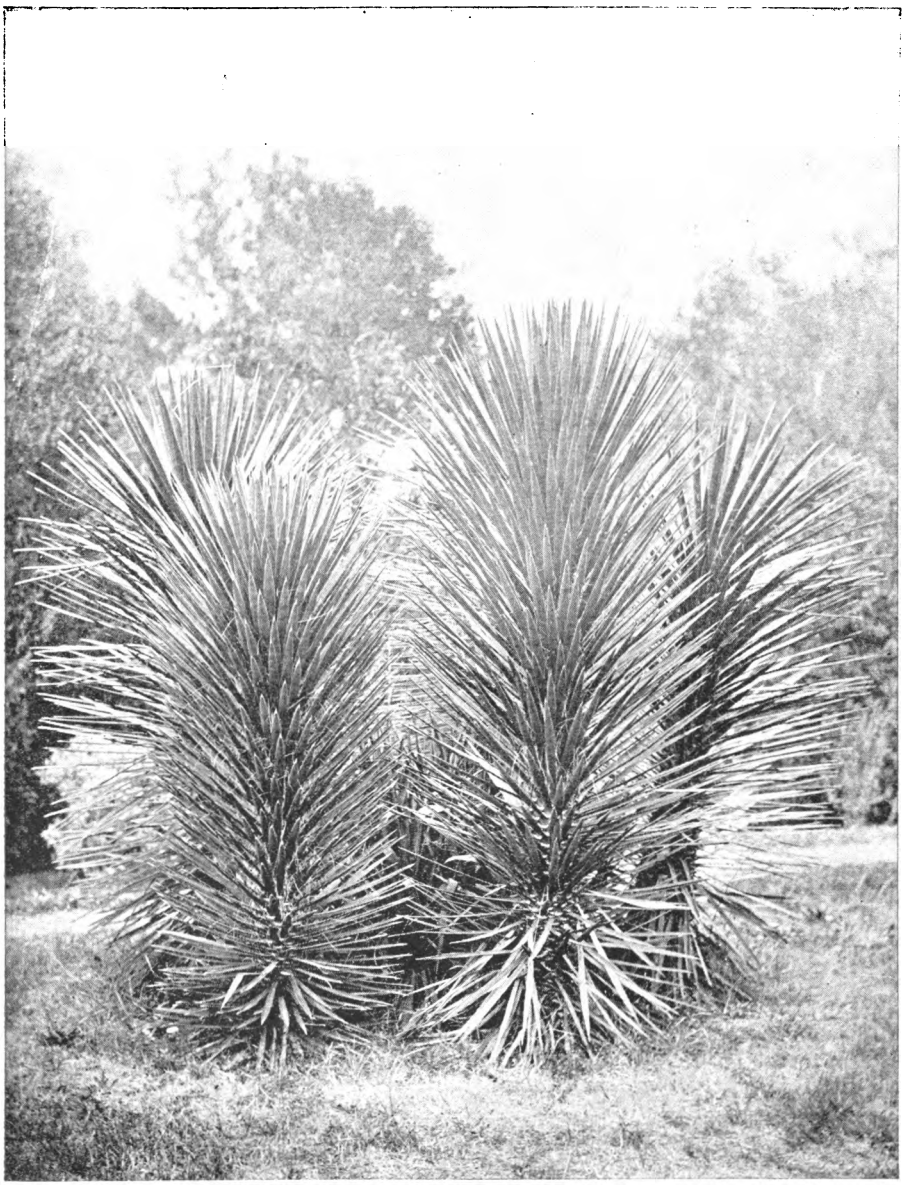
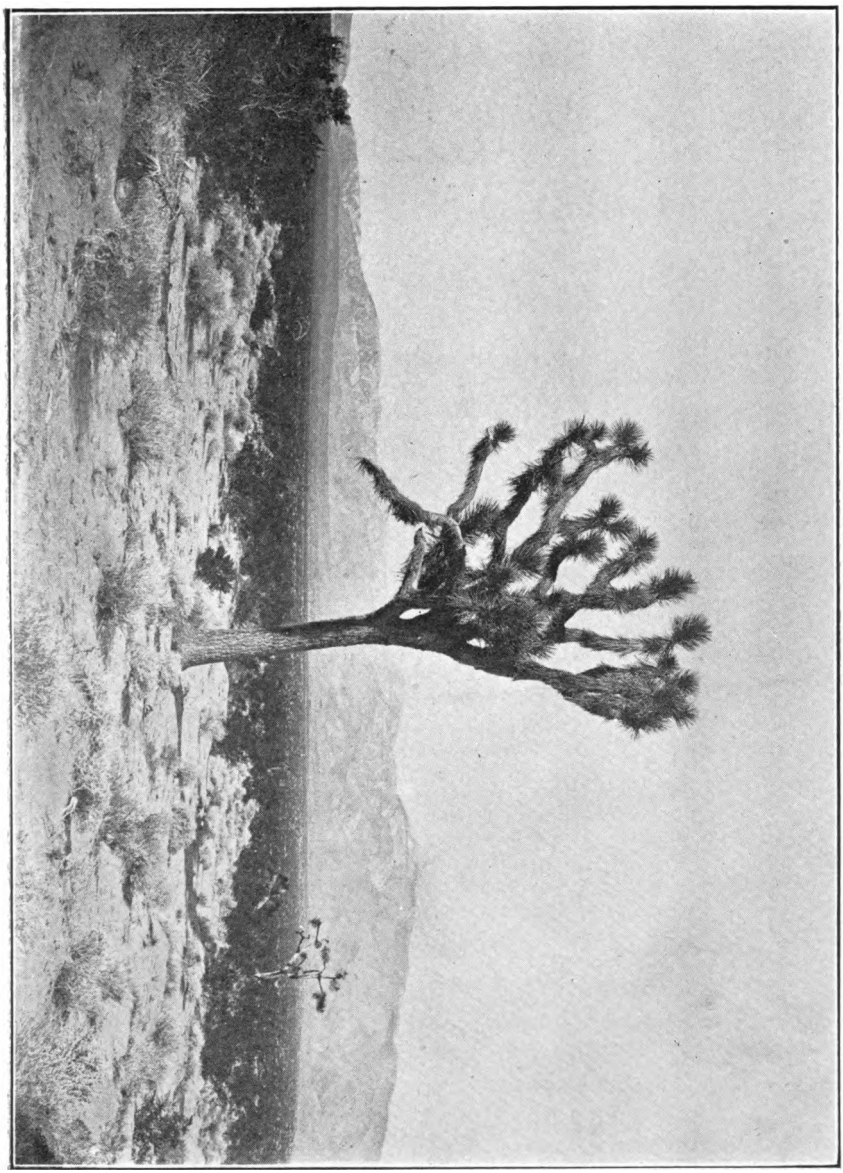


YUCCA FILIFERA.

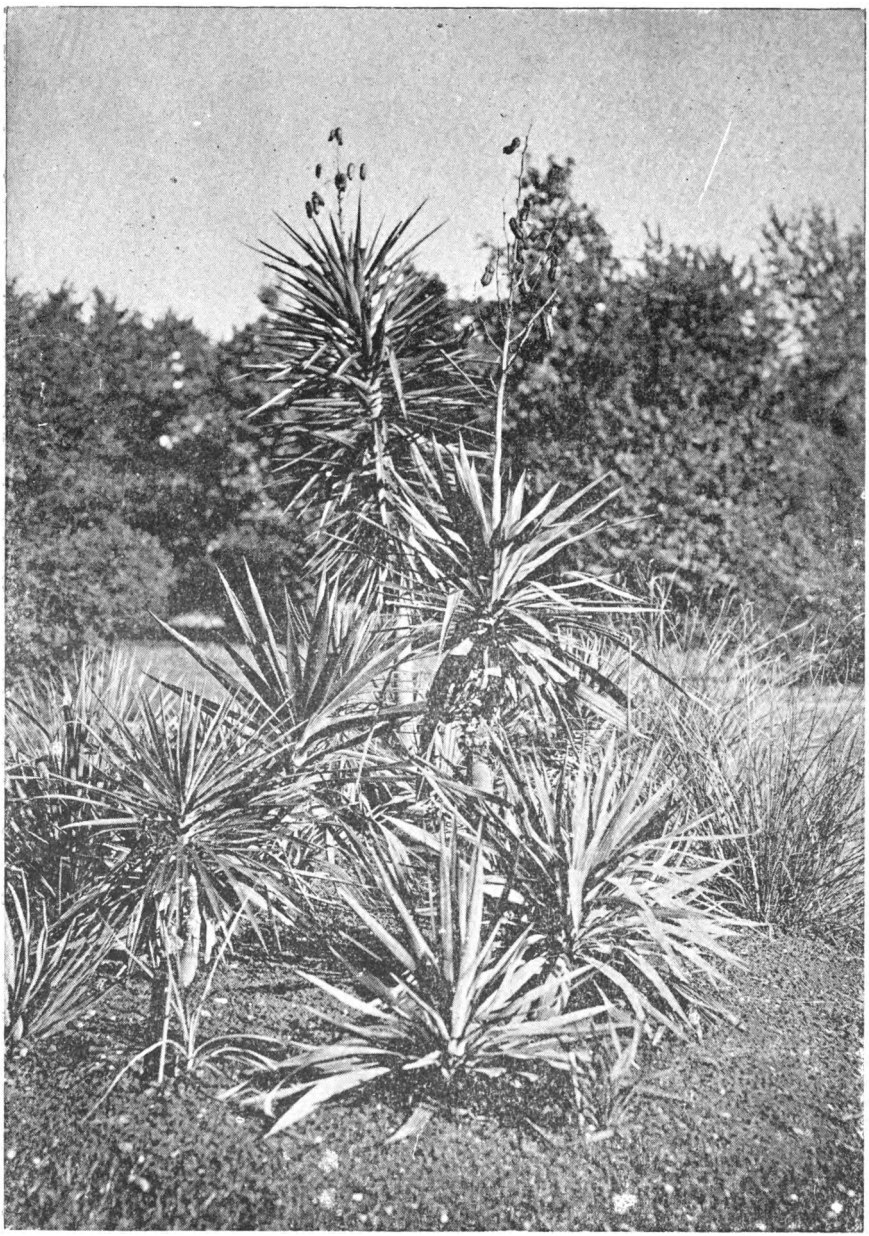
YUCCA FILIFERA.



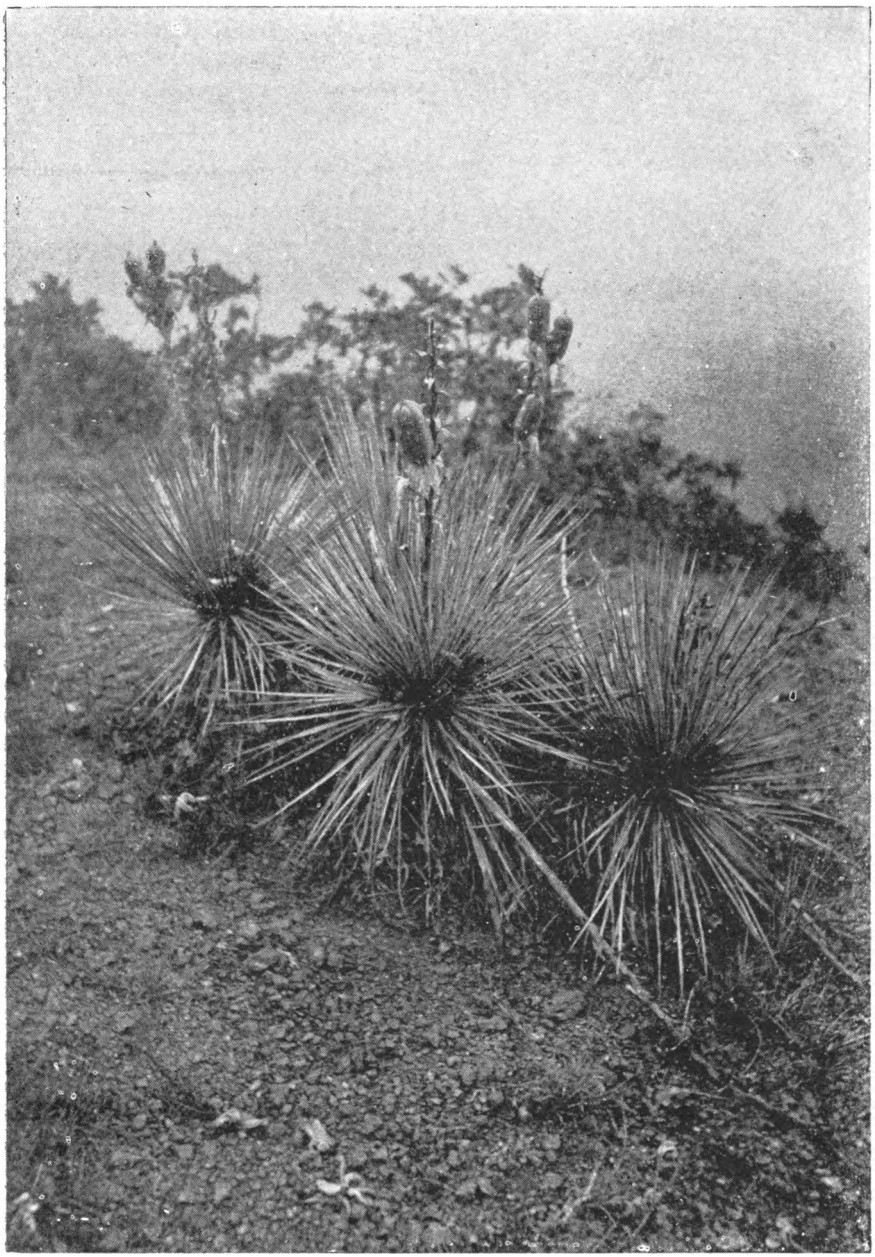
YUCCA BREVIFOLIA.

See Mo. Bot. Gard. sheet no. 140140

YUCCA GLORIOSA.



YUCCA ALOIFOLIA (*a*) AND Y. GLORIOSA (*b*).



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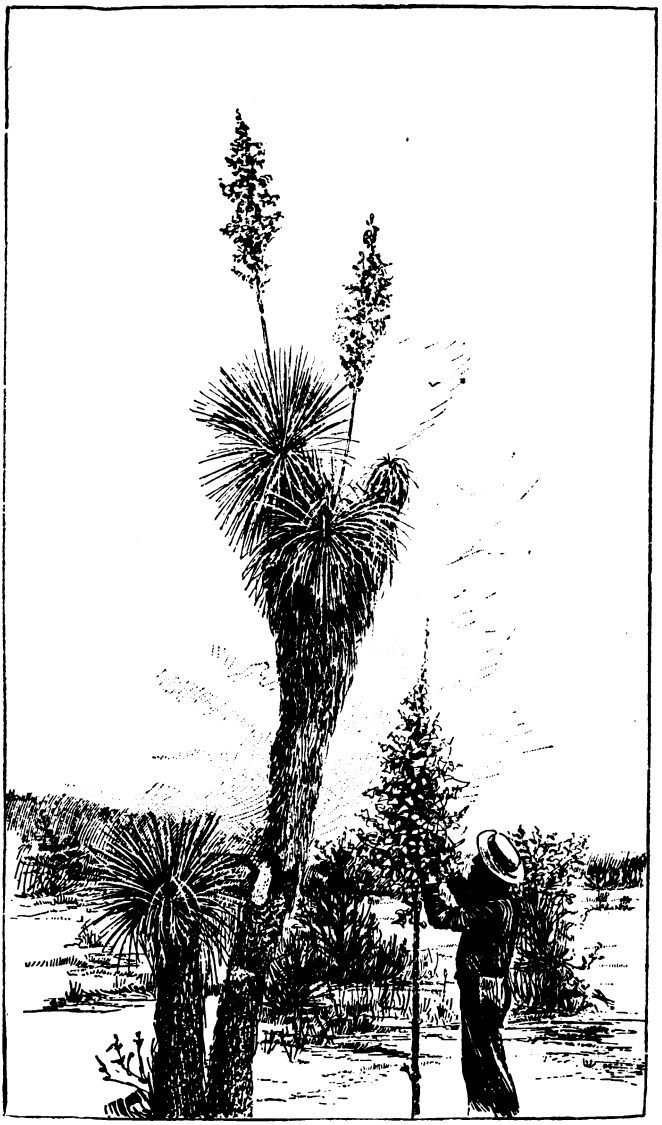
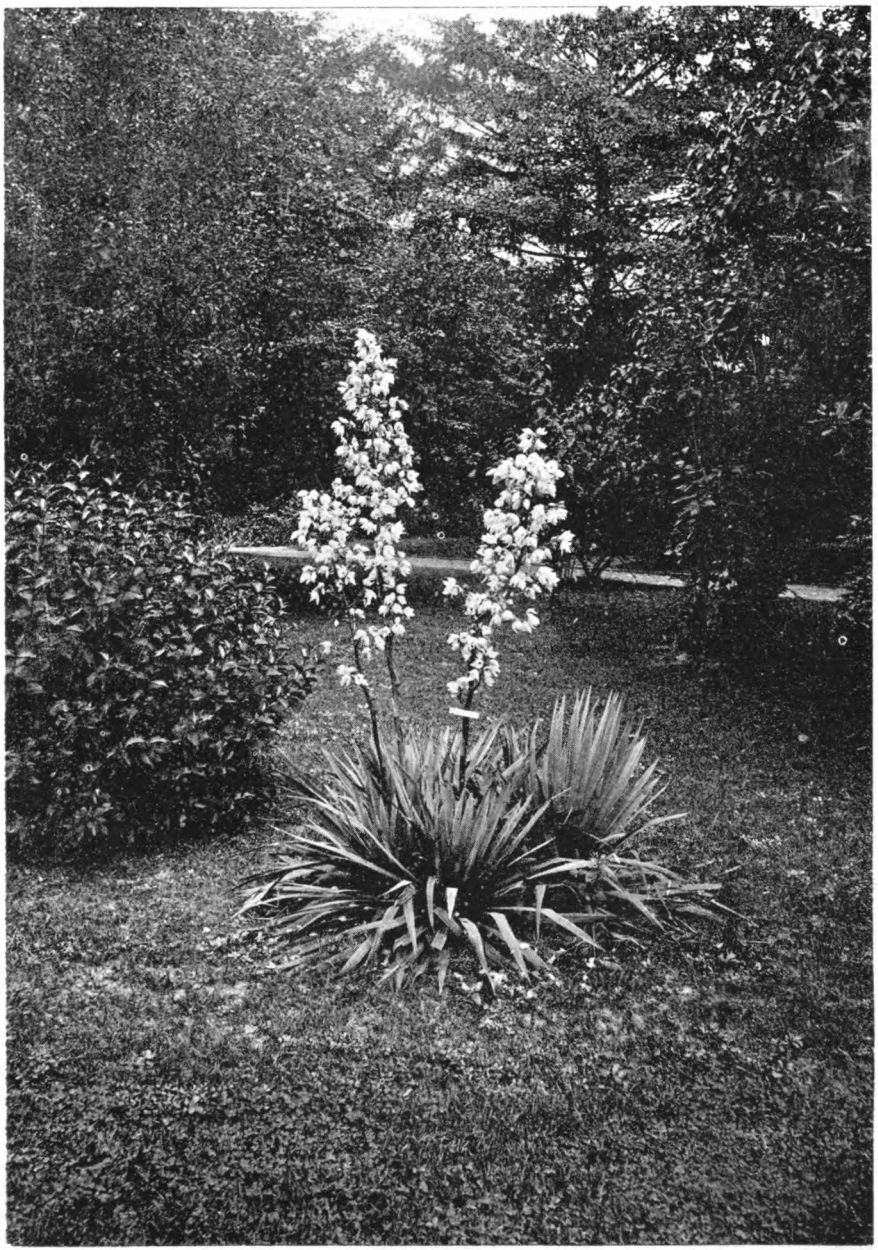


FROM GARDEN AND FOREST.

YUCCA ELATA.



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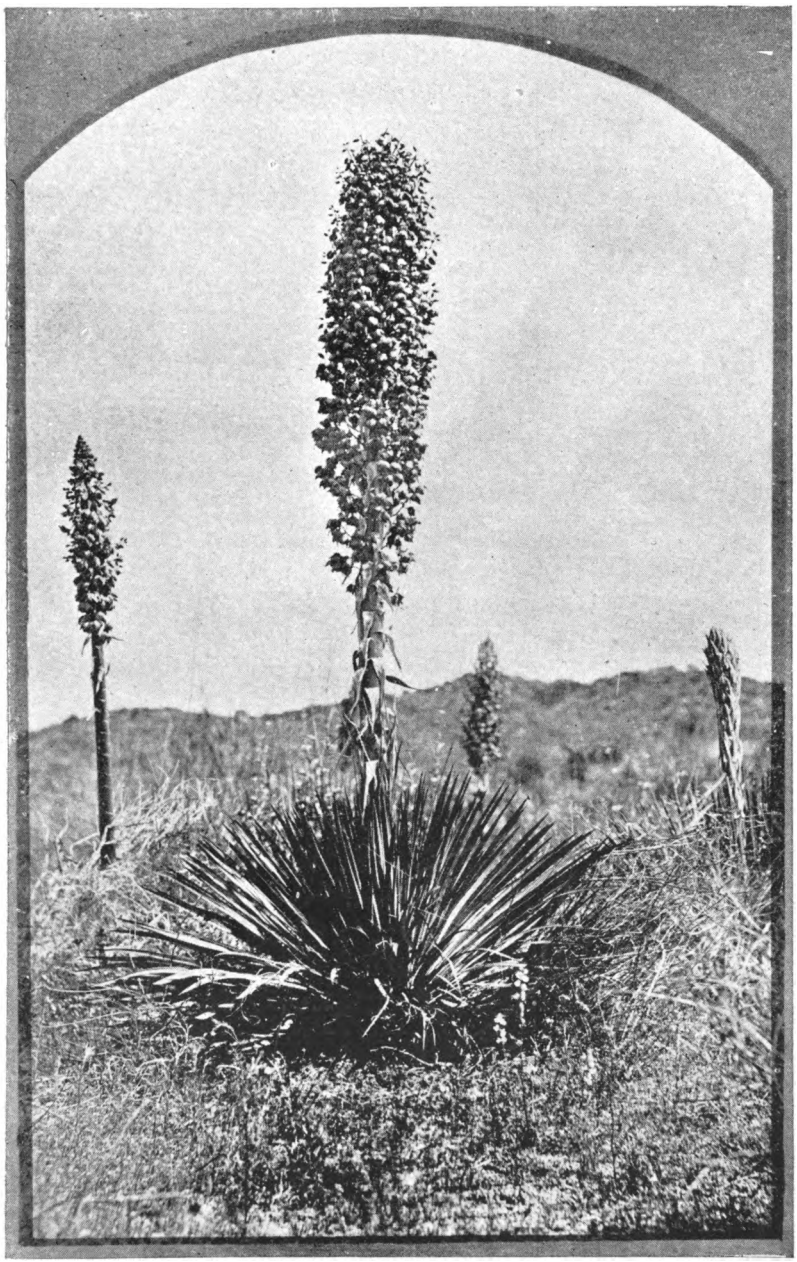

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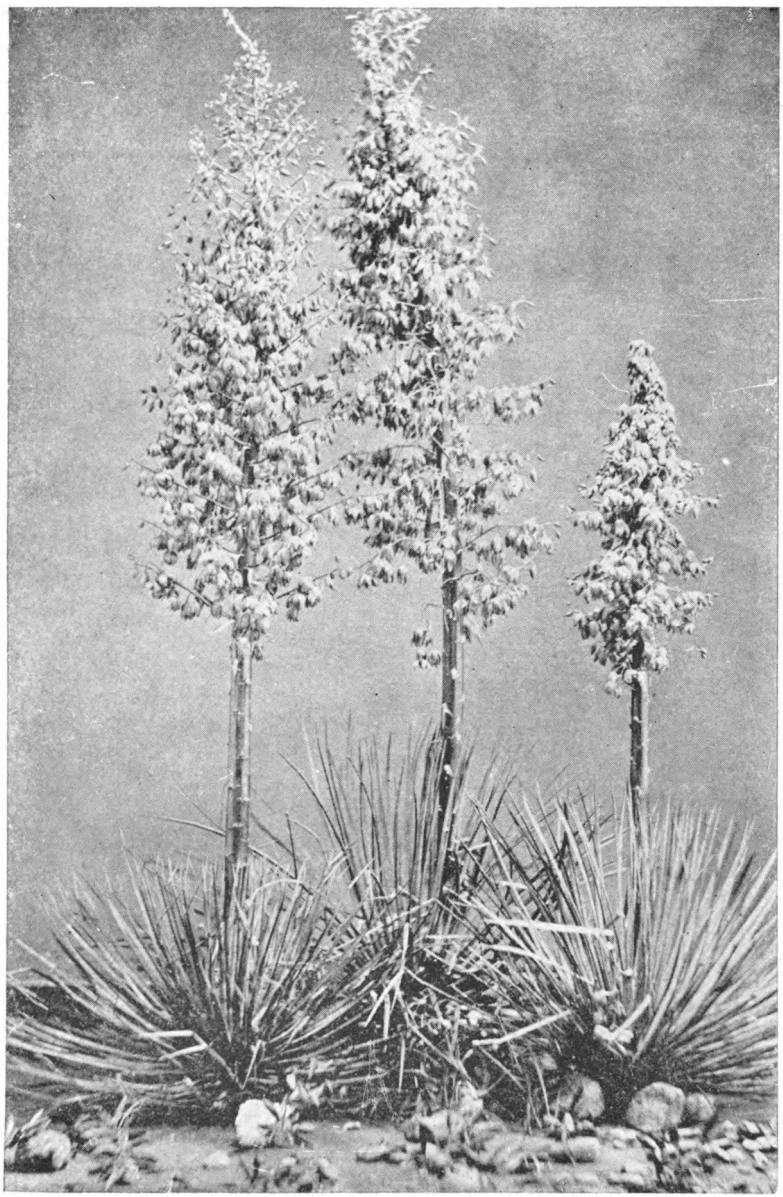

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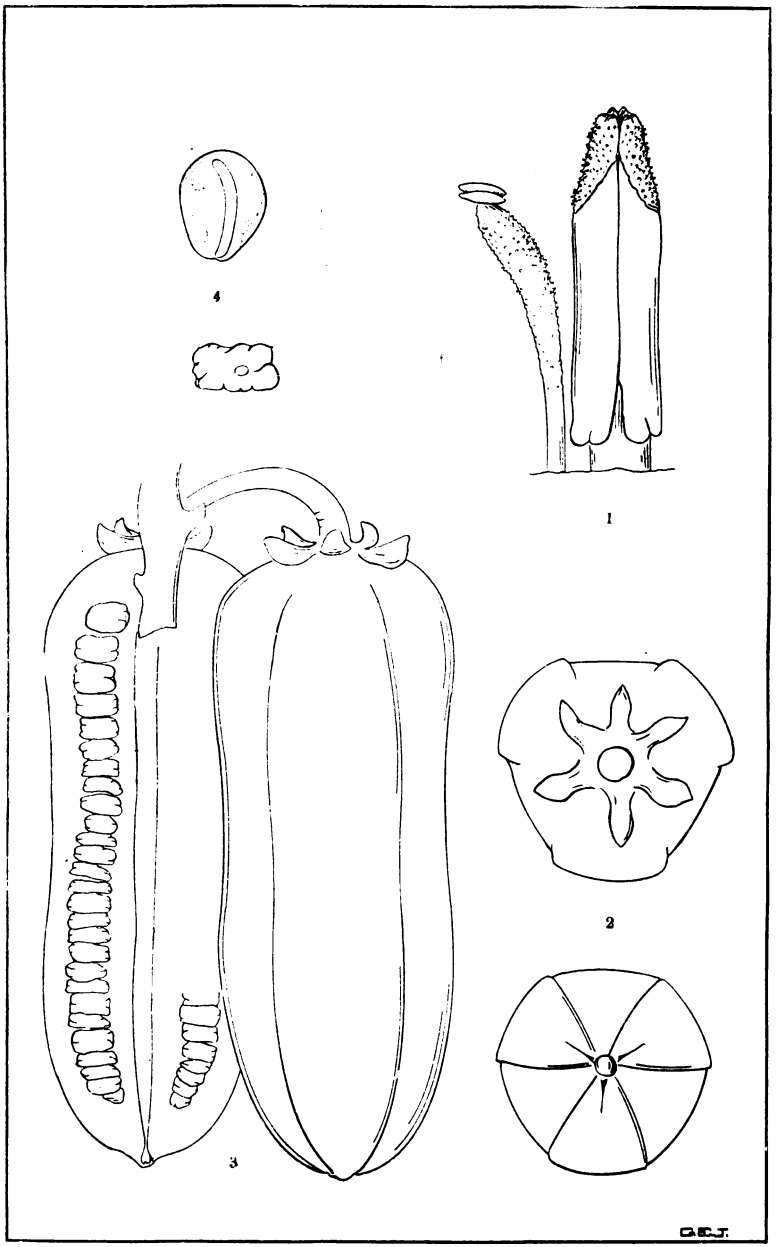

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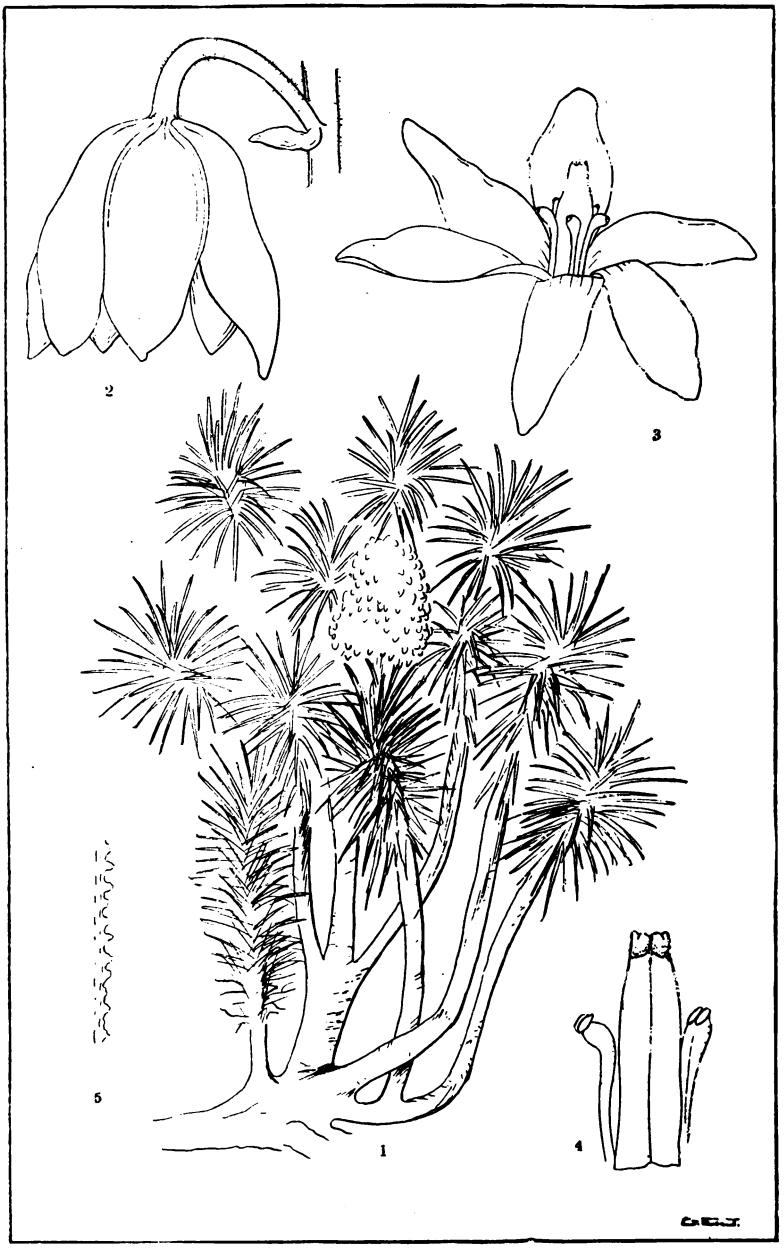

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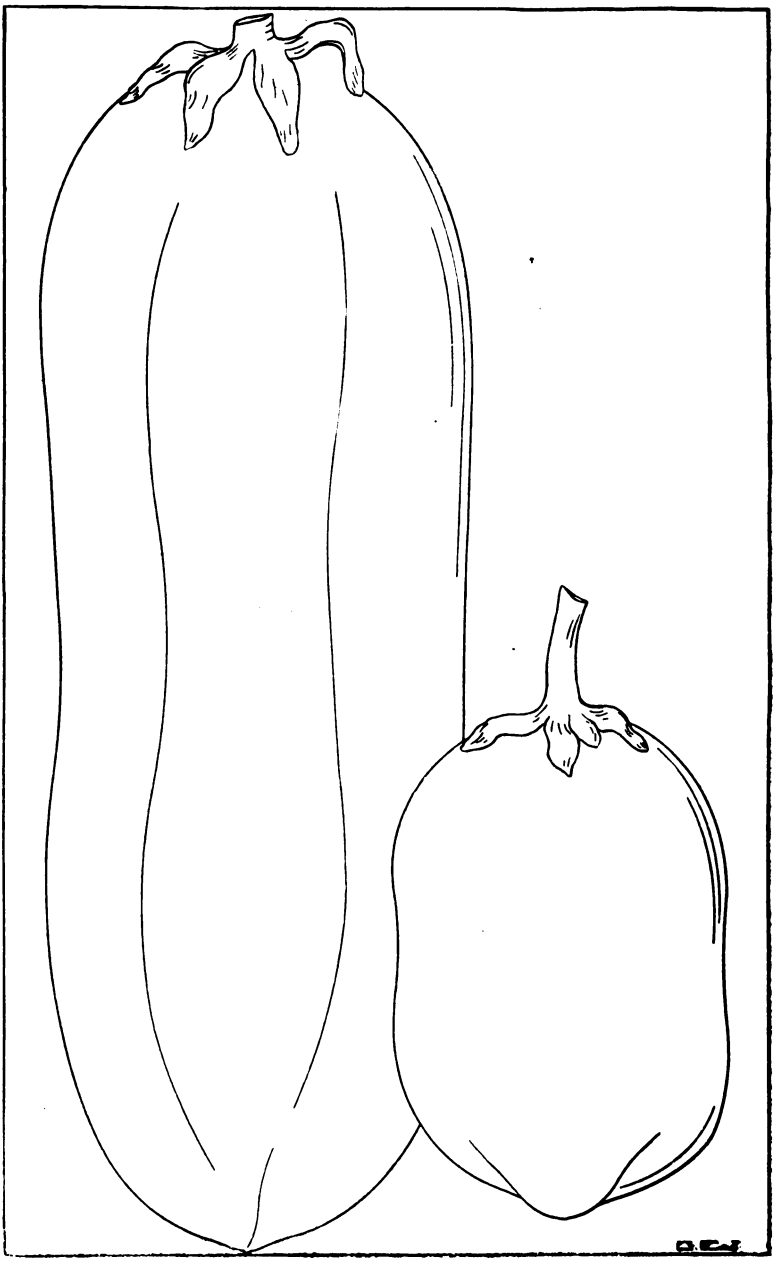

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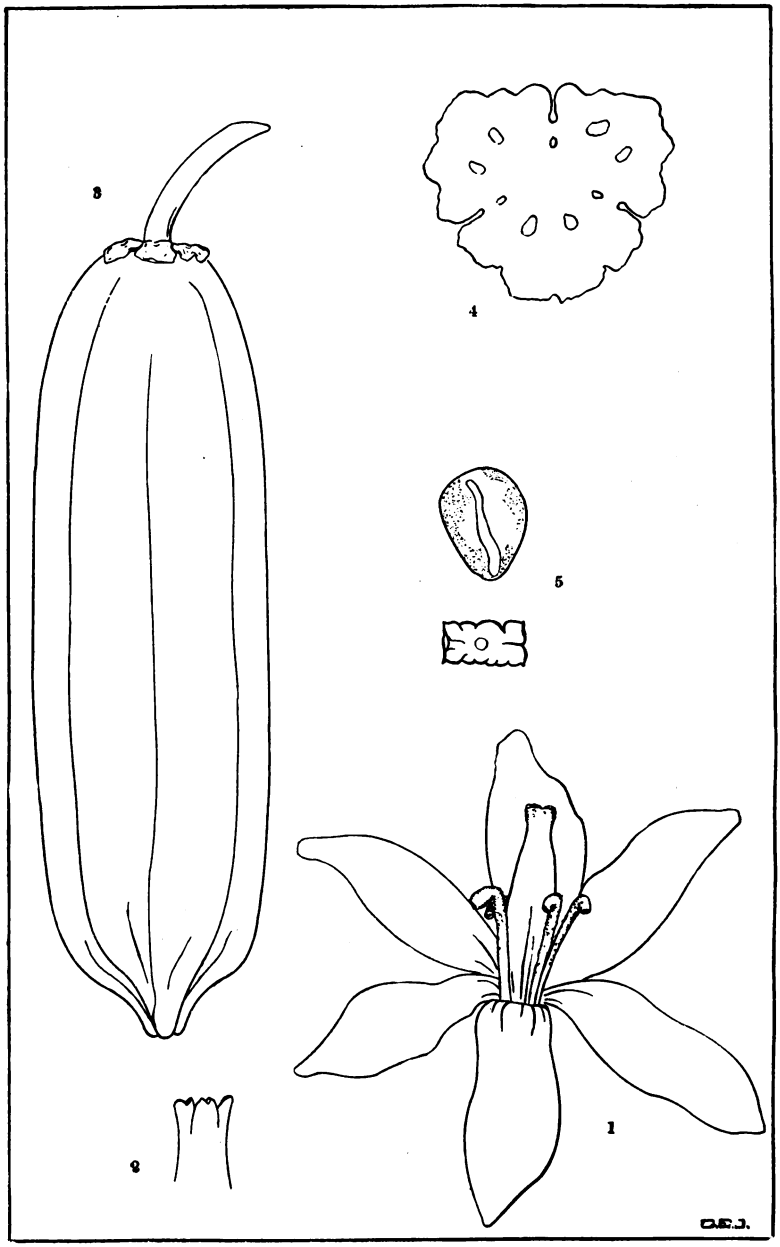

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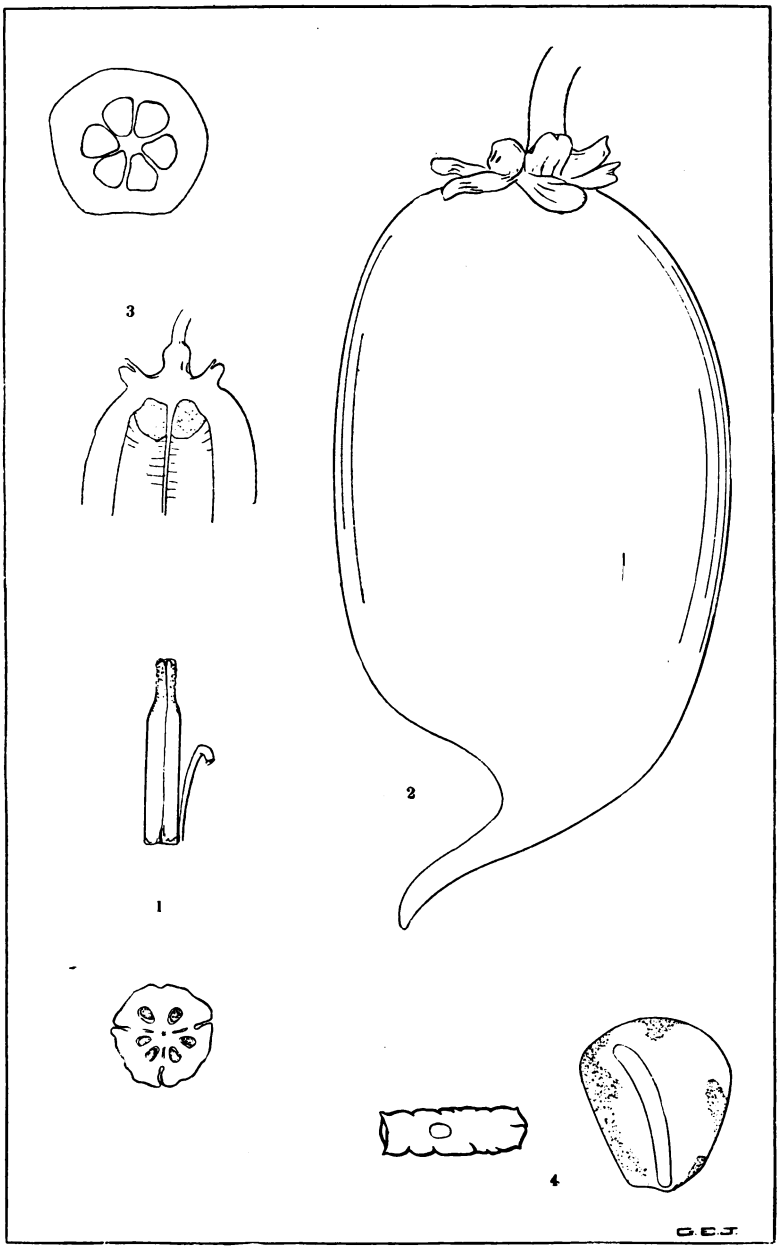

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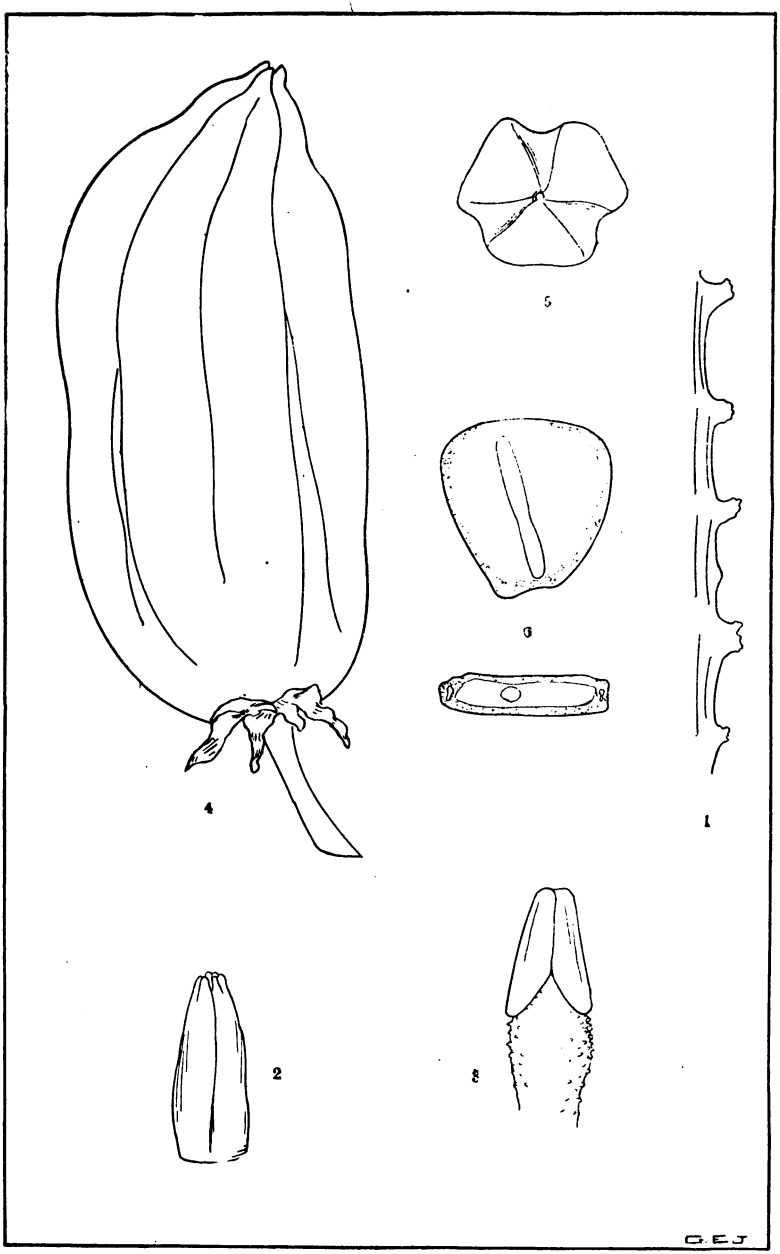

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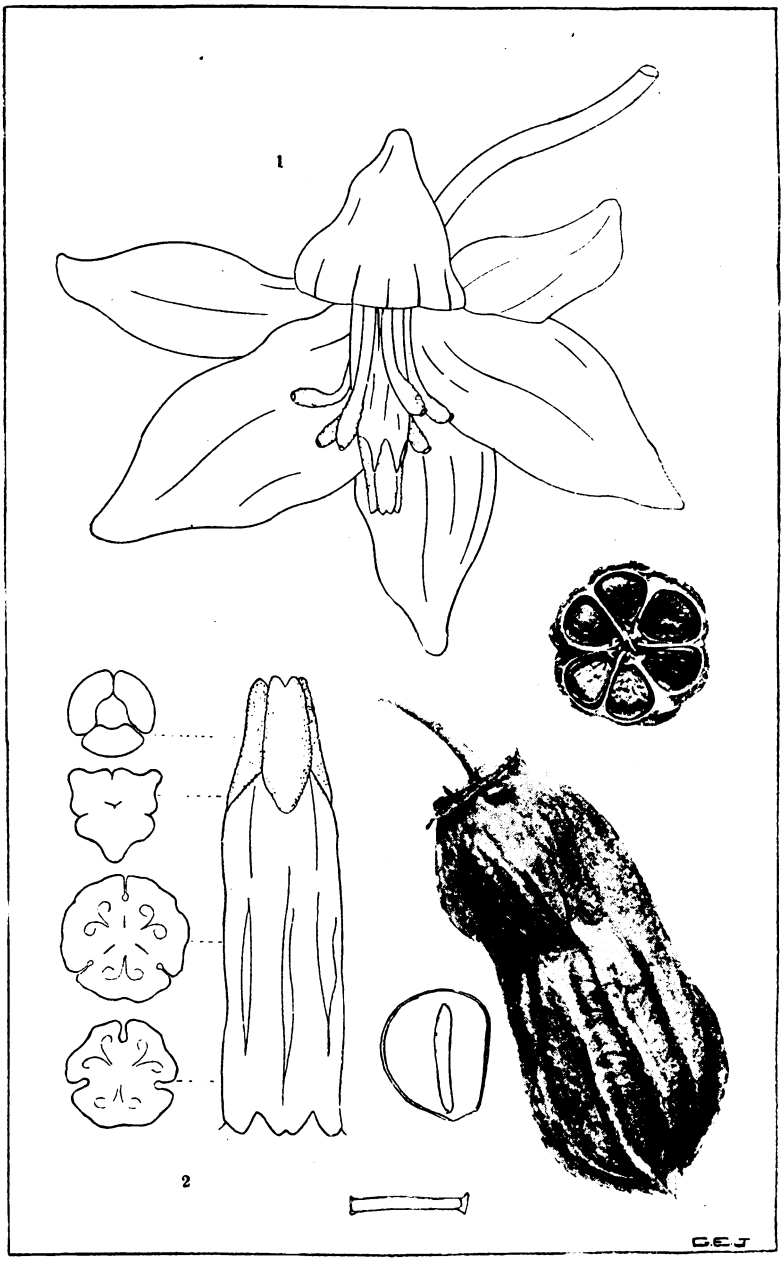

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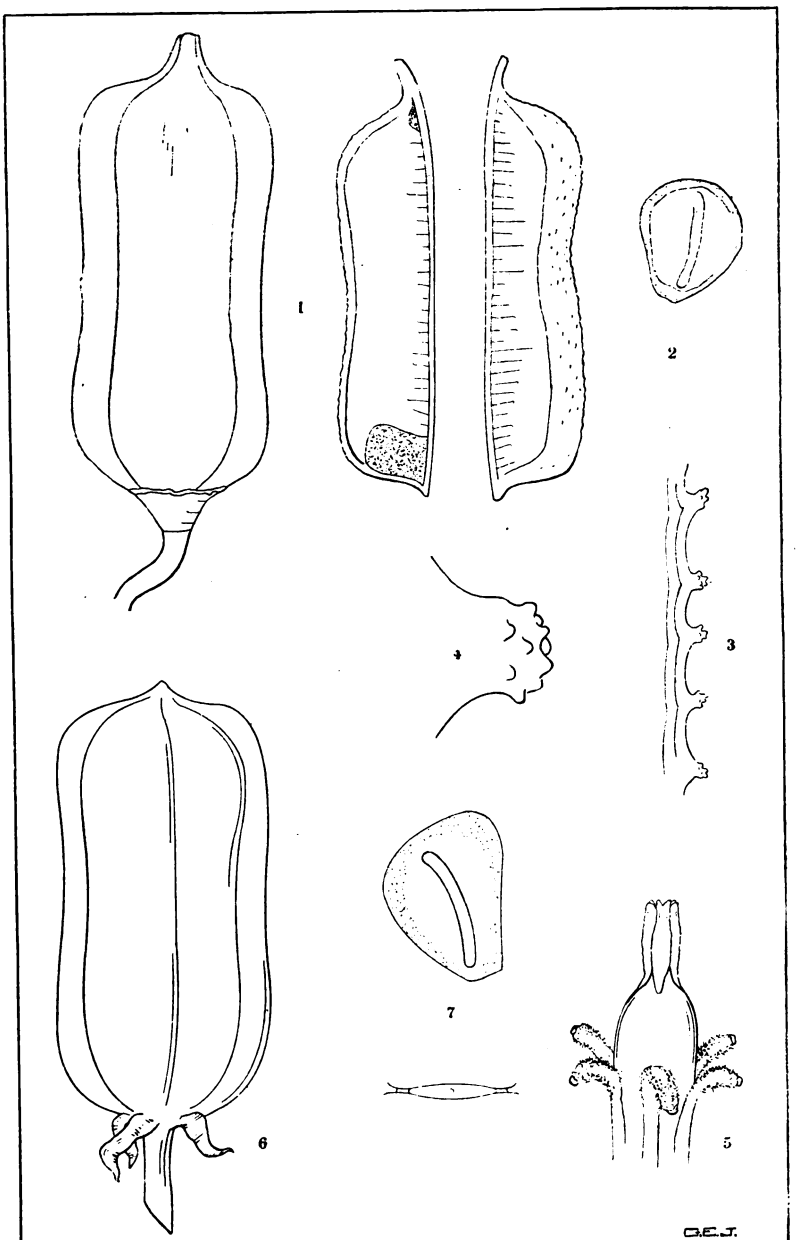

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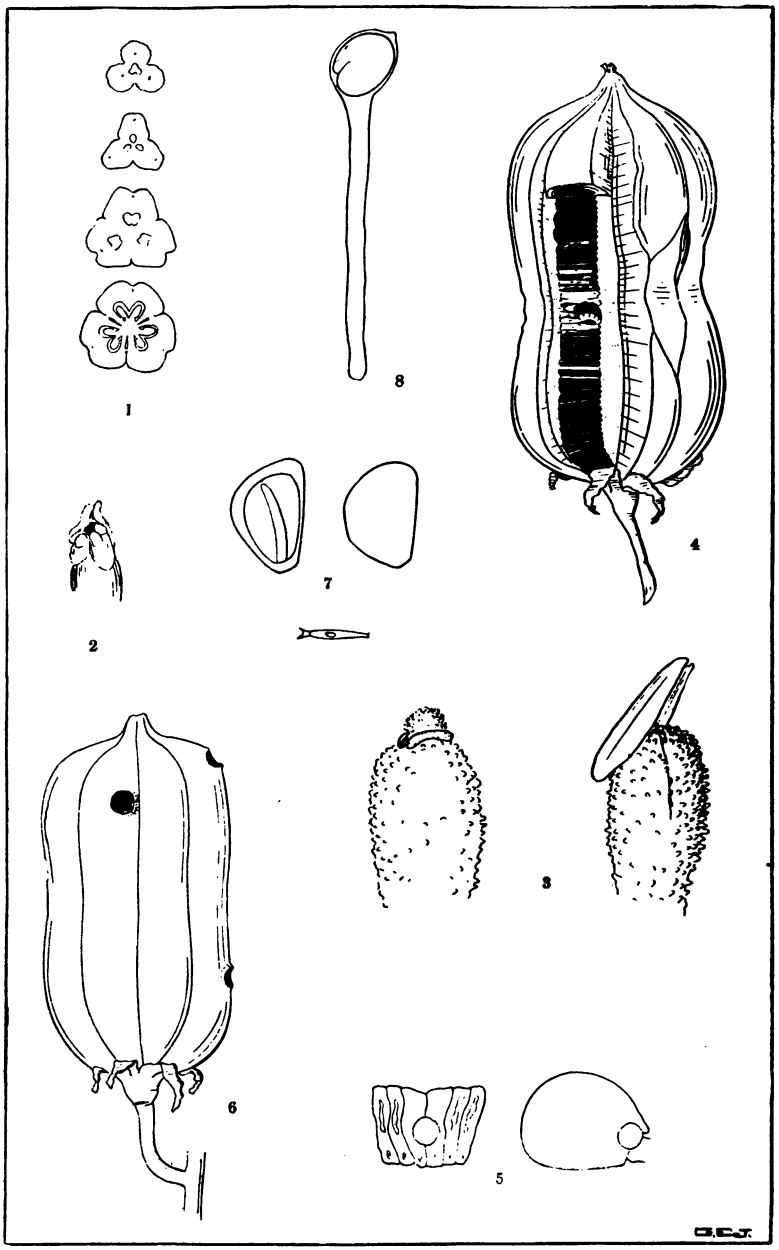

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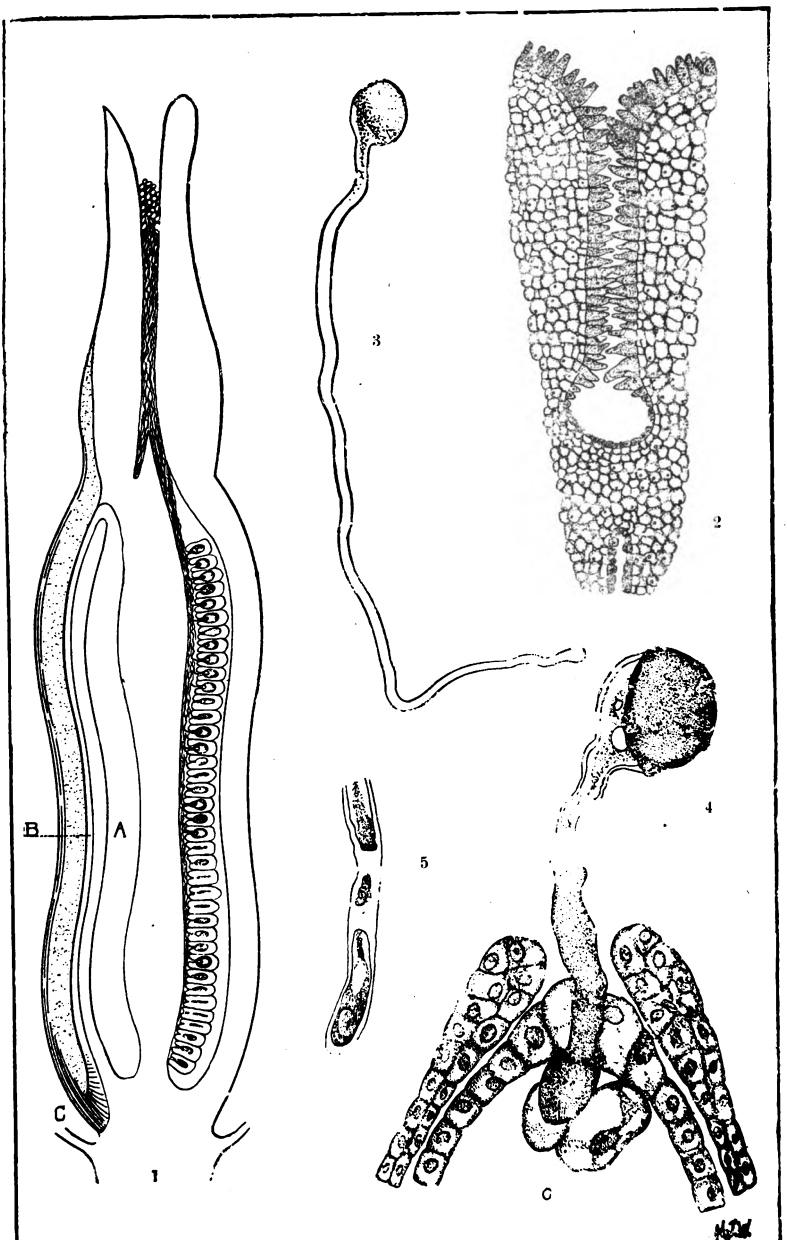

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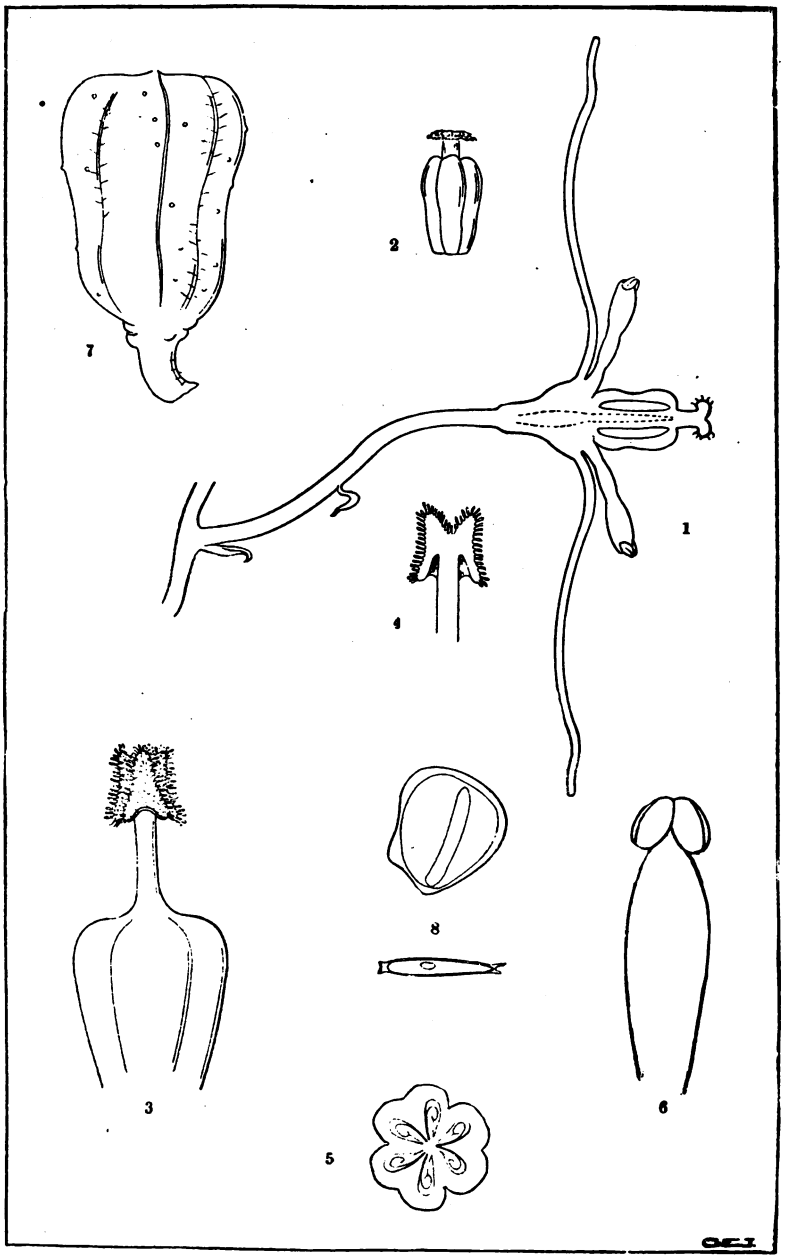

YUCCA WHIPPLEI.